2nd International Conference on Future of AM 2026

Advanced Manufacturing for Industry Transformation

4 - 6 August • Sands Expo and Convention Centre • Singapore

ACCSCIENCE PUBLISHING

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WELCOME MESSAGE

Dear FutureAM attendees,

It is my distinct pleasure to welcome you to the 2nd International Conference on the Future of AM 2026, a premier conference dedicated to advancing manufacturing for the future. I am delighted to have industry leaders, researchers and innovators from around the world join us for this important gathering.

Advanced manufacturing has evolved far beyond what we can imagined before, with the emergent of AI and new digital technologies. Today, it is reshaping industries, enabling more sustainable production, strengthening supply chain resilience, accelerating product innovation, and redefining how we design, manufacture, and deliver value. As these technologies continue to mature, collaboration across disciplines, industries, and borders has never been more important to achieve true advanced manufacturing and industry transformation.

Singapore is uniquely positioned as a global innovation hub and a gateway to Asia's dynamic manufacturing ecosystem. Through the conference, we seek to foster meaningful dialogue, encourage cross-sector partnerships, and accelerate the translation of research into industrial applications. Together, we can unlock new opportunities that will shape the next generation of advanced manufacturing.

This year's programme brings together internationally renowned experts, visionary, pioneering researchers, and emerging innovators. For the 2nd edition, we have more than 300 speakers from more than 20 countries sharing their latest research. We are also pleased to have more than 15 exhibitors, showcasing their technology advancements in various sectors in advanced manufacturing, ranging from 3D printing to robotics and artificial intelligence. During the inspiring presentations, insightful technical sessions, exhibitions and other networking opportunities, I encourage you to engage actively, exchange ideas openly, and build connections that extend well beyond the conference.

As we gather to explore new ideas and emerging technologies, I hope FutureAM 2026 serves as a catalyst for collaboration and lasting partnerships. Together, we can shape a smarter, more resilient, and more sustainable future for manufacturing.
I wish you a rewarding and memorable conference experience, and I look forward to meeting you throughout the event.

Welcome to FutureAM 2026 and have a pleasant stay in Singapore!

Professor Wai Yee Yeong
General Chair
2nd International Conference on the Future of AM, 2026

PROGRAMME

Day 1 – 04 August 2026

TIME	PROGRAMME
08:30 – 08:45	**Opening and Welcome Address** FutureAM General Chair – **Professor Wai Yee Yeong,** Chair, School of Mechanical and Aerospace Engineering, Nanyang Technological University
08:45 – 09:25	**Born Digital, Becoming Intelligent: Agentic AI and the Evolution of Additive Manufacturing** Plenary Speaker – **Professor Sang-Gook Kim,** Professor, Department of Mechanical Engineering, Massachusetts Institute of Technology
09:25 – 10:05	**Advances in Additive Manufacturing at SC3DP – Key Focus on Biomanufacturing** Plenary Speaker – **Professor Paulo Jorge Da Silva Bartolo,** President's Chair in Additive Manufacturing, School of Mechanical and Aerospace Engineering & Executive Director, Singapore Centre for 3D Printing, Nanyang Technological University
10:05 – 10:30	Tea Break
11:10 – 11:50	**Fatigue Life, Testing Methods and Prediction Models of 3D Printed Material with Characteristic Features** Plenary Speaker – **Professor Xinhua Wu,** Institute of Metal Materials and Intelligent Manufacturing, Soochow University
11:50 – 12:30	**Trends of Industrial Physical AI and Recent Advances of Continual Machine Learning for Smart Manufacturing** Plenary Speaker – **Professor Jay Lee,** Clark Distinguished Professor, Department of Mechanical Engineering & Director, Industrial AI Center, University of Maryland College Park
12:30 – 13:00	Lunch

BREAKOUT TRACKS

	Track 1	Track 1	Track 3	Track 4	Track 5
13:00 – 15:30	**Special Symposium – Microstructures and Properties of Additively Manufactured Metal Alloys**	**3D Bioprinting and Biomedical Applications**	**Meta-Materials, Lattices and Topological Optimisation**	**Automation and Robotics**	**Artificial Intelligence and Multi-scale Simulations**
15:30 – 15:50	Tea break				
1550 – 1830	**Special Symposium – Microstructures and Properties of Additively Manufactured Metal Alloys**	**3D Bioprinting and Biomedical Applications**	**Meta-Materials, Lattices and Topological Optimisation**	**Automation and Robotics**	**Artificial Intelligence and Multi-scale Simulations**

DETAILED PROGRAMME – BREAKOUT SESSIONS

Track 1 – 04 August 2026 (13:00 – 18:25) Special Symposium – Microstructures and Properties of Additively Manufactured Metal Alloys Chairs: Dr Zibin Chen, Dr Xusheng Yang	
13:00 – 13:30	**Multi-material Laser Powder Bed Fusion Additive Manufacturing (Keynote)** **Shoufeng Yang,** Chongqing Institute of Green and Intelligent Technology
13:30 – 14:00	**Microstructure Regulation and Biocompatibility Enhancement of Biomedical Titanium Alloys for Implant Applications (Keynote)** **Liqiang Wang,** Shanghai Jiao Tong University
14:00 – 1430	**Achieving Enhanced Structural and Functional Properties with Laser Additive Manufacturing (Keynote)** **Hongze Wang,** Shanghai Jiao Tong University
14:30 – 15:00	**Laser-metal Additive Manufacturing Towards Multifunctional Integral Components (Keynote)** **Dongdong Gu, Nanjing University of Aeronautics and Astronautics**
15:00 – 15:30	**Decoupling Strength and Isotropy in Microgravity Wire-Fed Laser AM of Ti Alloys: A Grain-Resolved CET–CPFE Study (Keynote)** **Hengyi Gong,** Institute of Mechanics
15:30 – 15:50	Tea break
15:50 – 16:20	**New Ideas for the Preparation of Gradient Materials Based on Additive Manufacturing Technology (Keynote)** **Baicheng Zhang,** University of Science and Technology Beijing
16:20 – 16:50	**Multi-Scale Engineering of Additively Manufactured Biodegradable Zinc (Keynote)** **Yageng Li,** University of Science and Technology Beijing
16:50 – 17:10	**Harnessing Abundant Elements: A New Paradigm for Strong and Ductile Titanium Alloys via Additive Manufacturing (Invited)** **Zibin Chen,** The Hong Kong Polytechnic University
17:10 – 17:30	**Synergistic Control of Formability and Performance for Lattice Structures Fabricated via Full-Contour Scanning Strategy in Laser Powder Bed Fusion (Invited)** **Linxuan Li,** Nanjing University of Aeronautics and Astronautics
17:30 – 17:50	**Effect of Transient Molten Pool Behaviour on Surface Defect Formation in Laser Beam Powder Bed Fusion of NiTi (Invited)** **Xin Lin,** Wuhan University of Science and Technology
17:50 – 18:10	**Highly Printable, Strong, and Ductile Ordered Intermetallic Alloy (Invited)** **Yinghao Zhou,** Harbin Institute of Technology
18:10 – 18:30	**Synergistic Regulation of the Eutectic Network–Grain Structure and High-Temperature Strengthening Mechanisms in a Laser Additive Manufactured Heat-Resistant Aluminum Alloy (Invited)** **Ning Li,** Yantai Research Institute of Harbin Engineering

Track 2 – 04 August 2026 (13:00 – 18:30) 3D Bioprinting and Biomedical Applications Chairs: Dr Khoon Lim	
13:00 – 13:30	**Unconventional Additive (Bio)Manufacturing Methods for Regenerative Medicine (Keynote)** **Shrike Zhang,** Harvard Medical School
13:30 – 14:00	**Convergence of Light and Acoustic Waves for Bioassembly of Multifunctional Tissue Constructs (Keynote)** **Khoon Lim,** University of Sydney
14:00 – 14:20	**Patient-Specific Additive Manufacturing of Cervical Orthoses for Dropped Head Syndrome: Design, Implementation and Clinical Evaluation (Invited)** **Deepak Kalaskar,** University College London
14:20 – 14:50	**Biofabrication of Vascularized Heterogeneous Tissue (Invited)** **Yang Wu,** Harbin Institute of Technology Shenzhen
14:50 – 15:10	**Printing at the Cell Level: AI-enabled Additive Manufacturing for Tumor DNA Enrichment (Invited)** **Yong Chen,** Hong Kong University of Science and Technology
15:10 – 15:30	**4D Bioprinting of Mesenchymal Stem Cell-laden Dynamic Hydrogels for Bone Regeneration (Invited)** **Zhong Alan Li,** The Chinese University of Hong Kong
15:30 – 15:50	Tea break
15:50 – 16:20	**Hierarchical Biofabrication of Physiological Structures (Keynote)** **Qi Gu,** Institute of Zoology
16:20 – 16:50	**Data-Driven Customized Medical AM in Low Cost: From Implant Imaging to Surgical Planning (Keynote)** **Yicha Zhang,** Xiangnan University
16:50 – 17:10	**4D-Printed Magnetoelectric/Piezoresistive Biomodal Sensor and its Performance (Invited)** **Hongzhi Wu,** Huazhong University of Science and Technology
17:10 – 17:30	**Artificial Intelligence-Assisted Design of 3D Composite Bone Scaffolds for Enhanced Osteogenesis and Angiogenesis in Critical-Sized Bone Defect Repair (Invited)** **Tianyi Wu,** The First Affiliated Hospital of Soochow University
17:30 – 17:45	**Design-Driven Control of Biological and Microbial Activity Using Architecture-Optimized 3D Scaffolds** **Laila A. Damiati,** University of Jaddah
17:45 – 18:00	**Effects of Powder Recycling and Laser-Powder Interaction in Selective Laser Sintering of Polycaprolactone Architectures** **Zhuoer Wang,** Nanyang Technological University
18:00 – 18:15	**Zero-waste Electrospun PLA Membranes with Biomass-derived Carbon Dots and Hydrochar for Sustainable Dye Removal** **Bong-Kee Lee,** Chonnam National University
18:15 – 18:30	**Design and Validation of a Low-Cost Open-Source Bioprinting Platform and its Application to Structured Seafood Manufacturing** **Afonso Gusmão,** Instituto Superior Técnico, Universidade de Lisboa

Track 3 – 04 August 2026 (13:00 – 18:15) Meta-Materials, Lattices and Topological Optimisation Chairs: Dr Binyang Song	
13:00 – 13:30	**Design and Manufacturing of Ultra-Lightweight Multi-functional Structures (Keynote)** **Wenhe Liao,** Nanjing University of Science and Technology
13:30 – 14:00	**From Architected Lattices to Adaptive Metamaterials for Multifunctional Acoustic Systems (Keynote)** **Wei Zhai,** National University of Singapore
14:00 – 14:20	**Two-Photon Polymerization Fabrication of Micro-Scale TPMS Scaffolds and Their Effects on Cell Morphology and Differentiation (Invited)** **Zheyu Yao,** Shandong University of Technology
14:20 – 14:40	**Laser Additive Manufacturing of a Biomimetic Active Flexible Metallic Metamaterial with Reconfigurable and Programmable Deformation Capability (Invited)** **Wenxin Chen,** Nanjing University of Aeronautics and Astronautics
14:40 – 15:00	**Generative Design of Heat Exchangers for Additive Manufacturing with Manufacturability and Performance Awareness (Invited)** **Binyang Song,** Nanyang Technological University
15:00 – 15:15	**Controlling Co-efficient of Thermal Expansion through Print Temperature in 4D Printing Applications** **Muthu Vignesh Vellayappan,** Singapore Institute of Manufacturing Technology
15:15 – 15:30	**TPMS Lattice Structures of 7xxx Aluminium Alloy via LPBF: Enabling Crack-Free Fabrication and Optimizing Mechanical Performance** **Jiani Huang,** The Hong Kong Polytechnic University
15:30 – 15:50	Tea break
15:50 – 16:10	**Harnessing Golden Ratio in Metamaterial Design: Enhanced Fracture Resistance through Delocalized Deformation (Invited)** **Xinxin Wang,** Central South University
16:10 – 16:30	**Automated Design and Fabrication of Electromechanical Systems (Invited)** Robert MacCurdy, University of Colorado Boulder
16:30 – 16:45	**Rethinking Design for Multi-Material Printing: Bridging Digital Models and Fabrication with OpenVCAD** **Charles Wade,** University of Colorado Boulder
16:45 – 17:00	**Analysis and Optimization of Load-bearing Performance of Various Lattice Materials Fabricated by Additive Manufacturing** **Xiaocui Yang,** Nanjing University of Industry Technology
17:00 – 17:15	**Architected Multifunctional Metamaterials by Additive Manufacturing** **Zhendong Li,** RMIT University
17:15 – 17:30	**Bandgap Tunability and Vibration Suppression in a 4D-printed Metamaterial** **Chenyang Xi,** Institute of High Performance Computing
17:30 – 17:45	**A Systematic Study of Disorder-connectivity Coupling in Mechanical Metamaterials via Dual-uncertainty-aware Framework** **Yinan Zhu,** Monash University
17:45 – 18:00	**A Repeatable Workflow for Constitutive model of FDM Nylon and Validation via Polygonal Lattice Compression** **Yizhe Lyu,** University of Glasgow
18:00 – 18:15	**Computational Analysis and Simulation of an Innovative Pellet-Fed Extruder for 3D Printing** **Sarah Delia,** University of Malta

Track 4 – 04 August 2026 (13:00 – 18:00) Automation and Robotics Chairs: Dr Marvin Carl May	
13:00 – 13:30	**Topology Optimization for Multi-axis Hybrid Manufacturing Incorporating Curved Layer Generation (Keynote)** **Jikai Liu,** Shandong University
13:30 – 14:00	**Multi-energy Field Assisted Ultra-precision Machining of Difficult-to-Cut Materials (Keynote)** **Suet To,** The Hong Kong Polytechnic University
14:00 – 14:20	**Smart Design of 4D Printed Actuators Based on Shape Memory Polymers (Invited)** **Yin Liu,** Agency for Science, Technology and Research
14:20 – 14:40	**Software Defined Manufacturing and Digital Twins for the Manufacturing of the Future (Invited)** **Marvin Carl May,** Nanyang Technological University
14:40 – 15:00	**Actuating Origami-Inspired Deployable Structures through 4D Additive Manufacturing (Invited)** **Jingyi Yang,** Singapore Institute of Manufacturing Technology
15:00 – 15:15	**Quantum-Inspired Information Modeling for Tool Condition Monitoring in Smart Manufacturing** **Jingwei Zhan,** Institute of Intelligent Machines
15:15 – 15:30	**Advanced Manufacturing of Liquid Crystal Elastomer Artificial Muscles for Soft Robotic Systems** **Theo Calais,** Université Marie et Louis Pasteur
15:30 – 15:50	Tea break
15:50 – 16:20	**Training Humanoid Robots for Factory Work — From Data to Deployment (Keynote)** **U-Xuan Tan,** Singapore University of Technology and Design
16:20 – 16:40	**A Self-deployable Parabolic Structure for Satellite Antenna Design Using Multi-Material 4D Additive Manufacturing Approach (Invited)** **Jiazhao Huang,** Singapore Institute of Manufacturing Technology
16:40 – 17:00	**Hybrid Multimodal Artificial Intelligence, Vision Sensory, and Robotic Cyber-Physical Systems for Plastic Inspection and Sorting in Digital Circular Remanufacturing (Invited)** **Michail Beliatis,** Aarhus University
17:00 – 17:20	**Control and AI-Driven Robotics for Human-Centered Smart Automation (Invited)** **Masami Iwase,** Tokyo Denki University
17:20 – 17:40	**Principles of Magnetic Field-Assisted Diamond Cutting and Fabrication of Micro/Nanostructured Functional Surfaces (Invited)** **Wai Sze Yip,** The Hong Kong Polytechnic University
17:40 – 18:00	**Toward Autonomous Terrain-Adaptive Additive Manufacturing: A Legged Robotic Framework for Infrastructure Repair (Invited)** **Tran Van Thai,** Nanyang Technological University
18:00 – 18:15	**A Multigrid Path Optimization Scheme for Computationally Tractable Thermal Path Planning in Metal Additive Manufacturing** **Yufan Zheng,** Xi'an Jiaotong-Liverpool University

Track 5 – 04 August 2026 (13:00 – 18:30) Artificial Intelligence and Multi-scale Simulations Chairs: Dr Yunlong Tang	
13:00 – 13:30	Next-Generation AI for Time Series Sensor Data Analytics (Keynote) Xiaoli Li, Singapore University of Technology and Design
13:30 – 14:00	Feature Addition via Metal Additive Manufacturing: Thermo-Mechanical Modelling and Experimental Validation (Keynote) Quanren Zeng, University of Bath
14:00 – 14:30	Real-Time Thermal Imaging and In-Situ Geometric Sensing for Residual Stress Estimation in Metal Directed Energy Deposition (Keynote) Hoon Sohn, Korea Advanced Institute of Science and Technology
14:30 – 14:50	Digital Twins for Additive Manufacturing: From Lattice Design to Process Monitoring and Control, and Smart Implants (Invited) Yunlong Tang, Monash University
14:50 – 15:10	Physics-informed Data-driven Methods for Inverse Problems in Advanced Manufacturing (Invited) Yanglong Lu, The Hong Kong University of Science and Technology
15:10 – 15:30	Laser Scan-based Anomaly Detection in Metal Additive Manufacturing using Multimodal Ensemble Learning (Invited) Jan Akmal, Aalto University
15:30 – 15:50	Tea break
15:50 – 16:20	Physics-Informed AI for Data-Efficient Inverse Design of Programmable, Manufacturable Architected Materials (Keynote) Seunghwa Ryu, Korea Advanced Institute of Science and Technology
16:20 – 16:40	A High-throughput LPBF-ML Framework for Accelerating Alloy Design and Property Discovery (Invited) Pei Wang, Institute of Materials Research and Engineering
16:40 – 17:00	Rheological Transition Driven Core-Skin Architecture for Transient Thermal Response in Material-Extruded Copper Systems (Invited) Seung Ki Moon, Nanyang Technological University
17:00 – 17:15	A Digital-to-Physical DFAM Framework for Next-Generation Patient-Specific Implants Shengping Zhong, Chongqing Institute of Green and Intelligent Technology
17:15 – 17:30	Chat with the Manufacturing Process: Knowledge-guided Cross-modal LLM for Machining Condition Predictive Maintenance Jun Li, Wuhan University of Science and Technology
17:30 – 17:45	Toward Function-Oriented WAAM: Single-Material Behavior and Deposition-Order Effects in Bimetallic Structures Ozan Can Ozaner, KU Leuven
17:45 – 18:00	AI-based Defect Detection and Localization in Laser Powder Bed Fusion Xinyi Yin, Aalto University
18:00 – 18:15	Additive Manufacturing Metallurgy-Guided Machine Learning Design of High-Strength Crack-Free Al-Zn-Mg-Cu-Ti-Zr Alloys for Laser Directed Energy Deposition Zhao Li, Soochow University
18:15 – 18:30	Process Development in Microwave Plasma Additive Manufacturing of Aluminum Alloy Walisijiang Tayier, Soochow University

PROGRAMME

Day 2 – 05 August 2026

BREAKOUT TRACKS					
	Track 1	Track 1	Track 3	Track 4	Track 5
08:30 – 10:00	Special Symposium – Additive Manufacturing of Future Food Systems	Special Symposium – Advanced Manufacturing and Digital Innovation in Korea	Metallurgy in Advanced Manufacturing	3D Bioprinting and Biomedical Applications	Advanced Manufacturing for Build Environment
10:00 – 10:20	Tea break				
10:20 – 12:30	Special Symposium – 3D Food Printing and Digital Gastronomy	Special Symposium – Advanced Manufacturing and Digital Innovation in Korea	Metallurgy in Advanced Manufacturing	3D Bioprinting and Biomedical Applications	Advanced Manufacturing for Build Environment
12:30 – 13:00	Lunch				
13:00 – 15:30	Industry and Applications	New Techniques and Applications	Materials Science in Advanced Manufacturing	3D Bioprinting and Biomedical Applications	Emerging Materials and Processing Techniques
15:30 – 15:50	Tea break				
15:50 – 18:30	Industry and Applications	New Techniques and Applications	Materials Science in Advanced Manufacturing	3D Bioprinting and Biomedical Applications	Emerging Materials and Processing Techniques
18:30	Conference Banquet Dinner Awards Presentation Ceremony Journal Awards Presentation Meiban–FutureAM Awards Sponsored by ASTM International				

DETAILED PROGRAMME – BREAKOUT SESSIONS

Track 1 – 05 August 2026 (08:30 – 12:35) Special Symposium – Additive Manufacturing of Future Food Systems / 3D Food Printing and Digital Gastronomy Chairs: Dr Yi Zhang, Dr Nana Zhang (co-organised by Dr Lay Poh Tan, Dr Thomas Becker)	
08:30 – 09:00	**Fundamental Research and Technological Exploration of Food 3D Printing (Keynote)** **Nana Zhang,** Jiangnan University
09:00 – 09:30	**Oyster Mushroom Powder and Rice Flour Blends as Bioinks for Extrusion-based 3D Food Printing - Linking Particle Structure, Rheology, Printability and Post-Processing Behaviour (Keynote)** **Joanna Harasym,** Adaptive Food Systems Accelerator – Research Centre
09:30 – 10:00	**AI-Driven 3D Food Printing for Personalized Nutrition and Special Medical Applications (Keynote)** **Yi Zhang,** University of Electronic Science and Technology of China
10:00 – 10:20	Tea break
10:20 – 10:40	**4D Printing of Potato Peels with pH- and Thermal Responsive Transformations (Invited)** **Aakanksha Pant,** Singapore University of Technology and Design
10:40 – 11:00	**Creating Novel Texture through Novel Nozzle Design and Robotic Arm (Invited)** **Guo Dong Goh,** Nanyang Technological University
11:00 – 11:20	**Rheology-guided Printing Parameter Modulation Strategies for Precise Soy-Based 3D Food Printing (Invited)** **Nathaniel James Hendrik,** TUMCreate
11:20 – 11:40	**AI-Synesthetic Tastes: Neuroaesthetic 3D-Printed Food Designs (Invited)** **Immanuel Koh,** Singapore University of Technology and Design
11:40 – 12:00	**Programmable Structuring of Plant Proteins by Extrusion-Based 3D Printing for Meat Analogue Texture Design (Invited)** **Nicole Cheam,** Nanyang Technological University
12:00 – 12:20	**Continuous Switching 3D Food Printing Technology and Its Personalized Applications (Invited)** **Zilong Zhao,** Jiangnan University
12:20 – 12:35	**Image Analysis-Based Evaluation of Dimensional Accuracy in 3D Printing of Soy Protein Hydrogels** **Rishika Batra,** Technical University of Munich

Track 2 – 05 August 2026 (08:30 – 12:15) Special Symposium – Advanced Manufacturing and Digital Innovation in Korea Chairs: Dr Dong-Gyu Ahn	
08:30 – 09:00	**Fusion of Additive Manufacturing and Physical Coating Technologies for Metamaterials (Keynote)** **Dong-Gyu Ahn,** Chosun University
09:00 – 09:30	**Architecting Wave and Heat Transport through Additive Manufacturing: From Electromagnetic Metamaterials to Flexible Two-Phase Thermal Devices (Keynote)** **Wonjoon Choi,** Korea University
09:30 – 10:00	**Versatile and Instructive Potentials of Nanobiomaterials as Smart Additives for 3D Bioprinting (Keynote)** **Dong-Wook Han,** Pusan National University
10:00 – 10:20	Tea break
10:20 – 10:50	**AI-Based Line Recognition in Piping and Instrumentation Diagrams (Keynote)** **Duhwan Mun,** Korea University
10:50 – 11:10	**Design and Additive Manufacturing of Gyroid-Based Multifunctional Structures for Bone Implants (Invited)** **Dahyun Daniel Lim,** Korea University
11:10 – 11:30	**Phase Extraction from Interference Fringe Pattern – From Conventional Phase-Shifting Technique to Recent Machine Learning Method (Invited)** **Yangjin Kim,** Pusan National University
11:30 – 11:45	**Off-Centered Rotational Stacking for Asymmetric 3D Rotational Stacking Lattices Fabricated by DLP 3D Printing** **Seo Rim Park,** Changwon National University
11:45 – 12:00	**Adhesion Characteristics of a Slippery Interface and Analysis of the Maximum Printable Area Using Conical Structures for Large-Area Continuous DLP 3D Printing** **Chae Hyeok Yoon,** Changwon National University
12:00 – 12:15	**Development of a Machine Learning-Based Prediction Model for Bead and Deposition Geometry in WA-DED Using Laser Vision Data** **Hwi Jun Son,** Changwon National University

Track 3 – 05 August 2026 (08:30 – 12:25) Metallurgy in Advanced Manufacturing Chairs: Dr Che-Nan Kuo	
08:30 – 09:00	**Applications of Metal Additive Manufacturing in Load-Bearing Implants (Keynote)** **Amit Bandyopadhyay,** Washington State University
09:00 – 09:30	**Microstructure Evolution and Mechanical Response of 3D Printed Al Alloys Developed by AI/MGI (Keynote)** **Che-Nan Kuo,** National Sun Yat-Sen University
09:30 – 10:00	**Contributions to Spatial Variations in Fatigue life in Laser Powder Bed Fusion of Ti6Al4V: A Mechanistic Assessment (Keynote)** **Dwayne D Arola,** University of Washington
10:00 – 10:20	Tea break
10:20 – 10:40	**Additive Manufacturing of Functional Magnetic Materials for Electrification and Energy Technologies (Invited)** **Varun Chaudhary,** Chalmers University of Technology
10:40 – 11:00	**Digital Bridge: "Twinning Oldest and Newest Manufacturing Processes for the 21st Century - Metal Casting meets Additive Manufacturing" (Invited)** **Guha Manogharan,** Pennsylvania State University
11:00 – 11:20	**Effect of Nitrogen Concentration on Microstructure and Mechanical Properties of AlSi10Mg Matrix Composites Fabricated by Laser Powder Bed Fusion (Invited)** **Wenhou Wei,** Chongqing Institute of Green and Intelligent Technology

11:30 – 11:50	**Tailoring Laser Absorption and Multiscale Strengthening in LPBF GH4169 through nano-Y2O3 Modification (Invited)** **Huiping Liu,** Nanjing University of Aeronautics and Astronautics
11:50 – 12:10	**LPBF Technology From Prototype to Mass Production: Application in Copper Heatsink and Industrial (Invited)** **Yinlan Zheng,** Fastform 3D
12:10 – 12:25	**Role of Yttria-Stabilized Zirconia Nanoparticles in Enhancing the Strengthening Mechanisms of Laser Powder Bed Fused AlSi10Mg** **Abu Syed Kabir,** Carleton University

Track 4 – 05 August 2026 (08:30 – 12:30)
3D Bioprinting and Biomedical Applications
Chairs: Dr Jia Min Lee

08:30 – 08:50	**Harnessing Biofabrication to Engineer Skeletal Tissue Microenvironments and Control Stem Cell Function (Invited)** **Marco Domingos,** The University of Manchester
08:50 – 09:10	**Engineering Multifunctional Biomedical Scaffolds via Extrusion-Based Additive Manufacturing (Invited)** **Bin Zhang,** Brunel University London
09:10 – 09:30	**4D Printing of Gastroretentive Drug Delivery Systems Using Sustainable PVA–Natural Cellulose Composites (Invited)** **Pattaraporn Panraksa,** Chiang Mai University
09:30 – 09:50	**High-precision freeform DLP bioprinting by thermo-reversible gelation (Invited)** **Qing Ye,** Nankai University
09:50 – 10:10	**Electrically assisted stereolithography 3D printing of graded composites for biomedical applications (Invited)** **Guanghai Fei,** Southeast University
10:00 – 10:20	Tea break
10:20 – 10:40	**Sustainable and Functional 3D Printing Platforms for Environmental and Biomedical Applications (Invited)** **Juha Song,** Nanyang Technological University
10:40 – 11:00	**Substrate-less Bioelectronic Fibres Fabrication Across Diverse Surfaces (Invited)** **Stanley Gong Sheng Ka,** University of Cambridge
11:00 – 11:20	**Rapid Image-based Evaluation of Conductive Ink Printability for AI-driven Formulation Selection (Invited)** **Jia Min Lee,** Nanyang Technological University
11:20 – 11:40	**Multiscale Particle-in-Cell (PIC) Simulations for Next-Generation Plasmonics & Optoelectronics (Invited)** **Lin Wu,** Singapore University of Technology and Design
11:40 – 12:00	**Machine Learning–Guided Optimization of Sodium Alginate/Methylcellulose–PEDOT Composites for Shape-Morphing Bioelectronic Systems (Invited)** **Guo Liang Goh,** Nanyang Technological University
12:00 – 12:15	**Large Knowledge Model-Assisted Bioprinting** **Xi Huang,** Nanyang Technological University
12:15 – 12:30	**AI-Empowered Bone Organoid Fabrication: Principles and Applications** **Long Bai,** Shanghai University

Track 5 – 05 August 2026 (08:30 – 12:05)
Advanced Manufacturing for Build Environment
Chairs: Dr Xin Meng

08:30 – 09:00	**Construction 3D Printing – Safety, Digitalisation and Sustainability (Keynote)** **Ming Jen Tan,** Nanyang Technological University
09:00 – 09:20	**Wall Climbing Robots for Building Inspections (Invited)** **Shunuke Nansai,** Akita University
09:20 – 09:40	**Wire-arc Directed Energy Deposition for Optimised and Hybrid Steel Structures in Construction (Invited)** **Xin Meng,** National University of Singapore
09:40 – 10:00	**A Toolpath-driven Digital Framework for 3D Concrete Printing of Bio-Inspired TPMS Breakwater Blocks for Sustainable Coastal Protection (Invited)** **Vuong Nguyen-Van,** National University of Singapore
10:00 – 10:20	Tea break
10:20 – 10:40	**Machine Learning Prediction of Printability and Mechanical Properties in 3D Concrete Printing (Invited)** **Daniel Tay,** Nanyang Technological University
10:40 – 11:00	**From Autonomous Inspection to Intelligent Fabrication: AI-Enhanced Robotics for the Future of Large-Format Additive Manufacturing in the Built Environment (Invited)** **Maryam Kouzehgar,** Engineering Institute of Technology
11:00 – 11:20	**From Material Design to Intelligent Construction: Advancing Spray-Based 3D Concrete Printing (Invited)** **Bing Lu,** Singapore Polytechnic
11:20 – 11:35	**Generative AI-Driven High-Fidelity Digital Twin Environment Construction and Sim-to-Real Transfer Technology for Smart Construction** **Rushi Dai,** The Hong Kong University of Science and Technology (Guangzhou)
11:35 – 11:50	**Large-Scale Metal AM in the Built Environment: A 11m WAAM Pedestrian Bridge at SUTD** **Chenxi Jiang,** Singapore University of Technology and Design
11:50 – 12:05	**Design for a Stainless Steel 3D Printed Pedestrian Bridge** **Stylianos Dritsas,** Singapore University of Technology and Design

Track 1 – 05 August 2026 (13:00 – 18:00)
Industry and Applications
Chair: Dr Punit Kumar

13:00 – 13:30	**Beyond the 3D Printer: Unconventional Manufacturing Frontiers for the Next Generation of Aerial Robots (Keynote)** **Shaohui Foong,** Singapore University of Technology and Design
13:30 – 14:00	**Trustworthy Situational Awareness for Industrial IoT (Keynote)** **David Yau,** Singapore University of Technology and Design
14:00 – 14:30	**Real-Time Prediction of Porosity Levels in Welds (Keynote)** **Tegoeh Tjahjowidodo,** KU Leuven
14:30 – 14:45	**Detect, Predict, Intervene: Physics-Informed, Pyrometer-Sensor-Driven Machine Learning for In-Situ Quality Assurance in Metal Additive Manufacturing** **Rajesh Kumar Balaraman,** Singapore University of Technology and Design

14:45 – 15:00	**Process-Aware Adaptive Exposure for First-Time-Right Metal 3D Printing** **Guglielmo Vastola,** SynaCore Pte. Ltd.
15:00 – 15:15	**Highly Pressure-Resistant and High-Rate Ultrathick Micro-Si Anodes For 3D Microbatteries via Direct-Ink-Writing of Directionally Continuous Porous Microstructure** **Chi Guo,** Southeast University
15:15 – 15:30	**3D Printing of Customized Li-S Microbatteries** **Mengli Li,** Southeast University
15:30 – 15:50	Tea break
15:50 – 16:10	**Enhanced Internal Cooling of Ceramic-Matrix Turbine Blades through Coupled Thermal-Conduction-Axis Orientation Design and Additive Manufacturing (Invited)** **Yi Huang,** Beihang University
16:10 – 16:30	**A Physics-Coupled Fourier Neural Operator for Data-Efficient Multiphysics Simulation in Laser Manufacturing (Invited)** **Xuyang Chen,** Institute of Engineering Thermophysics
16:30 – 16:50	**Investigation of Particle Deposition and Erosion in Airfoil-Fin Heat Exchangers for Enhanced Thermal System Performance (Invited)** **Hongying Li,** Nanyang Technological University
16:50 – 17:10	**Direct-Write Additive Manufacturing of Sustainable Functional Polymers (Invited)** **Shweta Agarwala,** Ahmedabad University
17:10 – 17:25	**Laser-induced growth of ZnO/CsPbBr3 heterostructure optoelectronic devices** **Zhengwei Li,** Shandong University of Technology
17:25 – 17:40	**Aluminium Matrix Composite Powder – Much More Than Just a Simple Powder Mixture: Production, Properties, Applications and Opportunities** **Robert Pippig,** CMMC GmbH
17:40 – 18:00	**Boosting the Mechanical Properties at 815°C of Laser Directed Energy Deposited Inconel 625 alloy by Introducing the Laves Phase (Invited)** **Zuo Li,** Hohai University

Track 2 – 05 August 2026 (13:00 – 18:00) **New Techniques and Applications** **Chairs: Dr Im Doo Jung**	
13:00 – 13:30	**Advanced Functional 3D Printing for Next-Generation Smart Devices (Keynote)** **Im Doo Jung,** Ulsan Institute of Science and Technology
13:30 – 14:00	**Translating Nature's Blueprints: Additive Manufacturing of Bio-Inspired and Fracture-Tolerant Architectures (Keynote)** **Jonathan Tran,** RMIT University
14:00 – 14:20	**Generative Process Modeling of Aerosol Jet Printing via Parameter-Conditioned Diffusion (Invited)** **Haining Zhang,** Korea Advanced Institute of Science and Technology
14:20 – 14:40	**Metal Component Flexible Forming Technology and Equipment (Invited)** **Wenting Li,** Nanjing University of Aeronautics and Astronautics
14:40 – 15:00	**Closed Cell Lattices Additively Manufactured Using Laser Pulsed Integration of Sheets (LAPIS) (Invited)** **Changquan Lai,** Nanyang Technological University

15:00 – 15:15	**A Design-to-Process Framework for in-situ Polymerized Composite Couplers in Hydrogen Pipelines** **Wang Chen,** Singapore Institute of Manufacturing Technology
15:00 – 15:15	**A Design-to-Process Framework for in-situ Polymerized Composite Couplers in Hydrogen Pipelines** **Wang Chen,** Singapore Institute of Manufacturing Technology
15:15 – 15:30	**Fabrication of Bimetallic Thin Wall Combustor Liners via Multi-axial Wire Laser Directed Energy Deposition** **Mithilesh Singh,** Indian Institute of Technology Bombay
15:30 – 15:50	Tea break
15:50 – 16:10	**3D-Printed IP-DIP Hollow Core Micro-Waveguides for High-Speed Optical Interconnects (Invited)** **Hongwei Gao,** Singapore University of Technology and Design
16:10 – 16:30	**Direct Ink Writing of Electrostatic Devices for Soft Robotic Systems (Invited)** **Yifan Wang,** Nanyang Technological University
16:30 – 16:50	**In-situ Observation of Spattering during Laser Powder Bed Fusion: Implications for Defect Prediction and Powder Degradation (Invited)** **Zhuoer Chen,** Soochow University
16:50 – 17:10	**Enhancing the Sensitivity of In-Situ Monitoring Data for Porosity Identification during the L-PBF printing of Spinal Cage Devices (Invited)** **Denis Dowling,** University College Dublin
17:10 – 17:30	**From Food Printing and Moving Sushi to Space Dining: A Digital Manufacturing Platform for the STAR-MEALS Project (Invited)** **Hidemitsu Furukawa,** Yamagata University
17:30 – 18:00	**In-Situ Radiant Auxiliary Heating in Fused Filament Fabrication (FFF) (Keynote)** **Eleonora Ferraris,** KU Leuven

Track 3 – 05 August 2026 (13:00 – 18:00) **Materials Science in Advanced Manufacturing** **Chairs: Dr Haider Butt**	
13:00 – 13:30	**Oxide Control Strategies for High-Strength Steel Processed by Laser Powder Bed Fusion (Keynote)** **Xin Lin,** Northwestern Polytechnical University
13:30 – 14:00	**3D Printing of Multi-material Nanocomposites for Multifunctional Applications (Keynote)** **Haider Butt,** Khalifa University of Science and Technology
14:00 – 14:15	**Multiscale Microstructure Engineering Enables Exceptional Strength-Ductility Synergy in Laser Powder Bed Fusion Processed AlSi10Mg (Invited)** **Xijie Zhao,** Harbin Institute of Technology
14:15 – 14:30	**Achieving the Strength-ductility Trade-off of Ti-10Mo Alloys by Laser Powder Bed Fusion via Phase Modulation (Invited)** **Yuezhi Wu,** Chongqing Institute of Green and Intelligent Technology
14:30 – 14:45	**Microstructure Analysis and Micro-Mechanical Properties of Cu-based Metallic Glass between Different Scanning Strategies by Laser Powder Bed Fusion** **Hsuan Min Lin,** National Sun Yat-Sen University

14:45 – 15:00	**Hydrogen Embrittlement in Additively Manufactured Maraging Steels: From Mechanism Understanding to Hydrogen-Resistance Design** **Shiqi Zhang,** Wuhan University of Science and Technology
15:00 – 15:15	**Study on High-Temperature Purely-dissolutive Wetting behaviors in Metallic Systems** **Youqing Sun,** Chongqing Institute of Green and Intelligent Manufacturing
15:15 – 15:30	**A High-volume-fraction L12 Precipitates-strengthened High-entropy Alloy with Synergistic Properties for High-temperature Applications** **Shiwei Wu,** Chongqing Institute of Green and Intelligent Technology
15:30 – 15:50	Tea break
15:50 – 16:10	**Programmable Design and Fabrication of Continuous Compositionally Gradient Interfaces in Multi-Material L-PBF Enabled by Custom Slicing Software (Invited)** **Xin Li,** Harbin Engineering University
16:10 – 16:30	**Grain Boundary α and its Effects on Mechanical Properties of Additively Manufactured Titanium Alloys (Invited)** **Kai Zhang,** Soochow University
16:30 – 16:45	**From Ti Addition to Al3Ti Nucleation: A Dissolution-governed Crack Suppression in Laser Powder Bed Fused 7075 Aluminum Alloy** **Kai Kang,** Chongqing Institute of Green and Intelligent Technology
16:45 – 17:00	**Harnessing Additive Manufacturing to Architect Microalloying-induced (TiB + Y2O3) Nanodispersions for Exceptional Strengthening of Near-α Titanium Alloy** **Bochao Li,** Harbin Engineering University
17:00 – 17:15	**Advanced Crystalline-amorphous Dual-phase Nanostructured Metals by Additive Manufacturing** **Xusheng Yang,** The Hong Kong Polytechnic University
17:15 – 17:30	**Voxel-Based Path Planning Method for Multi-Material Additive Manufacturing** **Liangcheng Chao,** Chongqing Institute of Green and Intelligent Technology
17:30 – 17:45	**Mechanical Properties and Microstructure Evolution of Copper-Manganese-Tin Alloy Using Selective Laser Melting and Development of Bimetallic Printed Alloys** **Bing-Ru Hsieh,** National Sun Yat-Sen University
17:45 – 18:00	**Robust Thermochromic Photothermal Coating with Ultraslippery Anti-icing/de-icing and All-season Temperature Regulation Performance** **Shize Sun,** Beihang University

Track 4 – 05 August 2026 (13:00 – 18:00) **3D Bioprinting and Biomedical Applications** **Chairs: Dr Changjin Huang**	
13:00 – 13:30	**Inkjet-printed Spherical Microwells for Sustainable Multicellular Structure Engineering (Keynote)** **Changjin Huang,** Nanyang Technological University
13:30 – 14:00	**3D Printing of Ceramics and Composites for Orthopaedic and Dental Applications (Keynote)** **Sumita Bose,** Washington State University
14:00 – 14:20	**3D (Bio)printing of Clinically-relevant Soft Tissues (Invited)** **Sanjairaj Vijayavenkataraman,** New York University of Abu Dhabi
14:20 – 14:40	**Granular Bioprinting for Functional Organoid-Laden Construct (Invited)** **Cyrus Beh,** Bioprocessing Technology Institute

14:40 – 15:00	**Additive Manufacturing System for Cell Laden Gelatin (Invited)** **Jiawei Tay,** Singapore University of Technology and Design
15:00 – 15:15	**From Nanopores to Microfibres: Micro- and Nano-Architected Bioactive Materials for Bone Repair** **Chun Xu,** University of Sydney
15:15 – 15:30	**Oxygen-Regulated UV Crosslinking for Programmable Swelling-Driven Shape Morphing in Extrusion-Based 4D Bioprinting** **Renzhi Hu,** Nanyang Technological University
15:30 – 15:50	Tea break
15:50 – 16:20	**3D Printing of Hard and Soft Smart Materials for Sustainable Biomedical and Environmental Applications (Keynote)** **Charlotte A. E. Hauser,** Graz University of Technology
16:20 – 16:40	**3D Bioceramic Bone Graft Implants: Technological Breakthroughs, Clinical Applications, and Market Opportunities (Invited)** **Chih-Kuang Wang,** Kaohsiung Medical University
16:40 – 17:00	**Nanoscale Transport and Mechanics in Energy and Biomedical Applications (Invited)** **Jingjie Yeo,** Cornell University
17:00 – 17:15	**3D Printing of Eutectic Gallium-Indium for Fabrication of Soft Biosensor** **Jaw Wei Qi,** Nanyang Technological University
17:15 – 17:30	**Tuning the Adsorption of Metal Ions in 3D printed Organogels via pKa Modification** **Samuel Lee,** Nanyang Technological University
17:30 – 17:45	**3D Printing of ZnO-modified Hydroxyapatite Scaffolds with Directional Pore Microstructure for Enhanced Mechanical Properties and Biocompatibility** **Xianglin Zhou,** Southeast University
17:45 – 18:00	**AI-driven Process Optimization and Yield Enhancement in Fermentation Manufacturing** **Chun-Chieh Chen,** TherapiAI Inc.

Track 5 – 05 August 2026 (13:00 – 18:00) **Emerging Materials and Processing Techniques** **Chairs: Dr Zhangwei Chen**	
13:00 – 13:30	**Microstructure-Driven Strain Hardening and Strength in Additively Manufactured Titanium Alloys (Keynote)** **Yuman Zhu,** Monash University
13:30 – 14:00	**Additive Manufacturing of Advanced Ceramics for Various Applications (Keynote)** **Zhangwei Chen,** Shenzhen University
14:00 – 14:30	**High Performance Plain Carbon Steels obtained Through 3D-printing (Keynote)** **Qiyang Tan,** The University of Queensland
14:30 – 15:00	**Microalloying during Laser Powder Bed Fusion and Laser Metal Deposition: Key Technologies to a Sustainable Production of Shape Memory Alloy Devices (Keynote)** **Jose M. San Juan,** University of the Basque Country
15:00 – 15:15	**Electrolyte-Defined Metal Growth for Confined Electrochemical Additive Manufacturing** **Daniel Jee Seng Goh,** Nanyang Technological University
15:15 – 15:30	**Extrusion-Based 3D Printing as a Strategy for Sustainable, Customizable Plant-Based Fermented Food Production Using Alternative Grains: An Ancient Sourdough Model** **H. Saadiye Eryilmaz,** Singapore University of Technology and Design

15:30 – 15:50	Tea break
15:50 – 16:10	**Effects of Femtosecond Laser Texturing on the Corrosion Resistance Of 316L Austenitic Stainless Steel Fabricated By Binder Jetting (Invited)** **Shaoyun Zhou,** Nagoya University
16:10 – 16:30	**Study on the Formation Mechanisms and Application Extensions of Electrospray-Printed Microstructures Based on Charged Droplet Deposition Regulation (Invited)** **Li Wang,** Xi'an Jiaotong University
16:30 – 16:50	**Laser Powder Bed Fusion of NiTi: Shape Memory Effect (Invited)** **Zhiheng Hu,** Singapore Institute of Manufacturing Technology
16:50 – 17:10	**3D-Printed Support for a Huygens Source Antenna: Design and Near-Field Impact (Invited)** **Yi Li,** Singapore University of Technology and Design
17:10 – 17:30	**In-situ Formation of Graphene-reinforced FeNiCrCo High-entropy Alloy Nanocomposites via Laser Powder Bed Fusion: Enhanced Strength without Sacrificing Ductility (Invited)** **Tan Shu,** Wuhan University of Science and Technology
17:30 – 17:45	**Fast Laser Processing of Silicon Carbide Ceramic Materials** **Jie Yin,** Shanghai Institute of Ceramics
17:45 – 18:00	**Swelling-Programmed Topography for Scalable and Size-Controlled Spheroid Manufacturing** **Seon Yeong Chae,** Pusan National University

PROGRAMME

Day 3 – 06 August 2026

BREAKOUT TRACKS					
	Track 1	**Track 1**	**Track 3**	**Track 4**	**Track 5**
08:30 – 10:00	**Industry and Applications**	**New Processes and Techniques**	**Advanced Metals Processing**	**In-process Monitoring and Process Control**	**Artificial Intelligence and Multi-scale Simulations**
10:00 – 10:20	Tea break				
10:20 – 12:30	**Industry and Applications**	**New Processes and Techniques**	**Advanced Metals Processing**	**In-process Monitoring and Process Control**	**Artificial Intelligence and Multi-scale Simulations**
12:30 – 13:00	Lunch				
13:00 – 15:30	**Industry and Applications**	**New Processes and Techniques**	**Materials Science in Advanced Manufacturing**	**Innovations in Advanced Manufacturing**	**Material Advancements in Manufacturing**
15:30 – 15:50	Tea break				
15:50 – 18:30	**Industry and Applications**	**New Processes and Techniques**	**Materials Science in Advanced Manufacturing**	**Innovations in Advanced Manufacturing**	**Material Advancements in Manufacturing**

DETAILED PROGRAMME – BREAKOUT SESSIONS

Track 1 – 06 August 2026 (08:30 – 12:30)
Industry and Applications
Chair: Dr Yi Cai

08:30 – 09:00	**Driving A*STAR's Industrial Additive Manufacturing Innovations (Keynote)** **Sharon Nai,** A*STAR Singapore Institute of Manufacturing Technology and Additive Innovation Centre
09:00 – 09:30	**Building Digital Twins for Efficient and Reliable Additive Manufacturing Processes (Keynote)** **Yi Cai,** The Hong Kong University of Science and Technology (Guangzhou)
09:30 – 10:00	**Fatigue Design for Additive Manufacturing and Qualification of Metal 3D Printed Parts (Keynote)** **John Pang,** Nanyang Technological University
10:00 – 10:20	Tea break

10:20 – 10:40	**From Research Validation to Industrial Trust: The Role of AM Qualification in Accelerating Regional and Global Adoption (Invited)** **Chen Ze,** DNV Singapore
10:40 – 11:00	**Advanced Manufacturing of Metal Matrix Composites for Thermal Management Applications (Invited)** **Asuka Suzuki,** Nagoya University
11:00 – 11:20	**Non-invasive Online Monitoring of Micro-Milling Tool Wear Based on Stray Magnetic Field of Motorized Spindle (Invited)** **Tongshun Liu,** Suzhou City University
11:20 – 11:40	**Advanced Microfluidics for Biomedical Applications (Invited)** **Ai Ye,** Singapore University of Technology and Design
11:40 – 12:00	**The Future of 3D Printing: Scientific and Patent Analytics for Strategic Innovation (Invited)** **Marisela Rodriguez Salvador,** Tecnologico de Monterrey
12:00 – 12:15	**Microwave in Additive Manufacturing - Near-Field Microwave-Plasma Metal Fusion** **Ka Wai Yeung,** Commonwealth Scientific and Industrial Research Organisation
12:15 – 12:30	**Mass Customization of Footwear Using Additive Manufacturing** **Phillis Teng,** National Institute of Education

Track 2 – 06 August 2026 (08:30 – 12:35) **New Processes and Techniques** **Chairs: Dr Young Jin Kim**	
08:30 – 09:00	**To be confirmed (Keynote)** **David Rosen,** Institute of Advanced Intelligence and Computing
09:00 – 09:30	**Ultrafast Photonics for Precision Manufacturing of Semiconductors and Secondary Batteries (Keynote)** **Young Jin Kim,** Korea Advanced Institute of Science and Technology
09:30 – 10:00	**The Complex Metallurgy Mismatch Emerging from LPBF Supportless Low Angle Printing (Keynote)** **Mathieu Brochu,** McGill University
10:00 – 10:20	Tea break
10:20 – 10:40	**Application-Driven Directed Energy Deposition for Industrial Remanufacturing (Invited)** **Chen Peng,** Singapore Institute of Manufacturing Technology
10:40 – 11:00	**Design and Additive Manufacturing of Structural Batteries (Invited)** **Zhiyang Lyu,** Southeast University
11:00 – 11:20	**Alignment-Controlled Printing of Anisotropic Materials via Lithography-Based Composite Manufacturing (LCM) (Invited)** **Pil-Ho Lee,** Korea Institute of Machinery and Materials
11:20 – 11:35	**Leaf Biowaste–Derived Conductive Platforms for Biodegradable Wearable Electronics and Direct-Current Triboelectric Energy Harvesting toward Sustainable Circular Electronics** **Min-Hsuan Lee,** National Tsing Hua University
11:35 – 11:50	**Laser-Induced Hydrothermal Growth of ZnO/MXene Heterostructures for On-Chip Multifunctional Sensors** **Tong Zhang,** Shandong University of Technology
11:50 – 12:05	**Waveform Optimization and Grayscale Binder Compensation for Furan-Resin Jetting Using an SG1024 Printhead in a Self-Built Sand-Mold Binder Jetting System** **Shu Chen Kuo,** Tamkang University
12:05 – 12:20	**Coaxial Printing of Liquid Metal Based Soft and Highly Conductive Bioelectrodes** **Xinchao Gao,** Nanyang Technological University
12:20 – 12:35	**Hybrid additive and Pressure Assisted Manufacturing of Thin Fe-6.5Si Metal–insulator–metal Composite Soft Magnetic Cores** **Taehyeob Im,** Nanyang Technological University

Track 3 – 06 August 2026 (08:30 – 12:35) **Advanced Metals Processing** **Chairs: Dr Yuchao Bai**	
08:30 – 09:00	**Physics-Guided Microstructure and Defect Engineering in LPBF of AA6061 via Laser Modulation and Substrate Preheating (Keynote)** **Lang Yuan,** University of South Carolina
09:00 – 09:30	**Designing against Failure in Monolithic and Graded Additively Manufactured Materials (Keynote)** **Allison Beese,** Pennsylvania State University
09:30 – 09:45	**Solidification Behavior Regulation and Strengthening-Toughening Mechanism of Green Laser Additively Manufactured Particle-reinforced 7075 Aluminum Alloy** **Tianshu Liu,** Soochow University
09:45 – 10:00	**In-situ Architecturing of 3D Microstructural Composites via Laser Additive Manufacturing for Synergistic Property Enhancement** **Kaihao Zhang,** The Hong Kong University of Science and Technology (Guangzhou)
10:00 – 10:20	Tea break
10:20 – 10:40	**Micro-scale Structure Control and Property Optimization Enabled by Precise Laser Energy Input in LPBF (Invited)** **Yang Yang,** Guangdong University of Technology
10:40 – 11:00	**Achieving Heterogeneous Interface Uniformity in Micronozzle-Controlled Laser Powder Bed Fusion via Continuously Variable Transmission-inspired In-layer Gradients Oof Powder Deposition (Invited)** **Lin Li,** Harbin Engineering University
11:00 – 11:20	**Laser Powder Bed Fusion of Ultra-High-Strength Maraging Steel: Towards High Performance and Excellent Surface Quality (Invited)** **Yuchao Bai,** Harbin Institute of Technology Shenzhen
11:20 – 11:35	**Processing–Microstructure–Property Relationships in Fe–Cu Biodegradable Alloys Fabricated by Laser-based Powder Bed Fusion of Metals** **Fengbing Ni,** National University of Singapore
11:35 – 11:50	**Support-Enabled In-Situ Heat Treatment for Microstructure Programming in Additive Manufacturing of High-Strength Aluminum Alloys** **Cherq Chua,** National University of Singapore
11:50 – 12:05	**Enhanced Mechanical Properties of Laser Directed Energy Deposition (LDED) Pure Titanium with Trace Interstitial Oxygen Solute** **Ziheng Tang,** Changsha University of Science and Technology
12:05 – 12:20	**Investigating and Mitigating Protrusion-Induced Powder Bed Anomalies in Laser Powder Bed Fusion** **Kanishka Chamod,** Monash University

12:20 – 12:35	**Design of Aluminum Alloys for Additive Manufacturing Based on Microstructure Control** **Qiuju Zheng,** Chongqing School University

Track 4 – 06 August 2026 (08:30 – 12:25) **In-process Monitoring and Process Control** **Chairs: Dr Dermot Brabazon**	
08:30 – 09:00	**Magnetic-assisted Laser Shock Peening of Magnesium Alloys with Real-Time Monitoring of Plasma Dynamics and Acoustic Emission (Keynote)** **Yongling Wu,** Shandong University of Technology
09:00 – 09:30	**Generating a Digital Twin of the Laser Powder Bed Fusion Process (Keynote)** **Dermot Brabazon,** DCU Institute for Advanced Manufacturing & I-Form, National Advanced Manufacturing Research Centre
09:30 – 09:45	**Intelligent System for Quality Assessment in EBM Additive Manufacturing using Deep Learning and Large Language Model** **Yoichi Takagishi,** Tohoku University
09:45 – 10:00	**Developing an In-situ Process Monitoring Framework using Acoustic Signals and Optical Emission Spectroscopy in Wire Arc Additive Manufacturing (WAAM)** **Kevin Angga Gunawan,** KU Leuven
10:00 – 10:20	Tea break
10:20 – 10:35	**Uninterrupted Subsurface Temperature Measurement at Multiple Build Heights in PBF-LB Using a Novel Thermocouple Insertion Technique** **Xitis Lal Shrestha,** KU Leuven
10:35 – 10:50	**Multi-scale Multi-physics Numerical Simulation Study of Laser Powder Bed Fusion Process** **Liu Cao,** Guangzhou University
10:50 – 11:10	**Addressing the Scale-Resolution Dilemma in Vat Photopolymerization Through a Motion-Aided Approach (Invited)** **Yang Xu,** The University of Hong Kong
11:10 – 11:25	**Real-Time Monitoring and Closed-Loop Control for Defect Mitigation in Directed Energy Deposition using Optical Emission Spectroscopy** **Mohit Singh,** Indian Institute of Technology Jodhpur
11:25 – 11:40	**Mitigating electrical anisotropy in FDM-printed electronics via laser sintering of copper-flake filaments** **Xiaoying Qi,** Singapore Institute of Manufacturing Technology
11:40 – 11:55	**Real-Time Interferometric Surface Topography Measurement Using Generalization-Optimized Physics-Informed Deep Learning** **Juncheol Bae,** Pusan National University
11:55 – 12:10	**Addressing Warpage in Vat Photopolymerization through an Energy Distribution-Based Exposure Strategy** **Taehyub Lee,** Nanyang Technological University
12:10 – 12:25	**Physics-Guided Learning Framework for Robust In Situ Defect Detection in Laser Powder Bed Fusion** **Jiayi Zhang,** National University of Singapore

Track 5 – 06 August 2026 (08:30 – 12:30) **Artificial Intelligence and Multi-scale Simulations** **Chairs: Dr Wenhui Yu**	
08:30 – 09:00	**Science-informed Materials Discovery via Computational Materials Engineering: Multi-Scale Multi-Physics Modelling (Keynote)** **Chinnapat Panwisawas,** Queen Mary University of London
09:00 – 09:30	**AM Qualification and Certification in the Age of AI (Keynote)** **Alex Liu, ASTM International**
09:30 – 10:00	**Scalable Fabrication of Ultra-Thin Shell Lattices via Laser Powder Bed Fusion using a Single-Track Scanning Strategy (Keynote)** **Lei Zhang,** Shanghai Jiao Tong University
10:00 – 10:20	Tea break
10:20 – 10:40	**Cellular Dislocation Networks in Additively Manufactured Alloys: A Double-Edged Sword for Hydrogen Embrittlement (Invited)** **Yakai Zhao,** Future Energy Acceleration and Translation
10:40 – 11:00	**Part-Scale Multiphysics Simulation of Digital Light Processing Vat Photopolymerization Using an Equivalent Irradiance Model (Invited)** **Guang Liu,** Institute of Advanced Intelligence and Computing
11:00 – 11:20	**In-situ High-speed X-ray Imaging of Crack Formation in 3D printed 7075 Alloy with Er and Zr Modification During Laser Remelting (Invited)** **Wenhui Yu,** Shandong University of Technology
11:20 – 11:40	**Domain-Adaptive Digital Process Twins from Sparse Metrology: A Physics-Informed Multi-Modal Graph Transformer Framework for Plasma Etching (Invited)** **Hyungwoong Ko,** Arizona State University
11:40 – 12:00	**Efficient Simulation of SMA Morphing Wings using Physics-informed Neural Networks (Invited)** **Ran Tang,** Institute of High Performance Computing
12:00 – 12:15	**Effect of Gravity on Free-Surface Oscillation Dynamics of Laser-Induced Melt Pools** **Yifan He,** Institute of Mechanics
12:15 – 12:30	**Machine Learning-assisted Thickness Prediction and 3D Surface Reconstruction for Multi-Material Powder Beds in Micronozzle-Controlled Laser Powder Bed Fusion** **Xiyuan Dong,** Chongqing Institute of Green and Intelligent Technology

Track 1 – 06 August 2026 (13:00 – 17:50) **Industry and Applications** **Chair: Dr Peng Song**	
13:00 – 13:30	**Logistics and Additive Manufacturing in Industries (Keynote)** **Shaligram Pokharel,** Qatar University
13:30 – 14:00	**Distributed Knitted Sensor Networks for Multi-Axis Body Movement Monitoring (Keynote)** **Hong Yee Low,** Singapore University of Technology and Design
14:00 – 14:15	**Generative Design and LPBF Manufacturing of a Patient Specific Bone Plate for High Tibial Osteotomy** **Weiting Xu,** University of Bistrol

14:15 – 14:30	**Analysis and Materials Characterization for 3D Food Printing: A Multi-Technique Perspective** **Heng Yong Nie,** The University of Western Ontario
14:30 – 14:45	**4D Printing of Semi-crystalline Thermoplastic Polyimide** **Thang Quyet Tran,** Singapore Institute of Manufacturing Technology
14:45 – 15:00	**Transient Studies on the Irradiation of Metals and Semiconductors by Femtosecond Lasers** **Yuewei Cui,** Shandong University of Technology
15:00 – 15:15	**Topology Optimization Design and Deformation Behavior Control of SMA-actuated Bistable Structures** **Zhi Xing,** Institute of High Performance Computing
15:15 – 15:30	**Brain-like Constructs based on Neural Stem cells Transplanted for Recognition Recovery** **Yu Song,** Tsinghua University
15:30 – 15:50	Tea break
15:50 – 16:10	**Designing Freeform Mechanisms for Exact 3D Path/Motion Generation (Invited)** **Peng Song,** Singapore University of Technology and Design
16:10 – 16:30	**Impact of Wire Arc Additive Manufacturing on Inconel 718 Microstructure and Properties (Invited)** **Shibo Liu,** Singapore Institute of Manufacturing Technology
16:30 – 16:50	**Stable-keyhole Laser Fusion Additive Manufacturing (Invited)** **Cang Zhao,** Tsinghua University
16:50 – 17:05	**A Study on Pressurized Sensing Channels in LPBF A205 Aerospace Components for Fatigue-driven Structural Health Monitoring** **Mirko Sinico,** KU Leuven
17:05 – 17:25	**Boosting the Mechanical Properties at 815 oC of Laser Directed Energy Deposited Inconel 625 alloy by Introducing the Laves Phase (Invited)** **Zuo Li,** Hohai University
17:25 – 17:45	**To be confirmed (Invited)** **Haifei Lu,** Wuhan University of Technology

Track 2 – 06 August 2026 (13:00 – 17:45) **New Processes and Techniques** **Chairs: Dr Xu Song**	
13:00 – 13:30	**Alloy Design Paradigms in Additive Manufacturing (Keynote)** **Chaolin Tan,** Soochow University
13:30 – 14:00	**Integrating Computer-aided Design, Computational Simulations and Additive Manufacturing for Developing Advanced Tissue Engineering Scaffolds (Keynote)** **Min Wang,** The University of Hong Kong
14:00 – 14:20	**AI-enabled Inverse Design of Multifunctional Lattice Metamaterials (Invited)** **Xu Song,** The Chinese University of Hong Kong
14:20 – 14:40	**Multifunctional Additive Manufacturing with Laser-Induced Graphene (Invited)** **Gerd Grau,** York University
14:40 – 15:10	**Investigating Inorganic Solid-Electrolyte Interphase Compounds for Stabilizing Lithium Metal Anodes (Invited)** **Mun Sek Kim,** Nanyang Technological University

15:10 – 15:30	**Reframing Additive Manufacturing through Textile-Integrated 4D Structures (Invited)** **Danchen Zhang,** RWTH Aachen University
15:30 – 15:50	Tea break
15:50 – 16:10	**3D Printing Forerunning Futuristic Spinal Implant Material Research (Invited)** **Naresh Kumar,** National University of Singapore
16:10 – 16:25	**Development of a Novel Method for Multi-Material 3D Food Printing via Single Inlet and Outlet** **Phoebe Leam,** Singapore University of Technology and Design
16:25 – 16:40	**Edge Computing Design Scenario for Direct-ink-writing 3D Printing** **Yu Liu,** Jiangnan University
16:40 – 16:55	**Effects of Spin-Coating Process on the Accuracy and Precision of Three-Dimensional Microchannels in Two-Photon Polymerization** **Juncheng Zhu,** Jiangnan University
16:55 – 17:25	**Electron Beam Powder Bed Fusion of Pure Tungsten: From Machine Development to Atomic-Scale Grain Boundary Engineering (Keynote)** **Kenta Yamanaka,** Tohoku University
17:25 – 17:45	**Development of a Low-cost Progressive Cavity Pump for Controlled Extrusion in 3D Food Printing** **Noel Quah,** Nanyang Technological University

Track 3 – 06 August 2026 (13:00 – 17:45) **Materials Science in Advanced Manufacturing** **Chairs: Dr Punit Kumar**	
13:00 – 13:30	**Imperceptible Augmentation of Living Systems with Organic Bioelectronic Fibres (Keynote)** **Shery Huang Yan Yan,** University of Cambridge
13:30 – 14:00	**Structurally Instructive Biofabrication: High-Fidelity Light-Based 3D Printing of Architected Scaffolds for Tissue Engineering (Keynote)** **Xiaoxiao Han,** Hunan University
14:00 – 14:20	**Simple Chemistries for the Vat Photopolymerization of Advanced Materials (Invited)** **Daryl Yee,** EPFL
14:20 – 14:40	**Research on Powder Spreading Technology and Process optimization in Multi-material Laser Powder Bed Fusion Additive Manufacturing (Invited)** **Xinyuan Wu,** Harbin Engineering University
14:40 – 15:00	**3D-Printed Electromagnetic Systems via Multi-Material Extrusion (Invited)** **Luis Fernando Velásquez-García,** Massachusetts Institute of Technology
15:00 – 15:15	**Ultrasonic Welding Process and Mechanism of 3D Printing Continuous Carbon Fiber Reinforced Nylon Composites** **Shuo Han,** Shanghai University of Engineering Science
15:15 – 15:35	**Impact of 3D Printed Meals in Local Nursing Home with Dysphagia Patients (Invited)** **Qing Yang Tan,** Singapore University of Technology and Design
15:35 – 15:50	Tea break

15:50 – 16:10	**Bioprinted Interfacial Complex Constructs for Advanced Healthcare Applications (Invited)** **Maria Chatzinikolaidou,** University of Crete
16:10 – 16:30	**Advanced Manufacturing Strategy of a Protective Coatings for y-TiAl Alloy Aero-Components with Long-Term High Temperature Service Performance (Invited)** **Yongsheng Wang,** Taiyuan University of Technology
16:30 – 16:45	**Next-Generation Fatigue Design of Laser Powder Bed Fusion Manufactured Inconel 718 through Realistic Loading Characterization and Constitutive Modeling** **Bimal Das,** Ahmedabad University
16:45 – 17:00	**Prediction of Defect Size in Friction Stir Additive Manufacturing Using Machine Learning Algorithms** **Shuja Ahmed,** Ahmedabad University
17:00 – 17:15	**A Temperature-controlled Multi-syringe Pneumatic System for Scalable Fish Gelatin Bioprinting** **Zhi Xiang Ong,** Singapore University of Technology and Design
17:15 – 17:30	**Isogeometric Concurrent Optimization of Continous Fiber Paths and Structural Topology for Additive Manufacturing** **Wenjie Ding,** Beijing Institute of Technology
17:30 – 17:45	**Development of NTi Shape Memory Alloy Using a Unique In-House Developed Twin Wire Arc Additive Manufacturing System** **Rajendra Goud,** Indian Institute of Technology Indore

Track 4 – 06 August 2026 (13:00 – 17:20)
Innovations in Advanced Manufacturing
Chairs: Dr Gim Song Soh

13:00 – 13:30	**Thermal-Driven Microstructure Evolution, Defect Formation and Property Control in Metal Additive Manufacturing (Keynote)** **Pan Wang,** Singapore Institute of Manufacturing Technology
13:30 – 14:00	**Recent Progress in Ultrafast Laser Micro/Nano Fabrication (Keynote)** **Hongyu Zheng,** Shandong University of Technology
14:00 – 14:30	**Acoustic and Multimodal Defect Detection for Wire Arc Additive Manufacturing (Keynote)** **Gim Song Soh,** Singapore University of Technology and Design
13:50 – 14:10	**Difference in Motivation, Process, and Performance in Horizontal and Vertical Interfacial Interfaces of Multi-Material Laser Powder Bed Fusion: An Interesting Interface Case Inspired by Continuously Variable Transmission (CVT) Mechanics (Invited)** **Qimin Shi,** Chongqing Institute of Green and Intelligent Technology
14:10 – 14:30	**High-resolution 3D Printed Integrated Photonic Devices (Invited)** **Dawn Tan,** Singapore University of Technology and Design
14:30 – 14:50	**Interfacial Phase Regulation and Bonding Strength in L-PBF Steel/Al Multi-Material Components (Invited)** **Yujie Cui,** University of Science and Technology Beijing
14:50 – 15:10	**Investigation of Volumetric Additive Manufacturing Technologies for Functional Devices (Invited)** **Shuai Peng,** Jiangnan University
15:10 – 15:30	**Experimental Investigation and Finite Element Modelling of 3D-Printed Recycled Polypropylene with Fused Granulate Fabrication (Invited)** **Phan Quoc Khang Nguyen,** Western Sydney University

15:30 – 15:50	Tea break
15:50 – 16:10	**Multi-Objective Optimization of TPMS-Based Multilayer Osteochondral Scaffolds Balancing Mechanical Strength and Porosity (Invited)** **Yan Xu,** University of Bristol
16:10 – 16:30	**Enhanced Resistance to H Embrittlement of Ni-based Alloy Fabricated by Laser Powder Bed Fusion with Crystallographic Texture Control (Invited)** **Ozkan Gokcekaya,** The University of Osaka
16:30 – 16:50	**Evaluating Powder Reuse Strategies for Ti-6Al-4V in Laser Powder Bed Fusion (Invited)** **Sankaranarayanan Seetharaman,** Singapore Institute of Manufacturing Technology
16:50 – 17:20	**Endowing Large Language Models with Efficient and Online Memory (Keynote)** **Soujanya Poria,** Nanyang Technological University

Track 5 – 06 August 2026 (13:00 – 16:45)
Material Advancements in Manufacturing
Chairs: Dr Jia An

13:00 – 13:30	**3D-Printable Composite Filaments with Controlled Water Resistance for Sacrificial Molding of Biomimetic Vasculatures (Keynote)** **Michinao Hashimoto,** Singapore University of Technology and Design
13:30 – 13:50	**Buckling Guided Architected Lattice Structures, From Instability to Optimized Functionality (Invited)** **Kamran Ahmed Khan,** Khalifa University of Science and Technology
13:50 – 14:10	**Additive Manufacturing for Next-generation Energy Storage Systems (Invited)** **Meng Cheng,** Wuhan University of Science and Technology
14:10 – 14:30	**WAAM Propeller Certification Process (Invited)** **Youssef Elkhouly,** Singapore University of Technology and Design
14:30 – 14:45	**Hydrogen Embrittlement in Additively Manufactured Maraging Steels: From Mechanism Understanding to Hydrogen-Resistance Design** **Shiqi Zhang,** Wuhan University of Science and Technology
14:45 – 15:00	**Using Image Recognition to Analyze Microstructure Evolution via Heat Treatment of 3D Printing Parameter Al/SiC Metal Matrix Composite** **Yi Chao,** National Sun Yat-Sen University
15:00 – 15:15	**Multifunctional Flexible Strain Sensors Based on Ag@Graphene/Resin Composites for Motion Monitoring and Morse Code Communication** **Renbao Wang,** Shandong University of Technology
15:15 – 15:30	**A Multigrid Path Optimization Scheme for Computationally Tractable Thermal Path Planning in Metal Additive Manufacturing** **Yufan Zheng,** Xi'an Jiaotong-Liverpool University
15:30 – 15:50	Tea break
15:50 – 16:20	**Multifunctional Architected Materials Enabled By Additive Manufacturing and Nanoengineering (Keynote)** **Shanmugam Kumar,** University of Glasgow
16:20 – 16:35	**To be confirmed** **Shun Wu,** Soochow University
16:35 – 16:50	**To be confirmed** **Feng Zhang**

ABSTRACT

Digital Bridge: “Twinning Oldest and Newest Manufacturing Processes for the 21st Century - Metal Casting meets Additive Manufacturing”

Dr Guha Manogharan

Pennsylvania State University

Abstract

In this seminar, we will discuss recent advancements in digital twin technologies enabled by additive manufacturing (AM) and how AM can be seamlessly integrated with other manufacturing methods, i.e., “indirect: metal AM to address major challenges in the oldest manufacturing technique: Casting processes.

Over 90% of all manufactured goods and machinery use a cast part. Sand casting is a manufacturing process that dates to 7000 BC and accounts for 70% of all cast parts. Sand casting has several critical applications in a variety of sectors including defense, energy, aerospace and automotive. According to American Foundry Society (AFS), you are always within 10 feet of cast part (e.g., automotive engines, valves, manifolds). However, conventional sand casting is regarded as a process of uncertainty due to its tendency to render higher scrap rates even in completely controlled processing environments. Casting defect analysis shows that over 90% of casting defects occur due to improper gating and feeding systems. This talk will first present a novel approach to rethink the design principles for: (a) sand cast parts and (b) gating and feeding systems to reduce defects through 3D sand-printing. Results from numerical analysis, computational melt flow simulations and experimental evaluation show that 3D Sand-Printing can lower melt flow turbulence in castings which reduces casting defects (35% reduction) and improves as-cast mechanical properties (15% increase in as-cast strength). Finally, a brief overview of other “direct” metal AM research, in particular Multi-Material Laser Powder Bed Fusion (MM-LPBF) will be presented.

Multi-material LPBF additive manufacturing

Yang Shoufeng

Chongqing Institute of Green and Intelligent Technology , Chinese Academy of Sciences

Abstract

Multi-material additive manufacturing (MMAM) enables spatially controlled material composition within complex parts, thereby offering a powerful route to fabricate heterostructures. Additive manufacturing (AM), also known as three-dimensional (3D) printing, encompasses a family of fabrication techniques in which complex geometries can be built directly on a platform from a computer-aided design (CAD) file. These processes construct components point by point, line by line, or layer by layer, without the need for moulds or subtractive machining. Nevertheless, most commercially available AM systems are designed for single-material processing. MMAM is emerging as the next generation of additive manufacturing, capable of controlling both geometry and material composition, and represents a promising approach to realise heterostructures. In this talk, I will review the current state of the art in multi-material additive manufacturing, present our dry powder micro-dispensing technology developed for laser powder bed fusion (LPBF)-based AM, and discuss recent progress in fabricating heterostructures using MMAM.

Effects of Spin-Coating Process on the Accuracy and Precision of Three-Dimensional Microchannels in Two-Photon Polymerization

Jun Ren, Juncheng Zhu, Feng Yu, Biao Luo

Jun Ren

Abstract

As a direct laser printing technology, two-photon polymerization (TPP) addresses the limitations of fabricating arbitrary three-dimensional (3D) microchannels for conventional lithography and additive manufacturing. However, as precision increases, the influence of the meniscus-induced protrusion of the photoresist surface will be magnified, as the light path is bent when traveling through the resin surface, thereby causing a shift in the focus point of the light beam. We conduct the spin-coating experiment to investigate the meniscus's effect. In this paper, we conduct spin-coating experiments at different angular speeds and accelerations to adjust the thickness of the resin vat at different depths. We investigate the effect of the spin-coating experiment by printing the identical standard models for micro-channels. An extended-depth-of-field microscope is employed to detect the shape and channels. The printed result from the group with the proper speed significantly exhibits the accuracy of the microchannel. This work demonstrates that, via spin-coating processes, accuracy and precision can be significantly improved, providing a possible strategy for high-quality printing.

Detect, Predict, Intervene: Physics-Informed, Pyrometer-Sensor-Driven Machine Learning for In-Situ Quality Assurance in Metal Additive Manufacturing

John Kgee Ong, Qing Yang Tan, U-Xuan Tan and Nagarajan Raghavan

Digital Manufacturing and Design (DManD) Centre, Engineering Product Development (EPD) Pillar, Singapore University of Technology and Design, Singapore 487372

Abstract

Laser-based additive manufacturing (LBAM) produces complex, high-value metallic parts but operates within a narrow, stochastic process window where small thermal perturbations drive porosity, lack-of-fusion, and property scatter. Conventional ex-situ quality assurance (QA) — computed tomography, Archimedes density, hardness testing — is costly, post-process, and too late for correction, while image-based deep learning demands heavy labelling and GPU-class compute that constrain shop-floor adoption. This invited talk presents a doctoral framework that converts scan-synchronous melt-pool thermal emission from in-situ dual-wavelength pyrometers into interpretable, computationally lightweight QA evidence, organised along a realistic detect–predict–intervene pathway.

Detection reformulates melt-pool thermal fields into multi-orientation profiles with physics-informed features (Melt-Pool Distance, ARTM), enabling shallow classifiers to identify multi-class porosity in Ti-6Al-4V at CPU-only, sub-millisecond latency. Prediction fuses machine settings, statistical pyrometer descriptors, and physics-based features to estimate maraging-steel part density ($R^2 \approx 0.95$) under label-scarce, production-like constraints. Intervention investigates pyrometer-guided second-pass laser remelting as a technique to monitor and validate process-parameter selection for defect reduction; wavelet multi-resolution descriptors and unsupervised anomaly screening flag high-risk regions and recommend selective Soft/Moderate/Hard remelting, balancing densification against thermal instability and surface penalties.

The talk is candid about present limitations — part-level rather than layer-resolved ground truth, controlled single-alloy datasets, and rule-guided rather than autonomous decisions — and uses them to frame a realistic forward path: layer-wise metrology, multi-sensor fusion (pyrometry, coaxial imaging, acoustic emission), uncertainty-aware decision gating, and a proposed supervisory closed loop with deterministic between-layer timing. Consolidating sensor logs, inferences, interventions, and verification into an auditable digital build profile, the work positions data-efficient, physics-informed sensing as a credible foundation for certifiable, self-correcting metal AM.
Keywords: In-Situ Pyrometer, Physics-Informed Machine Learning, Quality Assurance, Laser Remelting, Anomaly Detection, Digital Build Profile, Metal Additive Manufacturing

Distributed Knitted Sensor Networks for Multi-Axis Body Movement Monitoring

Low Hong Yee

Engineering Product Development | Digital Manufacturing and Design Centre

Abstract

Digital knitting enables the seamless integration of multiple yarn types, conductive, dielectric, and elastic into a single garment in one manufacturing step, with sensor placement, geometry, and interconnect routing all defined through a digital design file. Realising the full potential of this platform requires a principled design methodology where the spatial distribution and geometric configuration of sensors within the textile are as consequential as the manufacturing process itself.

Advancing from single-sensor designs, our group has shown that deliberately programmed multi-yarn and multi-functional yarn combinations set a new benchmark, collapsing sensing, signal transmission, compression, and structural functions into a single ready-to-wear garment requiring nearly no post-fabrication assembly. This is demonstrated through two systems: a knitted crop top embedding a network of eight strain sensors and interconnects for upper body monitoring, and a knitted knee brace integrating three geometrically configured sensors for knee stability assessment fabricated as single, seamless textile structures.

Sensor placement in both systems is derived from 3D skin strain mapping, positioning each sensor where electromechanical response is greatest during movement. This distributed architecture resolves what single-sensor designs cannot: complex, multi-axis joint kinematics across three planes of motion from a single wearable. The resulting signal networks enable a direct pathway to clinically meaningful outputs, including joint angle reconstruction, muscle fatigue prediction, and detection of movement asymmetries associated with injury risk. Applications span occupational ergonomics and sports injury prevention will be discussed in this talk.

A voxel-driven decomposition framework for support-free path planning in multi-axis additive manufacturing

Zhengren Tong, Lai Xu, Hongyao Shen

a) State Key Laboratory of Fluid Power and Mechatronic Systems, School of Mechanical Engineering, Zhejiang University, Hangzhou 310027, China; b) Zhejiang Key Laboratory of Additive Manufacturing Technology and Equipment, Hangzhou 310027, China

Abstract

Conventional three-axis additive manufacturing (AM) typically depends on support structures, which raise material and post-processing costs while degrading surface quality. Multi-axis AM can avoid supports by reorienting the workpiece during deposition. Volume decomposition, which splits a part into simpler sub-models that can be fabricated independently, is a practical way to plan such variable-pose toolpaths. Existing decomposition methods, however, commit to a single cutting form (either planar or curved) throughout the whole pipeline, and therefore handle poorly the diverse overhang geometries found in real parts. This work presents a voxel-based decomposition framework in which planar and curved cuts coexist under one discrete representation. Overhang and self-supporting regions are first separated through voxel-wise overhang analysis. The planarity of the interface voxels is then evaluated to decide, region by region, whether a planar cut (fitted by PCA on mesh-derived surface normals) or a curved cut (grown from a voxel distance field) better matches the local geometry. The selected scheme yields support-free toolpaths for each sub-model. Experiments on a five-axis laser-powder directed energy deposition platform with 316L stainless steel confirm the effectiveness of the approach.

Driving A*STAR's Industrial Additive Manufacturing Innovations

Sharon Nai

*A*STAR SIMTech & Additive Innovation Centre (AIC)*

Abstract

Industrial interest in additive manufacturing (AM) has intensified globally, driven by increasing demand from the defence, aerospace, space and semiconductor sectors. These market dynamics have accelerated both industrial adoption and academic R&D activities in additive and advanced manufacturing across Singapore and the broader region. Anchored in A*STAR's integrated, whole-of-ecosystem R&D strategy, this presentation will highlight key advancements in translating research into industrially relevant solutions.

Key developments will be highlighted across materials innovation, including novel alloys and feedstock optimisation; process advancements to enhance productivity and scalability; and the integration of digitalisation and artificial intelligence-driven advanced modelling to improve process control and component performance. The talk will further explore the evolving role of AM from producing single-function components to enabling multi-functional, high-value systems with enhanced performance and design complexity. By bridging research excellence with industry needs, A*STAR is driving the deployment of robust, scalable AM solutions that support industrial transformation and strengthen Singapore's position as a regional advanced manufacturing hub.

4D Bioprinting of Mesenchymal Stem Cell-laden Dynamic Hydrogels for Bone Regeneration

Shangsi Chen [a, b], Boguang Yang [a, b], Liangbin Zhou [a, b], Rocky S. Tuan [a, b], Zhong Alan Li [a, b,*]

[a.] Department of Biomedical Engineering, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong SAR, China; [b.] InnoHK Center for Neuromusculoskeletal Restorative Medicine, Hong Kong Science Park, N.T., Hong Kong SAR, P.R. China

Abstract

Introduction: 3D bioprinting of cell-laden hydrogels enables complex structure fabrication and stem cell delivery for bone tissue engineering. However, bone defects such as cranial defects possess inherent curvature, making it challenging for 3D bioprinted hydrogels to match the defect geometry. Therefore, developing 4D bioprinted dynamic hydrogels with shape-morphing capacities is highly desirable. To address this need, we prepared a photocrosslinkable bioink containing an effective UV absorber (RhB) to create graded crosslinking density in bioprinted hydrogels, enabling shape morphing upon swelling. Methods: BMSCs were suspended in bioink consisting of GelMA, OAlg, and MgHAp, then 3D bioprinted. Printability, microstructures, and shape-morphing behavior were evaluated. In vitro osteogenic and pro-angiogenic properties were studied using BMSC-laden hydrogels and coculture with HUVECs. In vivo bone regeneration was investigated using a rabbit calvarial defect model. Results: Bioinks exhibited excellent printability and high shape fidelity. Due to RhB's UV-absorbing properties, hydrogels displayed crosslinking density gradients, leading to gradual changes in pore size and swelling behavior, thereby inducing shape morphing. Finite element analysis corroborated these observations. BMSCs showed high viability (>90%) and spreading morphology. The hydrogels sustainably released Ca__ and Mg__, promoting osteogenic gene and protein expression in BMSCs. Coculture experiments revealed that hydrogels promoted vascular network-like structure formation by HUVECs. In vivo results, including micro-CT, histological staining, and immunohistochemistry, collectively showed that 4D bioprinted hydrogels resulted in significantly faster bone regeneration.

Conclusions: The bioinks displayed excellent printability and high shape fidelity. The bioprinted hydrogels showed programmable shape-morphing behavior, making it possible to match native calvarial bone defects. Moreover, due to MgHAp incorporation for sustained Ca__ and Mg__ release, the hydrogels exhibited excellent osteogenic and proangiogenic effects in vitro and in vivo. Support: InnoHK Center for Neuromusculoskeletal Restorative Medicine; CUHK.

Development of a 3D-Printed Carboxymethylated Agarose/Acacia Gum Scaffold Loaded with Tea Tree Oil for Enhanced Angiogenesis and Antimicrobial Wound Healing

Dua Yousaf Lone, Muhammad Taha Asghar

Department of Materials Science and Engineering, Institute of Space Technology, Islamabad Highway, 44000, Islamabad.

Abstract

A novel, potentially effective and precise 3D-printed scaffold will be fabricated for presumable wound healing applications. A natural polysaccharide agarose will be chemically modified to carboxymethylated agarose (CMA) to enhance its reactivity and compatibility towards Acacia gum (AG). Tea tree oil (TTO) will be loaded into the CMA/AG ink prior to 3D printing to build a biologically active scaffold with therapeutic and antimicrobial potential. This combination is selected due to its novelty and the favourable interconnected network that CMA and AG will form together, which will support controlled and sustained drug release. Scanning electron microscopy will reveal the microporous interlinked network structure and uniform distribution of TTO within the scaffold, which will also be validated by Fourier Transform Infrared Spectroscopy (FTIR). The CMA/AG/TTO scaffold will be evaluated for its ability to promote human dermal fibroblast (HDFa) growth and stimulate the release of proteins involved in skin regeneration, as will be assessed through WST-8 cell viability assay and biomarker studies. The scaffold will significantly enhance the release of vascular endothelial growth factor (VEGF) from co-cultured primary HDFa cells in comparison to bare HDFa cells, supporting angiogenesis and tissue repair. Significant bactericidal potency will be assessed against E. coli and S. aureus and will be quantified via viable colony forming units from both bacterial strains co-cultured with the developed CMA/AG/TTO scaffold. In-vivo studies will confirm that the fabricated scaffold will promote the re-epithelialization process and will minimize the risk of inflammation, as will be validated by histological analysis and the release of inflammatory cytokines. Conclusively, this study will feature the CMA/AG/TTO scaffold as a potential next generation wound healing biomaterial.

Chemically Modified Polysaccharides for 3D-Printed Hydrogels in Wound Healing Applications

Muhammad Taha Asghar , Dua Yousaf Lone

Department of Materials Science and Engineering, Institute of Space Technology, Islamabad Highway, 44000, Islamabad.

Abstract

Background:
Wound healing requires the right material at the right time. Natural source polysaccharides are used frequently due to their safety and similarity to the body's tissues. However, in their natural form they are too soft, break down unpredictably, and are not suitable for 3D printing.

Objective:
This review examines the application of chemically modified polysaccharides in 3D-printed hydrogels and wound healing applications.

Key Findings:
Chemical modification increases the ability of polysaccharide chains to bind to each other, leading to more durable networks. This improved structure ensures complete control of drug release, with compounds gradually released into the wound. These modified hydrogels can address multiple healing needs simultaneously: new blood vessels can develop, damaged skin cells can regenerate, infection can be controlled, and the scaffold remains in place during the entire healing process.

Conclusion:
Chemically modified polysaccharides provide researchers and clinicians with customizable material. Testing in real biological systems will be the final step to getting these hydrogels into patient care.

Advanced Manufacturing Strategy of a Protective Platinum Coatings for _-TiAl Alloy Aero-Components with Long-Term High-Temperature Service Performance

Yongsheng Wang

College of Materials Science and Engineering

Abstract

γ-TiAl alloys are a key lightweight structural material for advanced aerospace manufacturing because they combine low density with high specific strength, enabling weight reduction of aero-engine high-temperature components and improving operational efficiency. During high-temperature service, however, TiAl surfaces develop a mixed oxide layer that is loose, defective, and prone to cracking and spalling. These flawed oxide scales substantially degrade high-temperature oxidation resistance, creep performance, and fatigue durability, and they exacerbate the intrinsic brittleness of TiAl intermetallics, thereby limiting large-scale engineering use in advanced high-temperature systems. Conventional protective coatings mainly address oxidation resistance but frequently impair alloy creep, fatigue behavior, and room-temperature ductility. Here we report a facile electroless plating method to deposit a uniform Platinum (Pt) modification layer of approximately 200 nm on TiAl surfaces. Upon high-temperature exposure, Pt nanoparticles remain uniformly dispersed within the thermally grown oxide, refine the oxide microstructure, and enhance interfacial plastic deformation. This coating architecture produces concurrent, substantial improvements in oxidation resistance, high-temperature creep and fatigue performance, and post-oxidation room-temperature tensile properties. The surface-modification strategy thus provides a practical, broadly applicable route to protect high-temperature aerospace components and to promote reliable deployment of TiAl alloys in advanced aerospace manufacturing.

Additive Manufacturing Metallurgy-Guided Machine Learning Design of High-Strength Crack-Free Al-Zn-Mg-Cu-Ti-Zr Alloys for Laser Directed Energy Deposition

Li Zhao; Chaolin Tan

Soochow University

Abstract

Al-Zn-Mg-Cu alloys possess excellent specific strength and are attractive for lightweight aerospace structures. However, their application in laser additive manufacturing is limited by severe hot cracking susceptibility caused by a wide solidification range and rapid thermal cycling. In this work, an additive manufacturing metallurgy-guided machine learning framework was developed to design high-strength, crack-free, and cost-effective Al-Zn-Mg-Cu-Ti-Zr alloys for laser directed energy deposition (LDED). High-throughput CALPHAD calculations were first employed to construct a metallurgical dataset containing key descriptors, including solidification freezing range, hot cracking susceptibility, growth restriction factor, precipitation kinetics of MgZn2 and Al3Zr phases, and alloy cost. Machine learning surrogate models were then established to predict composition–property relationships, followed by multi-objective optimization using NSGA-III and TOPSIS to identify optimal alloy compositions. The introduction of trace Ti/Zr promoted the formation of Al3Ti/Al3Zr heterogeneous nucleation phases, leading to grain refinement and suppression of columnar grain growth, thereby reducing cracking tendency during solidification. Experimental validation demonstrated excellent formability without crack defects over a broad processing window. After heat treatment at 500 °C for 1 h and 170 °C for 10 h, the optimized alloy achieved an ultimate tensile strength of 530 MPa, yield strength of 453 MPa, and elongation of 6%, approaching the performance of forged 7075 aluminum alloys and surpassing previously reported LDED aluminum alloys. This work provides a rapid and efficient strategy for developing next-generation aluminum alloys tailored for additive manufacturing.

Oxidized gellan gum and pullulan based 3d printing incorporated with rare earth elements doped mesophorous bioactive glass nanoparticles

Fatima, Tatheer Jan, Muhmmad Haseeb Nawaz

Biotechnology Section, Department of Materials Science and Engineering, Institute of Space Technology, Islamabad, 44000, Pakistan

Abstract

Chronic and burn wounds remain a major healthcare challenge due to slow tissue repair, prolonged infections, and poor regeneration of damaged skin. According to the World Health Organization, burns cause nearly 18,000 deaths every year, with the highest burden in low and middle income countries, while chronic wounds affect approximately 1-2% of the global population. These challenges highlight the need for advanced wound dressings that actively support healing and can be customized for individual patients.

This study will develop a 3D printed bioactive hydrogel scaffold based on oxidized gellan gum (OGG), pullulan (PUL), and This study will develop a 3D printed bioactive hydrogel scaffold based on oxidized gellan gum (OGG), pullulan (PUL), and neodymium-doped mesoporous bioactive glass nanoparticles (Nd-MBGNs). Direct ink writing will be used because it will enable precise control over scaffold geometry, pore size and interconnected architecture while allowing fabrication of patient specific wound dressings. Oxidized gellan gum will provide reactive aldehyde groups for hydrogel formation, while pullulan will improve flexibility, hydrophilicity, and water retention. Nd-MBGNs will be incorporated to improve mechanical stability, controlled therapeutic release, enhance antibacterial performance, and introduce photoluminescent properties for potential wound monitoring. The fabricated scaffolds will be evaluated for rheological behaviour, printability, shape fidelity, swelling capacity, degradation profile, surface morphology, mechanical properties, antibacterial activity, and cytocompatibility using skin-relevant cell models. Their interconnected porous structure will be expected to support oxygen and nutrient transport, absorb wound exudate, and promote cell infiltration and tissue regeneration. the study will also investigate the influence of nanoparticle incorporation on scaffold stability and overall biological performance. The proposed additive manufacturing approach will provide a promising platform for the development of customizable, multifunctional, and bioactive wound dressings, with the potential to improve chronic burn wound management and contribute to future advances in regenerative medicine, personalized healthcare, and clinical relevant wound care technologies through scalable and cost-effective fabrication strategies.

Artificial Intelligence-Assisted Design of 3D Composite Bone Scaffolds for Enhanced Osteogenesis and Angiogenesis in Critical-Sized Bone Defect Repair

Tianyi Wu, Qi Zhang, Jun Zou

The First Affiliated Hospital of Soochow University

Abstract

Background: Artificial intelligence (AI)-assisted bioprinting has emerged as a promising strategy for the treatment of critical-sized bone defects, offering unprecedented opportunities for the rational design of tissue-engineered constructs. However, the development of 3D-printed scaffolds capable of simultaneously providing mechanical support, regulating the bone regenerative microenvironment, and promoting vascularization remains a major challenge. Previous studies have demonstrated that osteogenesis and angiogenesis are closely coupled processes that are essential for successful bone regeneration.

Methods: In this study, AI-based tools, including Tripo-AI, Blender, and Python, were utilized to establish three-dimensional digital models and optimize scaffold architecture. A multifunctional scaffold–hydrogel composite was subsequently fabricated. Polycaprolactone/nanohydroxyapatite (PCL/nHA) was employed as the structural framework to provide mechanical stability, while gelatin methacryloyl (GelMA) hydrogel was introduced into the porous network of the scaffold. Urolithin A (UA), a bioactive molecule capable of modulating the osteogenic microenvironment, and platelet-derived growth factor-BB (PDGF-BB), a potent pro-angiogenic factor, were incorporated into the GelMA matrix. By optimizing the PCL/nHA composition and GelMA crosslinking duration, a composite scaffold with favorable mechanical properties, biocompatibility, and regenerative potential was obtained.

Results: The optimized scaffold was implanted into a rat critical-sized calvarial defect model to evaluate its therapeutic efficacy. Micro-computed tomography (micro-CT), histological staining, and quantitative analyses demonstrated significantly greater new bone formation, enhanced vascularized tissue regeneration, and improved defect bridging in the composite scaffold group compared with the control groups. These findings indicate that the synergistic regulation of the osteogenic microenvironment and angiogenesis substantially improves bone repair outcomes

Conclusions: The AI-assisted 3D-printed composite scaffold effectively promoted both osteogenesis and angiogenesis, resulting in improved repair of critical-sized bone defects. These findings highlight the potential of AI-driven scaffold design as a powerful strategy for bone tissue engineering and suggest broader applications in the fabrication of complex tissues and future regenerative medicine.

Continuous Switching 3D Food Printing Technology and Its Personalized Applications

Zilong Zhao; Nana Zhang; Yu Liu; Daming Fan

Jiangnan University

Abstract

Insufficient personalization of 3D food printing technology is one of the key bottlenecks limiting its engineering and commercial applications. Although existing research using multi-nozzle 3D food printing has improved the degree of product personalization to some extent, this “bulk”-based forming mode—where different materials are simply stacked—remains limited. Therefore, this study developed a continuous switching 3D food printing technology to elevate the forming unit to the “voxel” level, thereby enhancing the personalization capacity of 3D food printing. Based on the continuous switching 3D printing equipment, the rheological properties of food materials were targeted, and numerical model analyses were conducted to identify the main factors influencing the continuous switching extrusion process. A control strategy for switching and filament formation behaviors was established, achieving a switching accuracy as high as 1 mm. For the forming process, a path generation strategy adapted to continuous switching 3D printing was developed, along with a high-throughput forming strategy, ensuring both high personalization and efficiency in customizing product morphology. Furthermore, leveraging the differences in mechanical behavior between two-phase gels, the spatial distribution of the two gel phases was tailored to achieve “soft-first-then-hard” structures and enhanced elasticity, enabling personalized texture customization and opening a new dimension for personalization in 3D food printing.

Fatigue Design for Additive Manufacturing and Qualification of Metal 3D Printed Parts

John Hock Lye PANG

Nanyang Technological University

Abstract

Qualification of parts printed by metal Additive Manufacturing (AM) requires fatigue test data for structural integrity design, asset life cycle analysis and risk assessment. The Singapore Standard (SS 666) on Qualification of Parts Printed by Metal Additive Manufacturing is a comprehensive AM part qualification procedure that requires mechanical and fatigue tests for metal 3D printed parts subjected to fatigue loading. For Laser PBF In-Process and Part Qualification procedures, compulsory fatigue tests are needed for critical mission parts. This talk will present fatigue test strategies for qualification of parts printed by metal AM baseplate design-built-test strategy as shown in Figure 1. The fatigue test strategy for fatigue S-N curve testing has led to the development of an AM Fatigue S-N curve design database software. An AM Defect Tolerance Crack Growth Analysis Software has been developed for fatigue crack propagation life prediction applications. 3D X-ray Computed Tomography (3D-XCT) defect inspection of AM defects provide comprehensive characterization of AM defect densities, location, size and shape and insights on the severity on the fatigue behavior. XCT studies on fatigue test specimens with AM defects located on the surface, sub-surface, and internal pores in fatigue specimens are analyzed before and after fatigue testing. Severity analysis of AM defects detected by 3D XCT are correlated to the root cause of fatigue failure by fractographic analysis.

Building Digital Twins for Efficient and Reliable Additive Manufacturing Processes

Yi Cai

The Hong Kong University of Science and Technology (Guangzhou)

Abstract

The translation of additive manufacturing (AM) from laboratory settings to wide industrial practice has been hindered by a critical lack of real-time monitoring and quality control systems. This presentation presents a comprehensive digital twin (DT) framework developed to address these challenges across multiple AM processes, with particular emphasis on micro/nano fabrication, reconfigurable robotic systems and TIG welding. Specifically, the presentation will cover the development and implementation of DT in various AM processes, including: (1) machine vision-assisted micro-filament detection for electrohydrodynamic inkjet printing using real-time image characterization; (2) virtual manufacturing based on deposition group-based toolpath planning for multi-robot additive manufacturing that classifies operational spatial constraints and optimizes concurrent fabrication; (3) augmented reality-enabled cyber-physical synchronization for reconfigurable multi-robot AM systems using marker-based coordinate transformation; (4) in-situ droplet monitoring for inkjet 3D printing employing image analysis and backpropagation neural networks achieving high classification accuracy; and (5) a DT-driven approach for TIG welding penetration prediction combining dual ellipsoid heat source analytical modeling with Neural Radiance Fields (NeRF) for 3D scene reconstruction, achieving lower penetration prediction errors and higher reconstruction quality. The results demonstrate that digital twin technology, when integrated with machine vision, machine learning, and AR-based human-computer interaction, enables real-time quality assessment, collision-free concurrent fabrication, and remote process intervention. This framework provides a practical pathway toward closed-loop control for a variety of AM processes.

Electromagnetic field in-situ regulation on the microstructure and tensile property of titanium alloy by laser directed energy deposition

Fanrong Zhang, Jian Zhou, Yongjian Wu, Yan Wen, Lechun Xie*, Lin Hua

Wuhan University of Technology

Abstract

This study explored the microstructure and tensile property evolution of titanium alloy fabricated by electromagnetic field in-situ regulation laser directed energy deposition (LDED). The results show that increasing electromagnetic field intensity drives the gradual transition of alloy _ grains from columnar to equiaxed. When the electromagnetic field intensity was 86 mT, the alloy achieves significant microstructural and mechanical optimization. Mechanistically, the electromagnetic field enhances solute and temperature uniformity in the molten pool, reduces the solidification front effective temperature gradient, and induced Lorentz force disrupts columnar dendrites growing along the heat flow direction. Grain refinement dominates the improvement of ultimate tensile strength, while the precipitation of _ phase at grain boundaries leads to a decrease in elongation.

From Research Validation to Industrial Trust: The Role of AM Qualification in Accelerating Regional and Global Adoption

Chen Ze

DNV Singapore

Abstract

Additive Manufacturing (AM) is moving rapidly from research innovation to industrial application, but qualification remains critical to bridge between technical possibility and market acceptance. For industry stakeholders, the key concern is not only whether AM parts can be produced, but also whether the whole AM process, from design, manufacturing, to inspection and testing can be documented, and verified with consistent quality accepted for real operating conditions

This presentation will discuss the importance of AM qualification in enabling reliable adoption from research to industry. It will cover how structured qualification frameworks, including material, process, manufacturer, and part qualification, help reduce technical uncertainty and build trust among end users, regulators, and asset owners

The presentation will also share some successful AM qualification cases conducted by DNV Singapore in past two years, and highlight the growing need for dedicated testing and validation support in Singapore as well as the wider regional market. By connecting research capability with industrial assurance, qualification can accelerate AM adoption and strengthen Singapore's role as a regional hub for advanced manufacturing.

From Architected Lattices to Adaptive Metamaterials for Multifunctional Acoustic Systems

Zhai Wei

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Abstract

Additive manufacturing has enabled architected lattice metamaterials as a new class of acoustic absorbers with tunable geometry and multifunctional capabilities. This talk presents a unified framework that advances acoustic metamaterials from structurally designed lattices toward bioinspired and adaptive systems. We first introduce additively manufactured plate- and truss-based lattice structures, where sound absorption is governed by geometry-dependent resonance mechanisms analogous to multilayer Helmholtz resonators. By tailoring pore and cavity configurations and incorporating heterogeneous lattice designs, broadband acoustic absorption can be achieved alongside excellent mechanical energy absorption. Building on this structural foundation, we then present bioinspired metamaterials derived from moth wing architectures, where graded pore distributions and hierarchical features enable the simultaneous integration of broadband acoustic absorption, thermal insulation, and mechanical energy dissipation within a lightweight structure. Finally, we introduce adaptive acoustic metamaterials based on bistable morphing resonators that dynamically reconfigure their geometry to access discrete impedance states. Through the integration of sensing, actuation, and data-driven control, these systems achieve real-time adaptation to varying acoustic frequencies and sound pressure levels. Together, these works demonstrate the evolution of acoustic metamaterials from static lattices to intelligent, adaptive systems driven by structure–function integration across scales.

Convergence of light and acoustic waves for bioassembly of multifunctional tissue constructs

Thomas Robinson, Hala Zreiqat, Tiziano Serra

University of Sydney

Abstract

Advanced biofabrication strategies are needed to recreate the hierarchical organisation of native tissues. Light-based techniques such as filamented light (FLight) provide precise architectural alignment but are limited in compositional complexity, while acoustic assembly enables label-free, non-contact patterning of cells and particulates without microscale structural guidance. Integrating these complementary approaches offers a pathway to engineer tissues with coordinated biochemical, mechanical, and architectural cues. We present a modular biofabrication platform that combines acoustic wave-based patterning with filamented hydrogels to generate hierarchically organised, multi-material constructs. Custom 1_mm-thick cassettes were used as discrete building blocks for spatially controlled biomaterial and cellular loading. Within each cassette, ceramic particulates were acoustically patterned into defined geometries in cell-laden hydrogel precursors (gelatin-methacryloyl (GelMA) and ruthenium/sodium persulfate). Selected cassettes were further engineered to incorporate aligned fibrous architectures via FLight exposure, while others retained bulk, non-aligned structures, enabling the creation of discrete regions with distinct topographical and mechanical properties.Following vertical assembly, constructs were photo-crosslinked using wavelength-specific light (401_nm or 526_nm) to achieve both cassette-specific and integrated crosslinking. This approach enabled precise control of filament orientation across layers and facilitated the fabrication of centimetre-scale constructs with spatially defined multi-material and multicellular organisation. Cell-laden constructs containing human mesenchymal stromal cells (hMSCs) maintained high viability (>90% over 21 days). Cells exhibited pronounced alignment and elongation within FLight-structured regions, while distinct morphologies and growth profiles emerged in bulk hydrogel and particle-patterned domains, demonstrating context-specific cell–matrix interactions. Specifically, when cultured in osteogenic differentiation media, hMSCs were able to differentiate into osteoblasts with distinct calcium depositions localised spatially with the presence of the acoustically patterned bioceramics. This modular, multi-modality platform enables the rapid assembly of engineered tissues with programmable structural and functional heterogeneity. Its versatility supports applications in regenerating complex interfaces (e.g., muscle–tendon), engineering zonal cartilage, and developing advanced, physiologically relevant in vitro models.

Design-Driven Control of Biological and Microbial Activity Using Architecture-Optimized 3D Scaffolds

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Abstract

Three-dimensional (3D) scaffold design has emerged as an effective strategy for regulating biological and microbial interactions across diverse industrial applications. This study demonstrates that scaffold architectural parameters, particularly porosity, play a significant role in influencing both cellular and microbial behavior. Variations in scaffold design were found to affect cell attachment, proliferation, and spatial organization, highlighting the ability of structural features alone to modulate biological performance without requiring chemical modifications or surface treatments.

In addition to their impact on cellular responses, scaffold structures were shown to influence bacterial adhesion and growth. The findings suggest that microbial activity can be controlled through careful scaffold design, offering a practical and sustainable approach for reducing biofouling and improving process efficiency. Such control is especially valuable in industrial environments where microbial contamination can negatively affect productivity and product quality.

The use of additive manufacturing technologies further enhances the potential of scaffold-based systems by enabling precise control over architectural features. This flexibility allows the development of customized biodegradable scaffolds tailored to specific industrial requirements. Beyond biomedical applications, these materials offer promising opportunities in bioreactors, fermentation processes, filtration and separation systems, water treatment technologies, and sustainable packaging solutions. By integrating advanced manufacturing with design-driven material engineering, scaffold systems can serve as multifunctional platforms that support both biological functionality and microbial regulation. Their ability to influence living systems through structural design provides a sustainable alternative to traditional chemical-based strategies.

Overall, this work highlights the potential of architecturally engineered 3D scaffolds as scalable, environmentally responsible solutions for industrial applications. The results demonstrate that optimizing scaffold architecture can enhance performance, improve microbial control, and create new opportunities for innovation in sustainable industrial design and manufacturing. This approach supports the development of next-generation materials capable of addressing both biological and engineering challenges across a wide range of sectors.

From Autonomous Inspection to Intelligent Fabrication: AI-Enhanced Robotics for the Future of Large-Format Additive Manufacturing in the Built Environment

Maryam Kouzehgar

Lecturer, Engineering Institute of Technology and Design

Abstract

Advanced manufacturing is increasingly extending beyond conventional factory environments into large-scale, site-based, and built-environment applications. In these settings, automation must encompass not only fabrication but also reliable inspection, defect detection, and condition monitoring to ensure safety, quality, and long-term performance. This talk explores the role of AI-enhanced robotics in enabling automated inspection for large-scale engineered surfaces and structures, tracing a research arc from a foundational case study toward an emerging vision for intelligent quality assurance at architectural and infrastructure scale.

The discussion is anchored in prior work on a self-reconfigurable façade-cleaning robot equipped with CNN-based crack detection, published in Automation in Construction (2019), in which robotic mobility, onboard visual sensing, and deep learning were combined to identify structural defects in hazardous high-rise environments. While rooted in façade maintenance, the underlying technical challenge is directly transferable to advanced manufacturing: how can robotic systems reliably detect surface defects, adapt to complex real-world conditions, and deliver actionable feedback on large-scale manufactured or built assets?

Building on this foundation, subsequent research (2020–2025) explored coordinated multi-robot systems operating across large-scale surfaces. The same operational context that large-format additive manufacturing now demands in practically urgent scenarios: a team of autonomous robots deployed across an ageing bridge deck, each independently mapping hairline fractures while collectively building a unified structural health model in real time; or a freshly printed large-format concrete component being autonomously scanned for structural defects before the next layer is placed. These are the logical extensions of a research direction already underway. Key challenges include perception under variable conditions, defect detection across complex geometries, and the transition from laboratory to field-ready deployment.

The central argument is that the future of large-scale advanced manufacturing depends not only on how structures are fabricated, but on how intelligently they are inspected, validated, and maintained using AI-enhanced robotics.

Surface Analysis and Materials Characterization for 3D Food Printing: A Multi-Technique Perspective

Heng-Yong Nie

Surface Science Western & Department of Physics and Astronomy, The University of Western Ontario

Abstract

Three-dimensional food printing — the layer-by-layer deposition of edible feedstocks including protein pastes, hydrocolloids, lipids, and starch blends — introduces surface and interface chemistry challenges distinct from those of conventional food processing. The outermost layers of a printed food structure govern flavour release, microbial adhesion, and moisture migration, while internal microstructure dictates texture and nutritional delivery. Surface and materials characterization is therefore essential for feedstock qualification, print parameter optimization, and food safety validation. Surface Science Western (SSW), an ISO 17025-accredited surface analysis and materials characterization facility at the University of Western Ontario, offers an integrated suite of analytical techniques directly applicable to these challenges.

At the molecular level, time-of-flight secondary ion mass spectrometry (ToF-SIMS) provides ultrasensitive surface chemical imaging of printed food surfaces, mapping lipid oxidation products, protein distributions, and potential migrants from printer contact materials. X-ray photoelectron spectroscopy (XPS) characterizes surface chemistry, while scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM/EDX) resolves microstructure and mineral distribution. Fourier transform infrared spectroscopy (FTIR) and laser Raman spectroscopy characterize protein denaturation and starch gelatinization.

Surface topography and internal architecture are addressed across length scales: atomic force microscopy (AFM) resolves nanoscale surface texture relevant to mouthfeel and microbial adhesion; confocal laser scanning microscopy (CLSM) maps three-dimensional microstructure and ingredient spatial distribution; and surface profilometry quantifies layer-to-layer finish. X-ray micro-computed tomography (Micro-CT) enables non-destructive visualization of internal porosity and air cell distribution — critical determinants of food texture. Thermal transitions and wettability are assessed by differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), and contact angle measurement.

Laser-metal additive manufacturing towards multifunctional integral components

Dongdong Gu

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Abstract

Our recent research progress in the field of material-structure integrated laser powder bed fusion (LPBF) additive manufacturing of multi-functional integral metallic components will be presented, considering the integrate multifunctional requirements of additive manufactured components in terms of lightweight, load-bearing, impact resistance, thermal protection, etc. The multi-material layout, innovative structural design, and tailored laser printing process are collaborated to yeild the multiple functions of integral metallic components. The process-related mechanisms, such as interaction of energy and printed matter, thermodynamic and dynamic behaviour of printing, relationship of process parameters, microstructure and properties, are disclosed. Through the continuous innovation and development in new materials, new structures, and new processes, additive manufactured metallic components will be endowed with disruptive performance and functionality to meet the strict engineering application requirements.

Multi-Objective Optimization of TPMS-Based Multilayer Osteochondral Scaffolds Balancing Mechanical Strength and Porosity

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Abstract

Osteochondral defects involve damage to articular cartilage, calcified cartilage, and subchondral bone, presenting a major challenge for tissue regeneration due to the complex hierarchical structure and limited self-repair capacity of the osteochondral unit. Three-dimensional printed scaffolds with controlled porous architectures offer a promising strategy to mimic the structural and mechanical characteristics of native osteochondral tissue. In this study, a multilayer triply periodic minimal surface (TPMS)-based scaffold design was developed for osteochondral tissue engineering, with a particular focus on balancing mechanical strength, porosity, and pore size. Key design parameters, including unit cell size and wall thickness, were investigated to regulate scaffold architecture and performance. Response surface methodology was used to establish predictive relationships between structural parameters and scaffold properties, while multi-objective optimization was applied to identify suitable design combinations that maximize compressive modulus and porosity while maintaining pore size within a biologically relevant range. The optimized scaffold design was further evaluated through structural characterization and mechanical testing. The results demonstrate that TPMS-based multilayer scaffolds can provide continuous interconnected porous networks, tunable mechanical properties, and improved structural integrity, supporting their potential application in osteochondral defect repair. This work provides a design-oriented framework for developing patient-specific, additively manufactured osteochondral scaffolds with balanced mechanical and biological requirements.

A Physics-Coupled Fourier Neural Operator for Data-Efficient Multiphysics Simulation in Laser Manufacturing

Xuyang Chen, Le Song, Zhiyong Huang, Baorui Du

Institute of Engineering Thermophysics, Chinese Academy of Sciences

Abstract

High-fidelity multiphysics simulation is critical for process understanding and optimization in advanced manufacturing, but its use is often limited by scarce high-quality data and high computational cost. Standard Fourier Neural Operators (FNOs) mix different physical fields in the spectral domain without explicitly considering their governing-equation couplings, and commonly rely on interpolation for coarse-to-fine grid transfer, which may weaken high-frequency melt-pool features.

We propose PCS-FNO, a physics-coupling-structured Fourier Neural Operator for industrial multiphysics process simulation. PCS-FNO encodes the PDE coupling graph into a block-structured spectral mixing mechanism, introduces a band-limited frequency-domain embedding for cross-resolution information transfer, and incorporates process parameters through FiLM modulation. Evaluated on a laser welding dataset involving temperature, concentration, and velocity fields, PCS-FNO reduces prediction error by approximately 34.9% compared with the FNO-3D baseline. These results show that embedding PDE coupling structures and spectral consistency into neural operators improves data efficiency and generalization in industrial small-data settings. The framework offers a promising route toward fast, physics-consistent AI surrogate models for additive manufacturing, laser welding, and related materials-processing applications.

Engineering Heterogeneity: A New Paradigm in Additive Manufacturing

Sahil Dhiman, Milan Brandt, Daniel Fabijanic, Wei Xu, Viswanath Chinthapenta

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Abstract

Additively manufactured (AM) components usually exhibit uncontrolled microstructural heterogeneity due to the dynamic thermal environment rendered by layer-by-layer fabrication. Rather than being an undesirable AM characteristic, such heterogeneity can be strategically exploited through deliberate spatial control, enabling user-defined microstructural allocation for enhanced functional performance in critical aerospace and nuclear components. Here, we propose the integration of laser powder bed fusion (LPBF) design flexibility with the “processing recipes” (optimised process parameters) to achieve user-defined, mesoscale microstructural heterogeneity in dual-phase Ti-6Al-4V alloy. Specifically, two typical microstructures, _’ martensite (high strength) and lamellar _+_ (superior ductility), are designed to appear in situ during LPBF as alternate stacked bands longitudinally and radially relative to the build direction. The band size and its spatial arrangement govern the local microstructure evolution and consequently the mechanical performance. A slip-trace analysis paired with 4D-STEM analysis elucidates the localised deformation behaviour and establishes the role of the transition region in dual microstructures. Further, through a comprehensive crystallographic analysis, this study identifies the formation of specific _/_ intervariant interfaces as the definitive microstructural fingerprints distinguishing the slow-cooling and martensitic transformation pathways for the formation of as-built lamellar _+_ microstructure. The findings of this work offer practical design guidelines to achieve precise user-defined microstructural heterogeneity in LPBF Ti-6Al-4V, facilitating wider industrial uptake.

Non-invasive online monitoring of micro-milling tool wear based on stray magnetic field of motorized spindle

Tongshun Liu

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Abstract

Traditional invasive tool wear monitoring methods are difficult to apply to micro-milling processes. The stray magnetic field of the motorized spindle can perceive load variations caused by tool wear, offering a new approach for developing non-invasive monitoring techniques. However, the influence of micro-mill wear on the stray magnetic field involves complex nonlinear mechanical-electromagnetic interactions, and the underlying monitoring mechanism remains unclear. Moreover, the ability of the stray magnetic field to sense load and wear varies with the vector control strategy and operating range of the motorized spindle, and is also susceptible to electromagnetic interference, leading to poor monitoring robustness. To address these challenges, this study aims to: develop a comprehensive nonlinear multi-time-delay/time-varying dynamic model of micro-milling and a nonlinear transfer model of load torque–stray magnetic field under vector control, to reveal the wear–torque–magnetic field interaction mechanism and clarify the monitoring mechanism; explore a nonlinear variational mode decomposition and filtering method constrained by air-cutting signals as a priori knowledge, to obtain high-quality stray magnetic field signals; and investigate the fusion and enhancement of two types of harmonic features—’far/near-zero harmonics’—based on their complementarity in sensing load and wear, to obtain a robust feature set and achieve non-invasive online monitoring of micro-mill wear.

Beyond the 3D Printer: Unconventional Manufacturing Frontiers for the Next Generation of Aerial Robots

Foong Shaohui

Singapore University of Technology and Design (SUTD)

Abstract

When we think of manufacturing aerial robots, the conversation quickly gravitates toward 3D printing, carbon fibre layups, and precision machining. But what if some of the most exciting advances are happening on a sewing table or a cardboard cutting mat? As aerial robots shrink in scale and diversify in application, weight, cost, and deployability are rising to the top of the design agenda and they demand unconventional answers. We explore how non-traditional manufacturing processes and everyday materials are enabling a new class of aerial robots that are lighter, softer, more packable, and more accessible than anything conventional fabrication can offer. From textile-based wings that fold into a pocket to rapidly assembled low-cost platforms built from surprisingly humble substrates, this talk makes the case that the future of aerial robot manufacturing is not just about making things more precisely but about fundamentally rethinking what things are made of.

Microstructure Evolution and Mechanical Response of 3D Printed Al Alloys Developed by AI/MGI

Che-Nan Kuo

Department of Materials and Optoelectronic Science, National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC

Abstract

Lightweighting has always been a key focus for researchers worldwide. With the maturation of additive manufacturing technology, it is easier to achieve efficient design and to introduce lightweight or high-specific-strength materials. Therefore, exploring and understanding the relationship between design, materials, manufacturing processes, microstructure, and performance is key to commercializing lightweight parts that utilize lightweight metal materials and lightweight structural designs. However, due to changes in manufacturing processes, materials, and design freedom, next-generation ultralight advanced materials still face some technical obstacles before widespread application: 1) low efficiency in lightweight structural design; 2) difficulty in controlling defects and microstructure of advanced materials during additive manufacturing. Therefore, this study aims to systematically investigate the scientific and technological issues before, during, and after 3D printing by introducing artificial intelligence to assist in lightweight structural design and combining the 3D printing process of high-strength aluminum alloys with the Materials Genome Initiative, thereby revealing the above-mentioned relationships.

Robot-Assisted Aerosol Jet Printing on Complex Shapes via Process-Window-Aware Toolpath Optimization

Chenyu Xu, Zhikai Shen, and Guoxin Fang

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Abstract

3D conformal electronics offer a route for integrating sensing, heating, interconnects, and functional circuits directly onto non-planar products. Aerosol jet printing (AJP) is well suited to this task because of its non-contact deposition, fine-line resolution, and millimeter-scale working distance, while robotic AJP further enables controlled nozzle motion over curved and spatially confined surfaces. However, most multi-axis AJP workflows still plan nozzle poses from surface normals and only later check collision clearance and robot feasibility, which can lead to toolpaths that require post corrections. Here, we propose a process-window-aware toolpath optimization framework for robot-assisted AJP on complex surfaces. A 48-condition standoff-tilt experiment is used to construct a differentiable gaussian radial basis function quality model based on printed-line width and cross-sectional skewness. This model is embedded into task-space optimization, where nozzle standoff and orientation are adjusted to preserve deposition quality while maintaining signed-distance-field collision clearance and pose smoothness. Orientation frames are selectively stabilized in low-normal-change path regions, and the optimized task-space trajectory is converted to ABB IRB 120 joint motion through inverse kinematics, graph-based branch selection, and forward-kinematics-constrained joint-space smoothing. By coupling experimentally calibrated AJP process response with robot-executable trajectory generation, the framework provides a practical route toward reliable conformal printing of electronics on complex three-dimensional carriers.

Evaluating Powder Reuse Strategies for Ti_6Al_4V in Laser Powder Bed Fusion

Syafiq Azrin[1], Mohammed Faizal[1], Nabihah Rahman[1], Chadurvedi Venkatesan[1], Jason Ten[1], Saritha Samudrala[1], Ng Si Rong[2], Ng Chee Koon[2], Lim San Hua[3], Sankaranarayanan Seetharaman[4]

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Abstract

This work investigates the influence of powder reuse on the behavior and performance of Ti_6Al_4V in laser powder bed fusion, with a focus on linking feedstock degradation to powder bed quality and part properties. Multiple reuse strategies were evaluated to assess changes in particle morphology, surface chemistry, and flow characteristics, alongside their impact on spreadability—a process-relevant metric governing powder layer uniformity and density. The study demonstrates that conventional flowability metrics alone are insufficient to predict build quality, while spreadability provides a stronger correlation with powder bed integrity. Despite observable degradation in powder characteristics with reuse, bulk mechanical properties of printed parts remain relatively stable under controlled reuse strategies, with notable degradation only under extreme conditions without powder refresh. Overall, the findings establish a framework for quantitatively assessing powder reuse and optimizing reuse strategies to enable cost-effective and sustainable additive manufacturing without compromising part performance.

AI-Synesthetic Tastes: Neuroaesthetic 3D-Printed Food Designs

Immanuel Koh, Nicholas Lim, Elissa Hartanto

Singapore University of Technology and Design

Abstract

This project investigates perceptual responses to material exposure and section-cut representation through a speculative series of sectioned kueh architectures derived from the textures and layered material properties of traditional Singaporean kuehs. The project combines architectural floorplans and sectional drawings of iconic Singaporean buildings with the physical morphology and material characteristics of kuehs to generate hybrid architectural forms. Generative AI workflows are used to computationally synthesise interior sectional conditions that respond simultaneously to the original architectural spatial organisation and the geometric constraints of the kueh form, producing a dataset of complete and sectioned architectural objects for comparative study. The project evaluates how exposed internal geometries, layering, and material legibility influence visual and tactile perception. EEG-based neuroaesthetic experiments are conducted to capture cognitive and emotional responses during participant interaction with the objects, while AI-assisted analysis methods are used to identify correlations between sectional exposure, attention, and engagement levels. By integrating computational design, generative AI, and neurophysiological analysis, the project explores the architectural section as both a representational and perceptual construct within AI-assisted sensory design research.

Design for a stainless steel 3d printed pedestrian bridge

Stylianos Dritsas, Soh Gim Song

Singapore University of Technology and Design

Abstract

We present the design for a stainless steel 3d printed pedestrian bridge spanning between the Singapore University of Technology and Design's campus and an adjacent parcel. Due to elevation difference between the properties of circa 3m vertically, and the existence of a public open drain rainwater canal underneath, the pedestrian bridge has the unusual form resembling stairs. The overall dimension of the bridge is circa 12 meters length by 2 meters width, approximately weighing 4 tons. The bridge is to be manufactured using Wire Arc Additive Manufacturing method using SS316L at the Robotics Innovation Laboratory of SUTD. The limited lab space dictated a modular design comprised of 74 components to be welded off-site and the bridge installed on shallow foundations as a single monobloc structure. Additionally cost control dictated the retention of the metal plates upon the components are built as part of the design. Building regulations pertaining safety and serviceability where integrated in a design aimed to arrive at an iconic but lightweight and elegant outcome. For the design of the bridge, a parametric modelling approach was employed including design generation, structural performance, regulatory compliance, quantity take-off, printability analysis and machine path generation.

Domain-Adaptive Digital Process Twins from Sparse Metrology: A Physics-Informed Multi-Modal Graph Transformer Framework for Plasma Etching

Hyunwoong Ko, Zahra Taheri, Suk Ki Lee

Arizona State University

Abstract

The AI era has elevated advanced semiconductor manufacturing to a strategic foundation of modern technology, where plasma etching serves as one of the most critical process steps governing device performance and yield. In this context, virtual metrology (VM) plays an essential role in process monitoring and control. However, realizing digital twins (DTs) in this setting remains fundamentally limited by sparse metrology labels, as existing data-driven approaches rely on supervised learning that utilizes only the small fraction of wafers bearing labels. To address this limitation, we propose a multi-modal graph transformer framework for learning digital process twins from sparse metrology. This framework integrates multi-scale temporal encoding, graph-based modeling of plasma–equipment interactions, and a unified three-stage training strategy. By jointly leveraging limited labeled and large-scale unlabeled wafer data through self-supervised pretraining and physics-informed learning, our approach enables efficient domain adaptation under process drift, chamber variation, and evolving production conditions. Validated on field data from an actual plasma etching production line, the framework demonstrates robust performance and stable long-term operation under real-world production constraints, highlighting a pathway toward scalable, domain-adaptive DT-based VM. More broadly, the proposed framework is applicable not only to plasma etching but also to other advanced manufacturing processes, including additive manufacturing and robotics-based manufacturing, where label scarcity and process variability similarly constrain scalable DT deployment.

Wall Climbing Robots for Building Inspections

Shunsuke Nansai

Akita University

Abstract

In this presentation, we will introduce two types of mobile robots we have been developing. The first is a bipedal wall-climbing robot. This robot is a wall-climbing platform developed primarily for cleaning the exteriors of high-rise buildings. By controlling vacuum suction cups via a cam mechanism, it can walk while maintaining adhesion to the wall surface. One key feature of this wall-climbing platform is the high terrain traversability inherent in its bipedal configuration. We designed a gait generator for this mobile platform. The prototype we developed is not only capable of walking safely on glass walls but also of overcoming uneven obstacles that simulate window frames. We also developed a walking plan that allows the robot to walk while covering soiled areas on a glass wall, and verified its effectiveness through numerical simulation. The second robot is the Lizard-Inspired Single-Actuated Robot. The most notable feature of this robot is its four-link mechanism. This not only enables two degrees of freedom -propulsion and turning- with a single degree of freedom but also allows for stable, non-slip walking on support legs. The ability to drive with a single degree of freedom offers a significant advantage in reducing the size and weight of wall-climbing robots, which must support their own weight. We developed a prototype that realizes the characteristic locomotion of a four-bar linkage mechanism. Furthermore, we designed a path-following control system that utilizes its kinematic properties and implemented motion control on a horizontal plane. In this presentation, we will introduce these two platforms, including experimental results.

Next-Generation AI for Time Series Sensor Data Analytics

LI XIAOLI

Singapore University of Technology and Design

Abstract

The rapid proliferation of sensors across manufacturing, transportation, energy, and other industrial domains has generated massive volumes of time series data, creating both unprecedented opportunities and significant analytical challenges. Conventional data analytics and machine learning techniques are increasingly insufficient for addressing the growing demands of predictive maintenance, equipment health monitoring, anomaly detection, and large-scale operational optimization.

This talk presents recent advances in artificial intelligence that are transforming the way sensor data is analyzed and utilized in real-world industrial environments. Key topics include self-supervised representation learning for extracting robust and transferable features from unlabeled time series data, unsupervised domain adaptation techniques for handling distribution shifts in multivariate sensor streams, and model compression and efficient AI approaches that enable real-time intelligence deployment on resource-constrained edge devices.

Drawing on research breakthroughs and practical industrial case studies, the talk will demonstrate how next-generation AI methods are advancing predictive analytics, improving system reliability and efficiency, and enabling smarter, more adaptive industrial operations.

Advanced Microfluidics for Biomedical Applications

Ai Ye

Singapore University of Technology and Design

Abstract

Microfluidic technologies capable of accurate cell analysis and precise cell manipulation can provide unprecedented capabilities to automate conventional biological assays. As acoustic waves can easily propagate through solids and fluids, acoustic technique readily enables non-contact cell manipulation in relatively long operating distances. The merging of acoustics into microfluidics has led to a new research direction, acoustofluidics, which generally exploits the use of ultrasonic waves to manipulate biological cells and other types of biological particles. In this talk, I will present the use of advanced microscale manufacturing techniques to fabricate our acoustic microfluidic platforms for precise microscale manipulation. We have further integrated single cell fluorescence detection with our acoustic microfluidic platforms to implement flow-based high-throughput fluorescence activated sorting of single cells. We have demonstrated the integrated acoustic microfluidic platform for different biomedical applications, for example sorting of live cells from cryopreserved cell samples in single cell sequencing, sorting of iPSC-derived cardiomyocytes for personalized drug testing and sorting of transfected cells for gene editing and cell therapy. This new type of acoustic manipulation platform has enabled high-precision and on-demand single cell sorting in diverse precision medicine applications.

Highly printable, strong, and ductile ordered intermetallic alloy

Yinghao Zhou, Ming Yan, Yilu Zhao, Tao Yang*

Harbin Institute of Technology, Southern University of Science and Technology, Harbin Institute of Technology (Shenzhen), City University of Hong Kong.

Abstract

Ordered intermetallic alloys are renowned for their impressive mechanical, chemical, and physical properties, making them appealing for various fields. However, practical applications of them have long been severely hindered due to their severe brittleness and poor fabricability. It is difficult to fabricate such materials into components with complex geometries through traditional subtractive manufacturing methods. Here, we proposed a strategy to solve these long-standing issues through the additive manufacturing of chemically complex intermetallic alloy (CCIMA) based on laser powder bed fusion (LPBF). The developed CCIMA exhibits good printability, enabling a crack-free microstructure with a low porosity of 0.005%. More importantly, a good combination of high tensile strength (~1.6_GPa) and large uniform elongation (~35%) can be achieved, which has not been reported in the existing additive-manufactured alloys. Such properties are attributed to the structural and chemical features of highly ordered superlattice grain decorated with disordered interfacial nanolayer, as well as dynamic evolutions and interactions of multiple dislocation substructures. These findings could provide references for developing high-performance intermetallic alloys and accelerating their practical applications.

Oyster mushroom powder and rice flour blends as bioinks for extrusion-based 3D food printing - linking particle structure, rheology, printability and post-processing behavior.

Alona Tiupova, Ewa Pejcz, Joanna Harasym

Wroclaw University of Economics and Business

Abstract

Three-dimensional food printing demands bio-inks that simultaneously offer extrudability, shape stability and post-processing resistance — a balance rarely achieved with single-component formulations. This study comparatively evaluated three extrusion-based systems: rice flour (RF), oyster mushroom powder (Pleurotus ostreatus, OMP) and their 50:50 blend (MIX), tracking properties from raw powders through printed and post-processed constructs. Granulometric, colour (CIELAB), techno-functional (WHC, WAC, WSI, OAC, FC/FS, EA/ES), pasting (RVA) and oscillatory rheological characteristics were determined alongside extrusion force, maximum buildable layer count, dimensional fidelity of cubes and cylinders, and total colour difference (ΔE) across processing stages. RF exhibited classical starch-driven pasting with the highest peak and final viscosity, the stiffest elastic network (G′ ≈ 5649 Pa for the printable paste), highest extrusion resistance (100 N) and the best buildability (53 stable layers,~Z81 mm). OMP showed non-starch structuring dominated by fibre–protein interactions, very high water-holding capacity (WHC ≈ 8.0), the strongest paste network at rest (G′ ≈ 20 346 Pa), low extrusion force (40 N), but rough surfaces and sudden local collapses (36 layers, ~72 mm). MIX displayed intermediate physicochemical and rheological behaviour yet, unexpectedly, the poorest structural stability — early inward “Greek vase” deformation and collapse at 33 layers (53 mm) — attributed to phase incompatibility between starch-rich and fibre-rich fractions disrupting continuous network formation. Sequential post-processing (oven crust formation followed by microwave drying) amplified shrinkage and intensified Maillard-driven darkening, with OMP and MIX showing pronounced lightness loss. The findings demonstrate that printability cannot be predicted as a linear combination of component properties and provide a foundation for predictive modelling and rational bio-ink design in 3D food printing.

Fabrication of Bimetallic Thin Wall Combustor Liners via Multi-axial Wire Laser Directed Energy Deposition

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Abstract

Design of advanced combustors is driven by the need of sever thermal gradient, aggressive oxidation environment and cyclic thermo-mechanical loading. Conventional monolithic combustor liners employing nickel based superalloys, Inconel 718 (IN718) leads to the inefficient material utilization. High-performance material are used even in the regions subjected to the moderate service conditions. Bimetallic combustor liners architecture offers an alternative by enabling location-specific material deployment. The pronounced radial and axial temperature gradient in combustor liners necessitate spatially tailored material selection. This makes liners ideal candidates for the bimetallic architecture fabricated by hybrid Laser-Directed Energy Deposition(L-DED).

The realization of bimetallic thin wall combustor liners remains challenging due to thermophysical mismatch, interface instability, and microstructure heterogeneity across dissimilar alloys. The thin wall fabrication using Laser-DED also introduces challenges related to the dimensional control, heat accumulation, and defects formation. In this study, a fabrication strategy for the bimetallic combustor liner employing IN718 and Stainless Steel 17-4 PH was developed. Iterative wall thinning was carried out on a hybrid universal milling centre (UMC) integrated with Laser-DED head to get finished bimetallic liner. The influence of deposition strategy on melt pool interlocking, elemental diffusion across the interface, and defect formation was investigated. The interfacial characteristics were analyzed using 4D X-ray microscopy, revealing significant improvement in interlocking and intermixing behavior with optimised deposition strategy. Cross-sectional analysis of the interface was further performed using scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS) to quantify elemental diffusion across the interface. Additionally, thermal fatigue testing was conducted to evaluate the structural integrity and performance of the fabricated liners.

This study provides insights into interface engineering and process optimization for multiaxial wire L-DED, contributing toward the development of reliable bimetallic combustor liners with enhanced thermo-mechanical performance.

Applications of metal additive manufacturing in load-bearing implants

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Abstract

Additive manufacturing (AM) enables the fabrication of complex geometries with unprecedented design flexibility, making it particularly suitable for patient-specific, defect-matched implants. Beyond structural customization, AM provides a powerful platform for developing novel alloy chemistries tailored to application-specific performance. This capability allows simultaneous control of composition and architecture across multiple length scales, enabling implants designed for targeted biological responses. For example, alloying strategies can enhance biocompatibility in load-bearing applications or introduce intrinsic antibacterial properties to mitigate infection risks in vivo. Structural features such as controlled porosity can also be integrated within a single manufacturing step. Our work focuses on Ti-, stainless steel-, and CoCr-based alloys to design and develop infection-resistant compositions for load-bearing implants. A part of this talk will highlight alloy design using powder-based laser-directed energy deposition and laser powder bed fusion, along with resulting mechanical performance, in vitro and in vivo biological responses.

CoCrMo alloy, a wear-resistant material of choice, is typically used in femoral heads for THAs. In vivo life of THAs is often reduced due to debris generation and Co and Cr metal ion release from modular junctions. Taper corrosion happens primarily due to mechanically assisted crevice corrosion (MACC) along with fretting and galvanic corrosion, and leads to adverse local tissue reactions (ALTR), an immune-mediated biological reaction due to elevated Co and Cr ions. An understanding of the onset of MACC can help design better devices for THAs. We have used our hip simulators to measure mechanically assisted crevice corrosion from trunnions of CoCrMo head, and Ti6Al4V stems, and from trunnions of Ti6Al4V head and Ti6Al4V stems. A part of this talk will focus on a novel experimental design to measure the early stage of taper corrosion from trunnions using hip simulators.

Design of Aluminum Alloys for Additive Manufacturing Based on Microstructure Control

Qiuju Zheng Shoufeng Yang

Chongqing School University of Chinese Academy of Sciences

Abstract

High-strength aluminum alloys fabricated via additive manufacturing (AM) and their multi-functional integration represent a research frontier in high-end manufacturing industries. However, high-strength aluminum alloys developed using conventional casting, forging, and welding processes face significant challenges, including poor compatibility with AM processes and low service performance. Achieving a combination of good printability and high strength-toughness poses a major challenge in aluminum alloy research. On the one hand, we propose to regulate the microstructure and defects of additively manufactured aluminum alloys through inoculation treatment, thereby significantly improving their formability and service performance. On the other hand, we introduce thermodynamic phase diagram calculations and artificial intelligence-assisted alloy design methods to efficiently screen alloy compositions and solidification pathways, successfully developing high-strength aluminum alloys suitable for laser-based additive manufacturing processes. This study provides a new strategy for the development of high-performance aluminum alloys tailored for additive manufacturing.

X-ray CT for fatigue failure tracking of LPBF 316L specimens

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Abstract

Laser Powder Bed Fusion (LPBF) processed 316L stainless steel exhibits excellent mechanical properties, yet its fatigue performance is critically governed by process-induced defects such as gas pores and lack of fusion. While the effects of defects in initiating cracks are well-established, the morphological evolution of these defects prior to crack initiation remains challenge. This study employs intermittent high-resolution X-ray computed tomography (XCT) coupled with sequential stress-controlled fatigue testing to track the internal defect history of LPBF 316L specimens throughout their fatigue life.

A specific focus is placed on the early-to-mid stage evolution of porosity. Contrary to the conventional expectation of monotonic defect growth, the intermittent XCT scanning data revealed a significant reduction in porosity rate during the early cycling stage. Specifically, comparison between the initial state (0 cycle) and 250,000 cycles revealed that a substantial population of larger pores effectively disclosed below the detection limit, attributed to local cyclic plastic deformation and stress redistribution mechanisms. The specimen subsequently failed at 1.93 million cycles, while the observation of defect volume reduction provides critical insights into the dynamic interaction between the material and defects under cyclic loading. These findings challenge the static-defect assumption in fatigue modeling and highlight the complexity of damage accumulation in AM metals, suggesting that closure mechanisms compete with damage accumulation in the high-cycle fatigue regime.

Segregation-controlled boride regulation and its interactions with the matrix in TiAl alloys

Shoufeng Yang

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Abstract

Controlling boride structure and morphology is critical for enhancing the performance of B-containing TiAl alloys. This work proposes and demonstrates for the first time the effectiveness of segregation control in regulating the morphology/structure of borides, achieving exclusive formation of monolithic B27-TiB needles in Ti-45Al-2Mn-2Nb-1B via segregation-controlled directional solidification, suppressing detrimental multiphase borides. By reverse solute rejection, we maintain a sustained low-Al environment that stabilizes the L→ β+ B27-TiB eutectic reaction. B27-TiB exhibits dual refining functions: serving as preferential nucleation sites for L→ β→ α→ α2+ γ phase transformations while simultaneously impeding phase growth. In contrast, TiB_2-containing borides formed in Al/B-enriched interdendritic regions fail to refine primary solidification due to spatial/temporal constraints, although both functions are equivalent in solid-state transformations. This segregation control strategy enables unprecedented control over boride phase, establishing a new pathway for regulating boride morphology and investigating refinement mechanisms of B-modified TiAl alloys.

A high-volume-fraction L12 precipitates-strengthened high-entropy alloy with synergistic properties for high-temperature applications

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Abstract

Precipitation-strengthened high-entropy alloys (PSHEAs), known for their high compositional flexibility and broadly tuneable mechanical properties, have attracted significant attention for applications across a broad temperature range from cryogenic to elevated. However, their behaviour and properties at high temperatures of 1000 °C and above remain inadequately understood. This presentation will introduce our recent progress of a novel multi-component Ni-rich high-entropy alloy (MNiHEA), designed for operation at temperatures above 1000 °C [1–3]. Through metallurgical design and microstructural manipulation, synergistic mechanical, thermal, oxidation, and manufacture properties have been achieved. Case studies will demonstrate the phase diagram calculation-aided compositional optimization, and the achieved coarsening resistance, strength-ductility properties from –196 °C to 1000 °C, and thermo-mechanical and laser powder bed fusion additive manufacturing processabilities in MNiHEA. The presentation will also include the uncovered underlying thermodynamic, kinetic, and mechanistic mechanisms responsible for the achieved synergistic properties. These findings offer valuable insights for the development of next-generation heat-resistant materials with enhanced properties, particularly for use in extreme environments such as aerospace and energy systems.

Keywords: Precipitation-strengthened high-entropy alloys; Compositional and microstructural design; Synergistic properties; Thermodynamic–kinetic–mechanistic mechanisms; High-temperature applications

Oxide Control Strategies for High-Strength Steel Processed by Laser Powder Bed Fusion

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Abstract

The high oxygen content in additive manufacturing powders (up to 100 ppm) significantly increases oxide inclusions and reduces toughness in high-strength steel. In this study, we investigates the effects of deposition efficiency and powder characteristics on the oxide features and, consequently, strength and toughness in laser powder bed fusion (LPBF) processed Fe11Cr9Ni6Co3Mo high-strength steel. The results show that, from a processing perspective, lowering deposition efficiency increases the cooling rate of the molten pool, triggering oxide nucleation (more but smaller oxides), which effectively mitigates their harmful effect on toughness. Regarding powder characteristics, while minimizing oxygen content, oxidation by low-affinity elements(Si/Mn) should be avoided, and high-affinity element(Al/Ti) levels should be controlled to achieve thermodynamic equilibrium with oxygen. Following this strategy, the powder oxygen content was set to 0.012 wt.%, and Al and Ti contents to 0.0017 wt.% and 0.011 wt.%, respectively. The heat-treated material exhibited properties comparable to conventional forgings: at room temperature, yield strength of 1249 MPa, tensile strength of 1348 MPa, elongation of 16.3%, and impact toughness of 224 J; at -196 °C, these values reached 1601 MPa, 1776 MPa, 26.0%, and 95 J.

Programmable Structuring of Plant Proteins by Extrusion-Based 3D Printing for Meat Analogue Texture Design

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Abstract

Future food manufacturing requires approaches that move beyond empirical formulation toward controlled, programmable structuring of food materials. In plant-based meat analogues, high-moisture extrusion remains one of the most effective methods for generating fibrous anisotropic textures, but the resulting structures are often uniformly aligned and can lead to tough or rubbery textures. Extrusion-based 3D food printing offers an alternative route by enabling spatial control over material deposition, filament orientation, and hierarchical architecture.

This presentation discusses the development of soy protein-based printable inks and the use of extrusion-based 3D printing to program meat-like structural anisotropy across multiple length scales. The work focuses on how formulation composition, water content, hydrocolloid addition, thermal treatment, and nozzle/die-induced flow influence printability and protein alignment within printed struts. Rheological characterization is used to define the processability window, while thermal analysis provides insight into protein transitions relevant to heat-assisted printing. Microstructural imaging and orientation analysis are then used to evaluate the formation and retention of aligned structures after printing.

The study further explores how printed toolpath design can translate single-strut alignment into larger-scale architectures that mimic the grain-like organization of muscle tissue. By linking material properties, processing conditions, structural alignment, and textural response, this work presents extrusion-based 3D printing as a programmable manufacturing strategy for future structured foods. The findings support the broader development of data-driven and standardized approaches for designing alternative protein products with tunable texture, improved reproducibility, and potential for personalized food structures.

Fatigue Behaviour of LPBF 316L Stainless Steel Lattice Structures: An Experimental and Numerical Study

Yi ZHOU, John Hock Lye PANG, Ninian Sing Kok HO

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Abstract

The incorporation of topological lattice structures into laser powder bed fused (LPBF) components is increasingly adopted in industry to reduce material consumption. Previous studies have primarily focused on deformation behaviour of lattice structures under monotonic tensile and compressive loading, with limited attention given to fatigue response under cyclic loading, which accounts for over 90% of in-service mechanical failures. In addition, internal defects inherently introduced during the LPBF process deteriorate the fatigue strength of lattice structures, leading to premature failures. Current defect detection methods mainly rely on microscopic examination of sliced samples, which cannot provide 3D defect characterization, thus limiting the analysis of defect effects on fatigue behaviour. In this study, 316L stainless steel fatigue specimens with lattice-integrated gauge sections are fabricated using LPBF, incorporating three representative topologies: cell-wall-like honeycomb, strut-like body-centred cubic (BCC), and surface-like gyroid. A high-energy X-ray computed tomography (CT) system is employed to detect and image internal defects, generating high-quality meshes for finite element models to analyse stress distributions and predict fatigue life. Preliminary numerical results, validated against experimental data, reveal distinct fatigue failure mechanisms across topologies, with gyroid structures demonstrating superior fatigue resistance. Key factors significantly affecting fatigue behaviour, including defect location and size, lattice topology, and geometric dimensions, are systematically investigated, providing a foundation for optimizing lattice structure design in fatigue-critical applications.

Ultrahigh Stiffness and Energy Absorption Properties of Isotropic Metallic Closed Cell Microlattices Manufactured via LAPIS

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Abstract

To validate leading theories on isotropic mechanical metamaterial designs, pSC-pFCC closed cell microlattices were fabricated from SS304L sheets using the LAPIS additive manufacturing technique. By removing excess material at each layer, the fully enclosed voids in the lattice design were faithfully reproduced, confirmed by micro-CT scan, without the need to introduce release holes for precursor materials. Material anisotropy caused by the layer-by-layer fabrication process was removed with a post-print heat treatment. The microlattices exhibited highly similar elastic deformation in the <100> and <110> axes, with stiffnesses at the Hashin-Shtrikman theoretical limit, as predicted previously. However, this isotropy in stress-strain response was unexpectedly extended to the plastic regime as well, even though the microlattices failed via plate buckling in <100> orientation, but by shear banding in <110>. Moreover, the microlattices also displayed remarkable specific energy absorption (15–33_J/g) and energy absorption efficiencies up to 44%, at stresses as high as 410 MPa. Material work hardening was key to this breakthrough performance, as it raised the plateau stress of the plate buckling failure to approximately the same level as the stretch-dominated elastic limit, which allowed ultrahigh stiffness to be united with excellent energy absorption characteristics in these mechanical metamaterials.

Effect of Gravity on Free-Surface Oscillation Dynamics of Laser-Induced Melt Pools

YiFan He , Wenshuai Xu , Yanhua Bian , Kuo Yan , Congrui Wang , Hengyi Gong , Jingyuan Liu , Jun Wang , Heng Jiang

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Abstract

Free-surface oscillation is a sensitive indicator of laser-induced melt pool stability, as it reflects the transient force balance among thermocapillary stress, evaporation-induced recoil pressure, capillary restoring force, viscous dissipation, buoyancy, and hydrostatic-pressure effects. In this study, a microgravity drop-tower platform is employed to investigate the influence of gravity on the free-surface oscillation dynamics of laser-induced melt pools, with particular attention paid to two representative melting regimes: conduction mode and keyhole mode. A combined experimental and numerical approach is adopted. High-speed imaging is used to capture the transient evolution of the melt pool free surface, while a finite element model is developed to analyze the temperature field, melt pool morphology, surface deformation behavior, and flow response under different gravity conditions. Based on image-based contour extraction and time-resolved signal analysis, the oscillation frequency, amplitude, and wave propagation characteristics of the free surface are quantified. The finite element results are further used to clarify the thermo-fluid coupling mechanisms underlying the observed oscillatory behavior. This study provides a fluid-dynamics-based interpretation of free-surface oscillation in laser additive manufacturing under different gravity environments and offers a mechanistic basis for understanding melt pool stability under microgravity conditions.

Hydrogen Embrittlement in Additively Manufactured Maraging Steels: From Mechanism Understanding to Hydrogen-Resistance Design

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Abstract

18Ni300 maraging steel is an advanced ultra-high-strength steel widely used in aerospace, high-end molds, and other fields. In recent years, the utilization of additive manufacturing technologies, such as laser-powder bed fusion (LPBF), in fabricating maraging steel has gained increasing attention. However, LPBF maraging steel faces hydrogen embrittlement (HE) risks due to its high strength, and existing research lacks a systematic understanding of its HE behavior. To address this, this work comparatively studies the microstructural and HE behavior differences between LPBF- and conventionally-processed 18Ni300 maraging steel, revealing the HE mechanism of LPBF-processed material. Additionally, the influence of typical heat treatment processes (solution treatment, aging treatment, solution treatment + aging treatment) on the hydrogen diffusion and HE behavior were also investigated. It was found that despite traditional heat treatment enhances the material's strength and toughness, it significantly degrades HE resistance. Building upon this, a novel low-temperature long-term aging treatment process was proposed. This novel process constructs a multi-scale, multi-dimensional hydrogen trapping network within the steel, enabling simultaneously enhancing material strength and HE resistance. This research provides new insights for designing additive manufactured hydrogen-resistant steels and advances the application of LPBF maraging steels in hydrogen-bearing environments.

Fatigue evaluation of binder jetted 316L parts for critical applications

Pang Hock Lye, John

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Abstract

Metal Binder Jetting is an Additive Manufacturing (AM) technique where binder is deposited on metal powder one layer at a time to create green parts that are subsequently sintered. As such, it offers the same freedom in part geometry as other more common AM processes, e.g. LBPF, while using relatively cheaper equipment and occupying a smaller footprint. Yet, it is less studied than other AM processes. In this study, the tensile properties and porosity of binder jetted 316L was found to differ significantly from those of 316L processed by other AM routes. Furthermore, the fatigue performance of 316L fabricated by binder jetting is evaluated against that of 316L made from other manufacturing processes. X-ray Computed Tomography scans before and after fatigue testing shed insight into the role of internal defects. The effect of skin removal on fatigue performance is investigated, where it was found that machining of the rough as-built skin did not improve the S-N performance. These findings allow for a cost-effective use of binder jetted 316L parts with respect to fatigue performance.

Tool wear condition monitoring based on a based on large language models and audible sound signals

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Abstract

Tool wear condition monitoring (TWCM) has been a research hotspot for decades due to its significance in intelligent manufacturing. However, despite a large volume of publications, its practical application remains limited. A crucial reason is that conventional monitoring sensors—such as those for force, vibration, temperature, and acoustic emission—often interfere with the natural machining conditions, restricting their industrial deployment. In contrast, microphone sensors, which collect audible sound (AS) signals, are considered a promising strategy for TWCM. They offer distinct advantages, including a close correlation with tool wear, convenient installation, high flexibility, and no interference with the machining process. The rapid development of large language models has provided a new way for extracting information about tool wear condition from AS, and our research verified its effectiveness in the milling and drilling scenarios.

Image Analysis-Based Evaluation of Dimensional Accuracy in 3D Printing of Soy Protein Hydrogels

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Abstract

This study investigates Fused Deposition Modelling (FDM)-based 3D printing of soy protein hydrogels for the production of meat analogues, with a focus on evaluating dimensional accuracy and structural fidelity. Conventional approaches in food 3D printing typically rely on manual metrology and simple 3D structures to assess printability. However, such methods can obscure geometry-dependent effects due to superposition, limiting a comprehensive understanding of material behaviour after printing. To address this limitation, an image analysis-based methodology was developed to enable a more systematic and objective assessment of print quality.

A camera-based system combined with digital image analysis was implemented to quantify the dimensional stability of printed structures. This approach enabled non-invasive, objective, and reproducible measurements of shape fidelity, providing a clear advantage over conventional subjective and manual assessment methods. To capture geometry-dependent performance, structures across multiple dimensions were evaluated, including three-dimensional (3D) cubes, two-dimensional (2D) planar grid structures, and one-dimensional (1D) single-line uniformity tests were performed, allowing for comprehensive evaluation of geometric performance.

The results demonstrate that print quality is strongly governed by both the structural response of the material during and after extrusion and the geometry of the printed construct, as reflected in dimensional deviations captured through image analysis. Differences in dimensional accuracy between 1D and 3D structures highlight the critical role of geometry in determining print outcomes, with 1D image-based analysis providing improved accuracy compared to evaluation of whole cubes. Image analysis enabled a reliable evaluation of printability and shape fidelity across geometries compared to manual metrology, while also revealing that robust measurement accuracy depends on careful hardware setup and environmental control, including standardized lighting conditions and consistent camera positioning.

Overall, the findings underscore the importance of geometry-sensitive assessment methods and establish image analysis as a reliable tool for optimizing the design and performance of protein-based materials in 3D printing.

Decoupling Strength and Isotropy in Microgravity Wire-Fed Laser AM of Ti Alloys: A Grain-Resolved CET–CPFE Study

Hengyi Gong, Wenshuai Xu, Heng Jiang

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Abstract

Microgravity fundamentally alters melt pool dynamics and solidification pathways in additive manufacturing (AM), yet its implications for mechanical performance remain poorly quantified. In particular, the columnar-to-equiaxed transition (CET), frequently observed under microgravity, has not been systematically linked to grain-scale deformation and macroscopic property evolution.

In this work, we establish a grain-resolved experimental–computational framework to directly connect CET behavior with mechanical response in wire-fed laser AM of titanium alloys. Microgravity conditions were reproduced via controlled drop-tower experiments, generating distinct solidification microstructures characterized by electron backscatter diffraction (EBSD). Based on these measurements, a crystal plasticity finite element (CPFE) model with one-to-one microstructure reconstruction was developed to simulate grain-scale deformation.

The results reveal that microgravity-induced CET promotes a transition toward equiaxed grains, accompanied by grain coarsening within the explored processing window, leading to a reduction in strength and hardness. Importantly, this evolution simultaneously enhances mechanical isotropy, effectively decoupling strength loss from isotropy gain. The improved isotropy suppresses orientation-dependent strain localization and enhances structural robustness under multi-axial loading conditions.

Mechanistically, slip-dominated deformation is identified as the governing factor underlying this trade-off, and the CPFE framework enables a quantitative evaluation of the associated performance bounds.

This study provides a quantitative, grain-scale linkage between microgravity solidification and mechanical response, offering actionable insights for the design of additively manufactured components in space environments.

Energy-efficient PTA deposition using induction-preheated metal-cored wire for high-productivity remanufacturing

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Abstract

“Surface remanufacturing is essential for extending the service life of continuous casting rolls in the steel industry, which are subjected to severe thermal-wear conditions. However, conventional Gas Metal Arc Welding (GMAW) and Submerged Arc Welding (SAW) processes are constrained by a trade-off between productivity and deposit quality. While Plasma Transferred Arc (PTA) enables precise control over dilution, its industrial application is limited by low deposition rates in large-scale repair operations.

To address this limitation, this study investigates an induction-assisted PTA approach where a metal cored wire (MCW) is preheated via induction prior to deposition. This configuration introduces an auxiliary heat source, reducing the energy required from the primary arc during deposition. Unlike solid wires, MCWs enable the incorporation of ferromagnetic constituents, thereby enhancing responsiveness to induction heating and improving deposition efficiency. A comparative analysis of solid wires, standard and ferromagnetic MCWs was conducted to evaluate their impact on preheating efficiency, deposition rate and energy consumption.

Experimental results demonstrated induction heating is a promising method for wire preheating with deposition rates improved by 60% as compared to conventional cold-wire PTA. Further results show that ferromagnetic MCWs absorbed 200% more induction energy than solid wires, while reducing arc energy consumption by 34%. This enables precise control of the thermal cycle within the heat-affected zone, mitigating the formation of undesirable phases such as delta ferrite. Such microstructural control is critical to preventing crack initiation under severe corrosion-fatigue condition, typical of continuous casting roll service.

These findings establish induction-preheated PTA deposition as a high-productivity, energy-efficient approach, supporting the development of scalable remanufacturing solutions for advanced manufacturing industries.”

Machine Learning Prediction of Printability and Mechanical Properties in 3D Concrete Printing

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Abstract

3D concrete printing offers significant advantages over conventional construction methods, including reduced material waste, lower labour costs, and greater design flexibility. However, identifying suitable concrete mix compositions for printing remains a resource-intensive challenge due to the vast number of possible ingredient combinations. This study applies XGBoost, an machine learning algorithm, to predict key rheological and mechanical properties of cement mixtures, such as slump, slump-flow, and compressive strength, from four input variables: Water/Binder (W/B), Sand/Binder (S/B), Fly Ash/Binder (FA/B), and Silica Fume/Binder (SF/B) ratios. Parameter improved model performance across all metrics, with the slump and slump-flow prediction model achieving an R_ of 0.732 after optimisation. Partial Dependence Plots (PDPs) were used to interpret feature interactions and identify the printable region, revealing that mixtures with W/B between 0.45–0.52, S/B between 1.0–1.4, and SF/B below 0.12 fall within acceptable printing bounds regardless of FA/B. For maximising compressive strength, an S/B of 1.6 and SF/B of 0.8 are recommended, paired with a low but printability-compatible W/B. The compressive strength model showed limited predictive power, attributed to an insufficient training dataset, highlighting the need for expanded experimental data in future work.

Metal additive manufacturing technology in microgravity of space

Kuo Yan, Heng Jiang, Wenshuai Xu

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Abstract

Space metal additive manufacturing technology stands as one of the key technologies in the future space manufacturing field. It features prominent advantages, such as manufacturing large-scale components beyond the constraints of launch envelopes, providing emergency support for the rapid maintenance of in-orbit platforms, and developing novel materials that are difficult to fabricate on the ground by taking advantage of the space environment.

As one of the unique space environments, microgravity (<10__ g) exerts a remarkable influence on the melting and solidification process of metal additive manufacturing. Under microgravity conditions, droplet transfer, wetting and spreading, liquid bridge stability, and solidification microstructure evolution constitute the core research focuses for the future development of space metal additive manufacturing technology.

We have carried out multiple single-track cladding experiments of laser wire additive manufacturing under microgravity based on the Beijing Drop Tower. Although the stable microgravity duration of each single experiment was only 3.6 seconds, key experimental data regarding liquid bridge stability and fracture characteristics, cladding layer morphology and microstructure growth were successfully acquired. Through analysis on drop tower experimental results and iterative optimization of process parameters, the critical process parameters for laser wire additive manufacturing under microgravity were determined. On this basis, the technical verification of space metal additive manufacturing was completed in January 2026 aboard the Lihong-1 sounding rocket, achieving a stable microgravity duration of over 180 seconds. Meanwhile, in April 2026, we completed orbital-level engineering verification at a 600 km orbit with the support of the Qingzhou cargo spacecraft.

Brain-like Constructs based on Neural Stem cells Transplanted for Recognition Recovery

Ke GAI, Feng LIN

Tsinghua University, Department of Mechanical Engineering

Abstract

Stem cell transplantation holds great promise for treating neurological disorders. However, conventional cell suspension injection has obvious limitations, including uncontrollable cell distribution, tumorigenic risk, and insufficient repair of tissue spatial defects. 3D implants derived from neural stem cells are expected to address these drawbacks through tailored structures and regulated cell behaviors. In this work, a 3D-printable hydrogel system consisting of gelatin, alginate and fibrinogen was developed. This hydrogel exhibits brain-matched elasticity, satisfactory printability and long-term stability. Encapsulated human neural progenitor cells achieved sustained survival and proliferation. After 14 days of culture, mature neural networks, calcium signals and functional electrical activities, including epilepsy-like potentials, were successfully detected. In vivo implantation into the rat hippocampus enabled stable cell colonization for more than one month. The 3D-printed brain construct maintains structural integrity after transplantation, effectively enhancing cell retention and spatial controllability. Further verification in Alzheimer's disease dementia models demonstrated significant functional restoration. This novel biomimetic implant offers an advanced and feasible strategy for in situ neural repair and functional reconstruction.

Architected Multifunctional Metamaterials by Additive Manufacturing

Zhendong Li

RMIT

Abstract

Additive manufacturing enables architected materials that combine outstanding mechanical properties with tailored multifunctionality. In this study, we design and fabricate lattice structures that are mechanically robust while exhibiting tunable acousto-mechanical coupling, serving both load bearing and acoustic roles. Through topology driven design and additive manufacturing techniques such as FDM, DLP and LPBF, we optimize strut geometry, connectivity, and material distribution to achieve high stiffness, high strength, and high specific energy absorption for lightweight energy absorbing applications. Within this strong backbone, we embed resonant acoustic features including Helmholtz cavities and quarter wave channels. These features enable low frequency broadband sound absorption, effective sound insulation, controllable absorption bandwidth, and spectral tunability of acoustic responses, all without sacrificing structural integrity. We classify acousto-mechanical coupling strategies as weak and strong. Weak coupling integrates acoustic absorbers such as micro perforated panels into optimized lattices, allowing separate control of acoustic and structural responses. Strong coupling uses the same lattice units for both load bearing and sound modulation, requiring co optimization and producing synergistic behaviors under mechanical load or acoustic excitation. The additive manufacturing framework accommodates other functions including vibration damping and thermal regulation. Through hierarchical architectures, biomimetic designs, and material efficient layouts, additive manufacturing enables truly multifunctional materials where unprecedented mechanical excellence coexists with broad functional adaptability.

In-Situ Formation of Graphene-Reinforced FeNiCrCo High-Entropy Alloy Nanocomposites via Laser Powder Bed Fusion: Enhanced Strength without Sacrificing Ductility

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Abstract

High-entropy alloys (HEAs) have attracted considerable attention due to their exceptional physical and mechanical properties. Among them, FeNiCrCo alloy with face-centered cubic (FCC) single-phase structure exhibits outstanding formability, yet its insufficient strength at room temperature severely limits practical applications. Laser powder bed fusion (LPBF), a mainstream metal additive manufacturing technology, offers an effective route for fabricating HEA-based nanocomposites through ultrafast cooling and non-equilibrium solidification. Graphene is an ideal reinforcement for metal matrix composites due to its intrinsic ultrahigh strength and flexibility, which can simultaneously enhance strength and ductility. However, graphene nanoplatelets tend to agglomerate and poorly adhere to spherical metal powders, posing significant challenges for LPBF processing. Graphene oxide (GO), sharing the same chemical skeleton with graphene while possessing abundant oxygen-containing functional groups, can uniformly coat powder surfaces via ball milling and in-situ reduce to graphene under laser irradiation. Herein, GO-coated FeNiCrCo HEA powders were prepared by high-energy ball milling and subsequently processed via LPBF. The resulting nanocomposite exhibited enhanced strength without sacrificing ductility. Molecular dynamics simulations revealed that graphene effectively impedes dislocation motion to strengthen the matrix, while its exceptional deformability accommodates stress concentration to maintain plasticity. This study provides new insights into designing high-performance HEA nanocomposites through additive manufacturing.

Digital Twins for Additive Manufacturing: From Lattice Design to Process Monitoring and Control, and Smart Implants

Yunlong Tang

Monash University

Abstract

Digital twins are transforming additive manufacturing from a tool for shaping materials into a platform for engineering intelligence. By connecting physics-based models, data and feedback across the product lifecycle, digital twins create new opportunities to design better structures, control complex processes and enable products that continue to generate value after fabrication. This presentation highlights three linked advances. First, digital twin models enable the design of stochastic lattice structures with tailored properties by linking geometry, simulation and predictive modelling. Second, service-oriented digital twin frameworks bring greater visibility and control to manufacturing processes, supporting quality assurance, proactive control and rapid exploration of process parameters, including for support-free structures. Third, additive manufacturing can create smart PEEK implants with embedded sensing capability, allowing printed components not only to be optimised during manufacture, but also to monitor healing and detect damage during service. Together, these developments point to a larger shift: additive manufacturing is evolving beyond digital fabrication toward intelligent, connected and sensing-enabled systems. In this vision, digital twins do not simply replicate manufacturing processes: they redefine how structures are designed, how products are made, and how they perform in the real world.

Study on High-Temperature Purely-dissolutive Wetting behaviors in Metallic Systems

Youqing Sun, Shoufeng Yang

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Abstract

Although high-temperature wetting plays a critical role in various industrial processes such as soldering, liquid metal infiltration, and laser powder bed fusion, our current understanding of this phenomenon remains highly fragmented. This is largely due to the intricate physicochemical interactions that occur at different interfaces, giving rise to a wide range of wetting behaviors—typically classified as inert, dissolutive, or product-forming. The difficulty of conducting experiments under well-controlled conditions further adds to the complexity. For example, even trace amounts of oxygen in the vapor phase can promote oxide formation, which in turn affects the generation of intermetallic compounds and ultimately alters wetting behavior.

In the present work, we examined the spreading behavior of molten metal droplets on solid metallic substrates by combining a high-temperature optical wetting setup with a confocal scanning laser microscope. A total of eight liquid/solid systems were studied: Cu/Ti, Cu/Ni, Cu/Fe, Ag/Ni, and Ag/Ti at 1150 °C; Sn/Cu at 800 °C; Ag/Cu at 1000 °C; and Sn/Fe at 950 °C. Based on two parameters—namely, the solubility of the solid element in the liquid (CS) and the solidification temperature range of the resulting solid solution (CR)—these systems fell into three categories. In those with relatively low CS and narrow CR, a slow, stepwise spreading pattern was observed. For systems with high CS, spreading was initially rapid but transitioned to a stepwise mode once the solubility limit (CS) was reached. Conversely, systems featuring a wide CR displayed consistently fast spreading throughout. Quantum-based simulations offered deeper insight into the mechanisms governing solid solution formation, while computational fluid dynamics validated the role of Marangoni flow in the stepwise spreading process.

Effect of nitrogen concentration on microstructure and mechanical properties of AlSi10Mg matrix composites fabricated by laser powder bed fusion

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Abstract

In this study, a new way for synthesising nanoscale AlN and Si_3N_4 co-reinforced aluminium matrix composites (AMCs) by means of laser powder bed fusion (LPBF) is presented. The method entails irradiating AlSi10Mg powder with a laser beam, thereby forming an Al matrix melt pool in an atmosphere of dilute nitrogen (N_2) concentration; simultaneously, the nearby N_2 undergoes pyrolysis, generating reactive nitrogen ions that react with dissolved Al and Si atoms within the melt pool to form AlN and Si_3N_4 precipitates. Benefiting from rapid solidification characteristic of LPBF, these nitrides nucleate and grow in an extremely short temporal window before precipitating in the melt pool. Finally, the (AlN + Si_3N_4)/AMC is fabricated through successive layer-by-layer application of this synthesis strategy. Herein, a comparative investigation was conducted between AMCs processed under varying N2 concentrations (2 vol%, 5 vol%, and 10 vol%) and a reference AlSi10Mg alloy produced in a pure argon (Ar) atmosphere (0 vol% N_2). Multiple analytical techniques (XRD, SEM, EDS, HR-TEM, and XPS analyses) verified nitrides incorporation into the AMCs matrix, meanwhile, EBSD characterised the grain morphology, dimension, and orientation. The strengthening–toughening mechanisms of the composites were systematically elucidated through comprehensive microstructural and mechanical property evaluations.

A Digital-to-Physical DFAM Framework for Next-Generation Patient-Specific Implants

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Abstract

Background: To drive industrial transformation within the medical sector, this study proposes an advanced Design-for-Additive-Manufacturing (DFAM) framework that integrates digital intelligence with physical production. By leveraging innovative technologies to enhance competitiveness and value-add in the manufacturing value chain, this research presents a closed-loop workflow for developing lightweight, patient-specific mandibular reconstruction plates (PSMRPs).

Methods: Central to this digital-to-physical transition is the application of topology optimization (TO), a key computational tool used to engineer two novel designs that achieve a 25% mass reduction compared to conventional implants. To ensure these optimized geometries push the manufacturing frontier without compromising performance, their biomechanical integrity was rigorously evaluated via Finite Element Analysis (FEA). Simulations under diverse physiological conditions—incisal biting and right group clenching—confirmed that the TO-derived plates maintain critical structural stability and fatigue durability, with PSMRP1 exhibiting the most balanced performance.

Results: The translation from digital designs to functional products was validated through high-fidelity additive manufacturing techniques. Physical prototypes were fabricated using Laser Powder Bed Fusion (LPBF) in Ti6Al4V, while anatomically accurate mandibular models were produced via PolyJet technology. This multi-tool approach confirmed both the manufacturability and precise assembly fit of the optimized designs.

Conclusion: By harmonizing scientific engineering advances with advanced materials, this study demonstrates a sustainable and efficient manufacturing pipeline. The results highlight how the integration of innovative design tools and 3D printing technologies can optimize resource use and provide exceptional value-add for the future of advanced manufacturing. This research contributes to a more sustainable, data-driven future for the medical device industry, aligning with the core objectives of driving sectoral transformation through technical excellence and innovative production engineering.

Dispensing Volumetric Additive Manufacturing

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Abstract

While conventional additive manufacturing (AM) enables the creation of tailored three-dimensional shapes, its sequential processing imposes fundamental limits on production rates and post-processing operations, restricting its broader application. Volumetric additive manufacturing (VAM) has emerged as a compelling alternative, solidifying material throughout an entire volume simultaneously to significantly reduce fabrication time. However, current computed axial lithography systems require manual operations per print cycle, such as filling a cylindrical vial with resin, aligning it with projection light (with or without an index-matching medium), and harvesting the printed object. These steps limit continuous, high-throughput production. We introduce a Dispensing Volumetric Additive Manufacturing (DVAM) method that prints and dispenses 3D structures directly within a resin droplet suspended from a glass pipette. The droplet serves as a self-contained, automatically replenished printing chamber, eliminating the need for a container or index-matching fluid. Because the curved resin-air interface introduces significant optical lensing effects, we implemented a refractive correction process. This strategy integrates real-time droplet profile estimation via a CCD camera with inverse ray-tracing and intensity compensation to counteract geometric deviations and ensure uniform light dose delivery throughout the rotating resin volume. The volumetric printing process occurs within a single rotating droplet, achieving complete exposure in 45 to 75 seconds. After curing and rotating, the print is dispensed, enabling simultaneous part removal and fresh resin replenishment within a few seconds. We demonstrate the rapid serial fabrication of 10 geometrically distinct objects within 10 minutes. DVAM establishes a practical and robust pathway for scalable, continuous volumetric manufacturing of complex 3D structures without conventional operational bottlenecks.

Bioinspired hetero-bilayer structures with dual-confinement effect for phase-change cooling

Yantong Zhu, Xiaolin Liu, Yan Wang, Xiaopeng Shang,Huawei Chen

Beihang University

Abstract

Spray cooling offers exceptional heat-dissipation efficiency, its performance under time-varying thermal loads and complex gravitational conditions is limited by an inherent conflict: thin liquid film control and sufficient liquid supply. Here, a counterintuitive liquid film wetting behavior, i.e., superhydrophobic-to-superhydrophilic state spontaneous transition of micro droplets on Kallima inachus wing scales has been discovered. Motivated by this bioinspiration, we engineered a hetero-bilayer structure through the droplet adaptation strategy and achieve a gravity-insensitive and ultra-thin liquid film, enabling an ultra-high critical heat flux of 1057 W·cm-2 with a heat transfer coefficient of 49.5 $kW\cdot^{-2}\cdot K^{-1}$ in spray cooling.

Robust thermochromic photothermal coating with ultraslippery anti-icing/de-icing and all-season temperature regulation performance

Shize Sun,Xiaolin Liu, Huawei Chen

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Abstract

Photothermal materials with higher conversion efficiency are a promising approach to preventing ice accretion on infrastructures like wind turbines. However, the conflict between weak-light inefficiency in winter and overheating hazards in summer remains a challenge for composites. Herein, we develop a robust thermochromic photothermal icephobic coating with switchable solar-driven anti-/de-icing and anti-overheating modes for all-season demands. During freezing winter, a 0.05 W/cm2 weak solar irradiation can raise the black coating (solar absorbance >97%) temperature from -10 °C to 7.6 °C and facilitate rapid ice shedding from rotating rotor. During summer, the thermochromic coating turns white with strong reflection and limits coating temperature below 51 °C, inhibiting composites oxidation above 60 °C. Strikingly, the interpenetrating elasticity and ultra-slippage endow the coating with exceptional ice detachment properties, exhibiting an ultralow ice adhesion strength (<31 kPa) and sliding angle (<8.3°), which are maintained even after 200 Taber abrasion cycles. This study successfully addresses the critical challenge of regulating all-season temperatures of photothermal coatings, pioneering a new pathway for designing intelligent anti-icing coatings for wind turbines and low-altitude rotorcrafts.

3D Printing of Multi-material Nanocomposites for Multifunctional Applications

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Abstract

Additive manufacturing (3D printing) is a disruptive technology that enables the fabrication of complex, multifunctional optical devices for sensing and biomedical applications. Advancements in the development of a diverse range of 3D printable materials, from biocompatible to metallic materials, including polymers, hydrogels, and their composites, have paved the way for broadening the prospects of sensing and optical devices for research as well as commercial purposes. The capabilities of open-source 3D printers enable the use of customized materials for printing tailored to the requirements of targeted applications. In this work, we have demonstrated 3D printing-based fabrication of soft, flexible, biocompatible, and multifunctional hydrogel contact lenses for ophthalmic applications.

In-house-developed HEMA hydrogel resins were used with a Vat Photopolymerization-based 3D printer to print soft contact lenses, and the resulting optical, mechanical, hydration, and material properties were assessed. The optical transmission properties of the 3D-printed nanocomposite lenses were found to be comparable to those of commercial lenses, and their water content and wettability were superior to those of some commercially available contact lenses used for cosmetic/vision correction. Hence, this work demonstrates the potential of 3D-printed multi-material contact lenses for multifunctional applications, such as ocular health management and, more generally, color-filtering applications.

3D (Bio)printing of clinically-relevant soft tissues

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Abstract

Digital Light Processing (DLP) has emerged as a transformative 3D bioprinting technique, offering superior precision, throughput, and cell viability compared to conventional extrusion-based methods. By utilizing light-based polymerization rather than mechanical deposition, DLP significantly reduces shear stress, making it an ideal platform for engineering complex, high-resolution tissue structures. We used DLP to fabricate of two distinct soft tissues—knee meniscal constructs and corneal stroma equivalents (CSE)—using a Gelatin methacryloyl (GelMA) base, optimized through specialized secondary crosslinking mechanisms to mimicnative physiological properties. For meniscal applications, a post-printing tannic acid (TA) crosslinking strategy was employed. This approach successfully reinforced the constructs, achieving a mechanical modulus of approximately 200 kPa, aligning with native meniscal values. Beyond structural integrity, TA-crosslinked GelMA exhibited potent antioxidant, antibacterial, and immunomodulatory effects. Notably, the treatment supported the chondrogenic differentiation of human Mesenchymal Stromal Cells (hMSCs) and promoted an anti-inflammatory microenvironment, characterized by the upregulation of cytokines such as IL-4, TGF-β1, and IL-10, while suppressing pro-inflammatory markers like TNFα, MCP1, and IFNγ. Conversely, corneal constructs were developed by integrating oxidized carboxy methyl cellulose (OxiCMC) to facilitate a Schiff's base reaction. This formulation enabled the high-speed production of six anisotropic constructs in just 20 minutes. The resulting CSEs demonstrated a compressive modulus of ~110 kPa and exceptional optical clarity, maintaining over 90% light transmittance at 500nm. Biological assessments revealed that human corneal keratocytes retained high viability (>94%) and their characteristic stellate morphology, while consistently expressing key phenotypic markers, including lumican and keratocan. Collectively, these results demonstrate that DLP bioprinting, coupled with tailored secondary crosslinking, provides a versatile and efficient pathway for regenerating specialized fibrocartilaginous and ocular tissues.

Application-Driven Directed Energy Deposition for Industrial Remanufacturing

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Abstract

Directed energy deposition (DED) is increasingly adopted in industry for repair, surface enhancement, and near-net-shape manufacturing of high-value components. However, wider deployment still depends on how well the process can address practical industrial needs, including material flexibility, deposition efficiency, defect control, and property consistency. This presentation will share application-driven research based on previous aerospace-oriented projects, with emphasis on how industrial requirements can guide DED process development and evaluation. Case studies will be used to illustrate the use of DED for repair and function-oriented material design, including process window establishment, thermal and dilution control, defect mitigation, and process–property correlation.

Non-contact ultrasound to assist laser additive manufacturing

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Abstract

In ultrasound-aided laser melting processes such as additive manufacturing, it is generally believed that acoustic cavitation is essential for grain refinement during solidification while acoustic streaming plays a negligible role. We design a non-contact ultrasound approach to provide low-intensity ultrasound, i.e., below the melt cavitation threshold, ensuring a pure acoustic streaming regime. Without cavitation, it is found that fine equiaxed grains still can be achieved. This is attributed to the combined effects of acoustic streaming and Marangoni force, which create a high-frequency-shaking type melt flow in the melt pool, leading to fatigue fracture of dendrites and thus grain refinement. Moreover, low-intensity ultrasound can offer stable melt pool modulation throughout layer-by-layer processing, enabling uniform grain refinement in large-scale samples, which is a challenge for the current direct-contact ultrasound approach.

The Future of 3D Printing: Scientific and Patent Analytics for Strategic Innovation

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Abstract

Three-dimensional (3D) printing is emerging as a transformative technology, driven by advances in materials and manufacturing processes and by the demand for personalized therapeutics. Significant research efforts have been dedicated to technical aspects such as materials and fabrication processes; however, comparatively less attention has been given to systematically identifying technological trends and innovative applications through foresight approaches. Strengthening this perspective is essential to better understand the future development and impact of this innovative field. In this context, Competitive Technology Intelligence (CTI) provides a framework for analyzing the evolution and future direction of emerging technologies, such as tissue engineering, pharmaceuticals, and related areas. CTI involves systematic collection and analysis of technological, scientific, and patent information to support strategic decision-making and identify opportunities for innovation.

This study presents key trends in the application of CTI to 3D printing for health applications, particularly concentrated in tissue engineering and oral drug delivery systems, including tablets, polypills, orodispersible films, and multi-compartment dosage forms. These systems enable precise control of drug release and patient-specific dosing, specifically y for central nervous system disorders. Recent studies in the field establish that strategic enablers include advances in digital design, Quality by Design approaches, and user acceptability. However, digitalization also introduces challenges such as cybersecurity. Overall, 3D printing is positioned as a cornerstone of future health innovation.

Converting soft hydrogels to hard materials via in-situ synthesis

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Abstract

Additive manufacturing of polymers has attracted a lot of attention, and efforts are underway to improve printing resolution, speed, and, most importantly, functionality. While polymers with a wide variety of functionalities such as stimuli-responsive and optical properties can now be printed, there are some functionalities such as conductivity and magnetism remain difficult to achieve or perform poorly compared to inorganic materials. 3D printing of composites offers a pathway forward, yet conventional methods with utilizing slurries or organic-inorganic hybrid resins have challenges with high viscosities, light-scattering and limited material compositions.

Here, we introduce a fundamentally different method: a post-fabrication method based on repeated ion infusion and in-situ precipitation that decouples printability from functionality. By utilizing 3D-printed “blank” hydrogels as templates, this repeated infusion-precipitation process progressively increases the inorganic loading post-fabrication. To demonstrate the versatility and utility of this approach, we successfully converted printed hydrogels into multifunctional composites exhibiting both magnetic responsiveness (~15 emu/g) and electrical conductivity (~10-2 Ωm).

Beyond composite materials, ceramics and metals thermally converted from the high inorganic loading composites prepared with our method also show superior properties than the state of the art. We systematically explored how hydrogel composition and network properties influence the in-situ precipitation and subsequent thermal conversion processes, which enables the complete conversion of high-loading (~90 wt%) composites into dense (~90%) ceramic and metallic architectures with high-fidelity. Notably, we achieved zero shrinkage from printed polymer to converted ceramic, which eliminates the need for pre-compensation during structural design. Given its compatibility with diverse gel-based 3D printing platforms, this technology paves the way for the multi-scale fabrication of previously impossible advanced architected materials and smart devices.

Mechanical Properties and Microstructure Evolution of Copper-Manganese-Tin Alloy Using Selective Laser Melting and Development of Bimetallic Printed Alloys

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Abstract

With the rapid advancement and increasing maturity of additive manufacturing (AM) processes, Laser Powder Bed Fusion (LPBF) technology has been successfully employed to fabricate components from stainless steel, aluminum alloys, and titanium alloys. However, numerous studies have highlighted the persistent challenges in fabricating highly dense copper alloy components via LPBF. This difficulty is primarily attributed to two factors. First, copper alloys exhibit low optical laser absorptivity, resulting in significant laser reflection and exceedingly low energy absorption. Second, the inherent high thermal conductivity of copper alloys leads to the rapid dissipation of absorbed heat. The combination of these two phenomena results in low and unstable energy conversion efficiency, which subsequently impedes complete powder melting and induces melt pool instability. To address the growing trend of product miniaturization and the demand for versatile applications in AM, the development of bi-metallic and small-scale printing serves as a primary objective of this research.

Furthermore, when utilized as resistive materials, copper alloys require a near-zero temperature coefficient of resistance (TCR). This parameter is predominantly influenced by two factors: the intrinsic properties of the material and its internal microstructure. Microstructural features, including grain boundaries, solute atoms, and precipitates, significantly affect the TCR. Therefore, this research focuses on optimizing the LPBF processing parameters for copper alloys and developing bi-metallic printing techniques. Additionally, this study investigates the modulation of internal microstructures through various heat treatment protocols to evaluate the corresponding alterations in electrical and mechanical properties. Ultimately, the integration of two distinct metals is explored as a mechanism to tailor and achieve a near-zero TCR.

Mass Customization of Footwear Using Additive Manufacturing

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Abstract

Footwear is commonly designed for standardized body weight ranges, with variation largely limited to foot size, which may result in suboptimal cushioning performance for individuals outside the intended weight range. This study aimed to develop mass-customized footwear incorporating three-dimensional (3D) printed cushioning inserts at the heel and metatarsal head regions to better accommodate variations in body weight. To identify suitable infill densities, 3D-printed samples (50 mm _ 50 mm _ 20 mm) were fabricated and subjected to compression testing across six infill levels (10%, 15%, 20%, 30%, 40%, and 50%). Based on these results, infill densities of 24% and 30% were selected for the metatarsal and heel inserts, respectively. Thirty healthy adults (body weight range: 45–88 kg) participated in a within-subject study, walking at a self-selected speed along a 10-metre walkway while ground reaction force (GRF) data were collected from the right foot. Each participant completed six trials under two randomized conditions: footwear with 3D-printed inserts and a minimalist barefoot shoe. The test condition demonstrated significantly lower GRF during mid-stance to heel-off ($p < 0.05$), but significantly higher GRF during initial contact and loading response ($p < 0.01$). These findings indicate that the 30% infill heel inserts were effective in reducing GRF compared to minimalist walking for this weight range, whereas the 24% forefoot inserts were less effective. Future work should focus on optimizing infill density and structural design to further enhance GRF reduction and support the integration of 3D-printed inserts into mass-customized footwear, including incorporating the inserts into traditional injection moulding processes.

Design and Validation of a Low-Cost Open-Source Bioprinting Platform and Its Application to Structured Seafood Manufacturing

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Abstract

“Three-dimensional bioprinting is a promising manufacturing strategy for structured cultured seafood because it enables precise control over construct geometry, material composition, and internal organisation. This is particularly relevant for the development of cell-based seafood products, where reproducing the structure of native tissue is essential for texture, appearance, and functionality. However, the high cost, reduced adaptability, and limited accessibility of many commercial systems remain major barriers to broader implementation in both research and food manufacturing contexts. In this work, we present LusoBioMaker, a low-cost, open-source extrusion bioprinter developed to support the fabrication of structured food constructs with commercial-grade performance.

Built from a modified Ender 3-V2 platform, the system integrates dual screw-driven extrusion, independent active temperature control from 2 to 50 °C, and in situ 365 nm photocuring, while delivering extrusion forces up to 320 N. The platform was validated using bioinks with distinct gelation mechanisms, including κ-carrageenan, gelatine methacrylate (GelMA), and GelMA/PEGDA formulations. Calibration and acceptance tests based on ISO 230-1 and ISO 230-2 guidelines confirmed high positional accuracy, low dimensional error, and robust repeatability. Printed lattice structures achieved a printability factor of 0.995, demonstrating reliable filament deposition and high shape fidelity across a range of processing conditions. The system also maintained strong biological performance, with 96–97% L929 cell viability after 14 days.

Beyond conventional scaffold fabrication, LusoBioMaker offers a high degree of customisation, including compatibility with different syringe geometries, multi-material deposition, on-head photocuring, and printing on inclined surfaces. To demonstrate its relevance for cellular agriculture, the platform was used to fabricate structured seafood prototypes by depositing muscle- and fat-mimicking bioinks in controlled spatial arrangements, generating sashimi-like and fillet-inspired constructs.

These results establish LusoBioMaker as an accessible, versatile, and robust bioprinting platform for manufacturing structured cultured seafood products and other advanced biofabrication applications.”

Friction stir aided laser directed energy deposition hybrid additive manufacturing technology- induced microstructural control and strength-ductility synergy

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Abstract

To solve the problem of strength-ductility synergy caused by undesired microstructure and metallurgical defects in laser-directed energy deposition (LDED) aluminium and titanium alloys, a novel method of laser deposition hybrid additive manufacturing technology assisted by friction stir processing (FSP) is proposed. This work will discuss and analyze the effects of FSP on macro and micro structures of deposited layers, establish the matching relationship between typical parameters and microstructural characteristics, and clarify the strong plastic deformation behavior of FSP and the regulation mechanism of deposited layers. In addition, the matching relationship between the stable formation of multistage and multilayer periodic microstructure and cyclic manufacturing is established through the study of the re-melting and re-solidification microstructure in the secondary deposition region. Finally, the concurrent enhancement mechanism of strength-ductility of aluminium and titanium alloy fabricated by hybrid additive manufacturing technology is revealed.

Effects of Powder Recycling and Laser-Powder Interaction in Selective Laser Sintering of Polycaprolactone Architectures

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Abstract

Polycaprolactone (PCL) is widely used in medical implants due to its favorable biocompatibility and biodegradability. With the advancement of additive manufacturing, bioresorbable PCL scaffolds with tunable architectures can be fabricated, offering significant potential for applications in bone tissue engineering. In this work, Selective Laser Sintering (SLS) is employed to investigate the interactions between process parameters and powder properties in the fabrication of PCL scaffolds.

The quality of SLS-fabricated parts is influenced by both process parameters and material properties. Key processing parameters, including printing temperature, layer thickness, laser power, and scanning speed, directly influence the powder behavior during fabrication. Simultaneously, the intrinsic properties of PCL powder such as crystallinity and particle size distribution evolve under repeated thermal exposure, affecting powder recyclability and printability. These combined effects lead to variations in microstructural features of the printed parts, including porosity, pore size distribution, and bulk density, even for identical designed geometries. In addition, a notable limitation of SLS is that a significant proportion of powder within the build chamber remains unsintered, which necessitates effective powder recycling strategies while preserving material performance and printability.

This work systematically investigates the influence of both process- and material-related factors on printing quality. Input energy density is evaluated across different parameter sets and correlated with the resulting microstructural characteristics, providing insights into laser-powder interactions and the thermal behavior of the material during processing. In parallel, powder ageing effects are characterized through changes in crystallinity and particle size distribution, and their impact on printability is assessed. The findings offer guidance for process optimization and material management strategies in the SLS of low-melt, semi-crystalline polymers, contributing towards improved sustainability.

A Repeatable Workflow for Constitutive model of FDM Nylon and Validation via Polygonal Lattice Compression

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Abstract

Manufacturing parameters, specimen architecture and testing methodology strongly influence the measured mechanical response of polymers produced by material extrusion additive manufacturing. This study proposes a practical and repeatable experimental route to (i) identify a constitutive description for FDM printed Nylon and (ii) validate that description using lattice type unit specimens in compression. A rectangular tensile specimen is adopted to reduce premature end failure associated with infill line shear interactions, enabling reliable extraction of Young's modulus and a true stress and strain response up to necking. Post necking behaviour is reconstructed from intermittent measurements of the minimum cross sectional area. The collected stress and strain data of necking point are fitted by power law expression to establish a constitutive model, and the constitutive model is output as a uniform plastic curve and imported into Abaqus. Regular polygon lattice specimens are then tested in quasi-static compression and compared with finite element simulations. Infill line interactions, print parameters, print path sequence and ambient humidity are found to measurably affect stiffness and strength. With controlling the drying process, adjusting the Cura parameters, keeping the ambient humidity constant and the filling flow rate of 100%, the proposed workflow can obtain stable and repeatable samples and simulation results, which can better capture the plastic response characteristics in the experiment.

Feature Addition via Metal Additive Manufacturing: Thermo-Mechanical Modelling and Experimental Validation

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Abstract

Feature addition using Metal Additive Manufacturing (MAM) enables the direct deposition of functional geometries onto existing substrates, including baseplates, specifically designed profiles, and standard structural sections (e.g., H-sections, tubes, and angle bars). With the potential to reduce material consumption by over 90% compared to conventional subtractive manufacturing approaches, this strategy offers significant advantages for sustainable manufacturing and value-retention remanufacturing. Despite growing industrial interests, predictive modelling frameworks of feature addition process for better understanding of the thermo-mechanical behaviour remain insufficiently developed.

This study presents a coupled thermo-mechanical modelling framework to analyse process-induced deformation and residual stress during feature addition. A thin-wall structure deposited onto a flat substrate is adopted as a typical case. Transient thermal simulations are conducted to capture heat transfer via conduction, convection and radiation, incorporating process parameters and geometrical inputs. The resulting temperature fields are sequentially coupled to a structural analysis to predict stress evolution and distortion by using a birth-death element activation strategy. Experimental validation is performed with measured distortions showing good agreement with simulation results. Deviations are analysed and primarily attributed to mesh discretisation and uncertainties in emissivity modelling.

The proposed framework provides a basis for predictive modelling of feature addition processes. Future work will address multi-axis deposition, superalloy-specific (e.g., Hastelloy X), and integration with life cycle assessment to quantify sustainability impacts.

Using image recognition to analyze microstructure evolution via Heat treatment of 3D printing parameter Al/SiC metal matrix composite

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Abstract

Lightweighting is a critical objective in the aerospace, automotive, and healthcare industries, primarily achieved through high-specific-strength materials and optimized porous architectures. Aluminum alloys are highly promising for these applications due to their low density, high thermal conductivity, and excellent processability. To further enhance performance, this study incorporates Silicon Carbide (SiC) as a reinforcing phase within an Aluminum-Magnesium-Scandium (Al-Mg-Sc) matrix. While metal matrix composites (MMCs) offer significant potential, traditional manufacturing methods are often limited by high costs and geometric constraints. Laser Powder Bed Fusion (LPBF) provides a sophisticated solution, enabling the fabrication of complex geometries with a more uniform distribution of SiC particles compared to conventional casting. However, a significant challenge in LPBF-produced Al-SiC composites is the formation of brittle intermetallic compounds (e.g., Al4C3), which can severely compromise tensile strength and ductility. A central focus of this research is the optimization of post-processing heat treatments in conjunction with LPBF printing parameters. Given the rapid solidification inherent to the LPBF process, the Al-Mg-Sc matrix becomes highly supersaturated. This study emphasizes how subsequent thermal cycles trigger the precipitation of coherent Al3Sc nanoprecipitates, which are vital for grain refinement and precipitation strengthening. Furthermore, these heat treatment protocols are designed to stabilize the Al-SiC interface and minimize the growth of detrimental intermetallics. To overcome the limitations of traditional qualitative observation, this study integrates advanced image analysis and pattern recognition techniques to systematically identify, segment, and quantify complex microstructural features, including grain size and microstructure evolution. Alongside this microstructural characterization, the samples will be evaluated using a comprehensive suite of macroscopic tests, as well as laser-flash analysis for thermal conductivity. By establishing a definitive, data-driven correlation among printing parameters, heat treatment regimes, quantified microstructural features, and mechanical responses, this work aims to unlock the full potential of high-performance Al-SiC composites for advanced industrial applications.

Structure–Property Correlation in WAAM-Fabricated AZ31B Magnesium Alloy

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Abstract

AZ31B magnesium alloy is increasingly being explored as a promising material for biodegradable biomedical implants. Its biocompatibility, mechanical behaviour comparable to human bone, self-dissolving nature in physiological environment, and osteo-promotive characteristics make it a suitable candidate for temporary implant applications. In the present study, wire arc additive manufacturing (WAAM) has been utilised to deposit AZ31B alloy in the form of a thin-wall (single-line) structure. The deposited specimens have been evaluated through macrostructural examination, microstructural analysis, density measurement, hardness, tensile testing, and corrosion study. No visible defects or voids were observed during the macrostructural analysis, indicating sound deposition. However, the density of the WAAM-fabricated sample (1.728 ± 0.002 g/cc) was found to be slightly lower than that of the rolled base plate (1.77 g/cc). The microstructure mainly consisted of equiaxed α-Mg grains with an average grain size of 25 ± 9 µm, along with the presence of intergranular $Mg_{17}Al_{12}$ precipitates. A variation in grain size was observed along the build direction, where grains were relatively coarser in the middle layers and finer near the top and bottom regions. The hardness distribution was found to be nearly uniform across the deposition, with an average value of 58.43 ± 10 HV. The ultimate tensile strength and percentage elongation were measured as 216.99 ± 5 MPa and 19.64 ± 2%, respectively. Corrosion studies in 3.5% NaCl solution using potentiodynamic polarisation indicated comparable corrosion resistance, with a relatively lower corrosion rate (1.08 mm/year) than the base plate (2.41 mm/year).

Microstructure Analysis and Micro-Mechanical Properties of Cu-based Metallic Glass between Different Scanning Strategies by Laser Powder Bed Fusion

Lin Hsuan Min, Kuo Che Nan

Ph.D. student

Abstract

With the development of additive manufacturing (AM) technology, scientists noticed that both the high cooling rate and the little-scale molten pool properties in this technology might be the way to fabricate Bulk Metallic Glasses (BMGs). By well controlling the parameters according to the energy density equation, molten pool in Laser Powder Bed Fusion (LPBF) process can be stacked together, forming the final products. Although LPBF has such excellent characteristics for manufacturing BMGs theoretically, two major issues still exist. First, the densification of printing objects will be affected by the related parameters. Specifically, the laser power (P), scanning speed (v), hatch distance (h), and layer thickness (t), all these four parameters comprise the energy density, which will determine the behavior of the molten pool. Hence, finding the optimized parameters to get the most appropriate arrangements of the molten pool inside the specimen is the most important factor for densification. Second, the Heat Affected Zone (HAZ), caused by the heat transfer around the molten pool, would reheat the printed amorphous alloy and cross Tg, resulting in crystallization.To address these challenges, this study introduces a repetitive scanning strategy. In the initial scan, a lower energy input partially melts the metal powders, creating a porous structure that enhances heat dissipation and mitigates the impact of the HAZ. A subsequent scan with higher laser energy then fully melts the porous structure, ensuring densification while minimizing crystallization risks.

Microstructural analysis revealed that the two scanning strategies produced distinct phase separation morphologies. Furthermore, nano-indentation testing demonstrated that these variations in scanning strategy led to differences in micro-mechanical properties across different regions within each molten pool. In conclusion, this research focuses on comparing the effects of single-pass and repetitive scanning strategies on microstructural evolution and micro-mechanical performance, providing insights into optimizing LPBF parameters for BMG fabrication.

Granular Bioprinting for Functional Organoid-Laden Construct

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Abstract

Cells in bioprinted constructs require access to nutrients and oxygen in order to remain viable and functional. However, the absence of vascularization in most constructs means that their scalability is constrained by the diffusion limit. While it may be possible to introduce a large number of channels in the structure, this process is slow, and the channel size and density are also limited to hundreds of microns, due to the printing resolution of most bioprinters. To address this challenge, we developed a granular hydrogel bioink composed of gelatin methacryloyl (gelMA) microparticles that can be bioprinted into macroporous scaffolds, where the void spaces between particles serve as conduits through media can freely flow. We demonstrate bioprinting of highly metabolically active, insulin-secreting spheroids into these scaffolds. Not only did the cells remain viable, but their glucose-responsive insulin secretion function also remained intact. This approach represents a promising strategy for achieving high density culture of cell aggregates such as organoids, which can serve as functional biological units.

Generative Process Modeling of Aerosol Jet Printing via Parameter-Conditioned Diffusion

Haining Zhang*, Hyeongcheol Kim, Yong-Jin Yoon*

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Abstract

Aerosol Jet Printing (AJP) is a promising technology for fabricating fine-feature electronics, but the development of robust process models is often hindered by the high cost of data acquisition, severely limiting systematic design exploration. To bridge this gap, this work proposes a novel parameter-conditioned diffusion framework for the AJP process. Initially, a U-Net is employed to preprocess raw experimental images, robustly extracting clean spatial representations of the printed lines. Subsequently, physical process parameters are encoded to condition a diffusion model, guiding it to learn the complex stochastic mapping from 1D operational inputs to these 2D print morphologies. Functioning as a virtual process surrogate, the trained model directly maps process parameters to synthesized morphological predictions, thereby facilitating efficient, trial-free exploration of the vast design space. Furthermore, inference is expedited via Latent Consistency Model (LCM) distillation, which reduces the required sampling steps from 50 to 4. Experimental results demonstrate that the distilled model maintains state-of-the-art physical and geometric fidelity while achieving a ~12.5_ speedup in inference, showing strong potential for real-time, simulation-driven optimization. This approach offers a robust generative framework for stochastic process modeling and rapid parameter exploration in advanced manufacturing.

Identifying and prioritizing machining factors for sustainable ultra-precision grinding of silicon carbide

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Abstract

Silicon carbide (SiC) is a key third-generation semiconductor material in high-performance optics and power devices, but its ultra-precision grinding poses significant sustainability challenges, including high energy consumption, cooling fluid waste, and subsurface damage. To address these issues, this study proposes an integrated method combining patent text mining, social network analysis (SNA), principal component analysis (PCA), and TOPSIS to identify and prioritize key technological factors for sustainable ultra-precision grinding of SiC. From 264 valid patents retrieved via Google Patents, a keyword co-occurrence network was constructed to build a patent-based social network. PCA was applied for dimensionality reduction, extracting core common factors representing principal dimensions of sustainable grinding. TOPSIS was then used for multi-criteria evaluation, yielding a prioritized sequence of factors with strategic significance for green manufacturing. Comparative analysis with conventional PCA_SNA rankings shows that the proposed approach more precisely identifies sustainability_oriented technology areas, including SiC material properties, subsurface damage control, green cooling/lubrication, and energy consumption optimization, whereas conventional methods emphasize general process parameters. This data_driven framework provides clear decision support for achieving low_carbon, low_damage, high_efficiency sustainable manufacturing.

Additive Manufacturing for Next-Generation Energy Storage Systems

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Abstract

“The rapid proliferation of personalized wearable electronics and integrated smart systems has necessitated energy storage solutions with high design flexibility, structural complexity, and superior electrochemical performance. In this presentation, recent advancements in the additive manufacturing (AM) of functional materials and devices are reported, with a specific focus on 3D-printed secondary batteries and supercapacitors.

Firstly, the critical challenges of volumetric expansion and dendrite growth in lithium/zinc-based batteries are addressed. Through the engineering of rheological properties in composite inks using nano-fillers, high-precision printing of solid-state electrolytes is achieved, yielding an enhanced ionic conductivity. Furthermore, Triply Periodic Minimal Surface (TPMS) structures are introduced as 3D current collectors, fabricated via Selective Laser Melting (SLM). A multi-level roughness strategy, characterized by the preservation of internal porosity and the polishing of the top surface, is developed to homogenize the electric field distribution and guide uniform lithium deposition, effectively realizing dendrite-free anodes.

Secondly, the development of high-performance supercapacitors via coaxial direct writing (DIW) of functionalized continuous carbon fibers is discussed. To synchronize mechanical robustness with electrochemical capacity, a multi-stage helical (braided) architecture is designed. Experimental results demonstrate that a 4-tow braided structure significantly improves tensile strength and toughness while nearly doubling the specific capacity compared to basic units. These devices are shown to maintain over 92% capacitance retention after 4,000 cycles, even under significant physical damage.

Finally, the application of 3D-printed hydrogels in thermoelectric conversion and self-powered flexible sensors is presented. It is confirmed that instant voltage signals can be generated through finger bending, demonstrating the potential of these devices in human-machine interaction and wearable communication. This work underscores the critical role of additive manufacturing in revolutionizing the integration of harvesting and storage functions into future energy systems.”

Multiscale Particle-in-Cell (PIC) Simulations for Next-Generation Plasmonics & Optoelectronics

Lin Wu

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Abstract

“Computational electromagnetism has been transformed by the growing need to model dynamic and multiscale materials, particularly quantum plasmas, where carrier dynamics play a central role. Conventional approaches, such as the Finite-Difference Time-Domain (FDTD) and Finite Element Method (FEM), encounter fundamental limitations in these regimes, whereas the Particle-in-Cell (PIC) method offers a powerful alternative by self-consistently capturing electromagnetic fields and particle motion across scales. We employ multiscale PIC simulations to investigate graphene-based plasmonic systems, including graphene antennas and resonant nanostructures, and reveal emergent even-order nonlinearities that enable frequency-tunable infrared upconversion. In particular, we propose a mechanism for second-harmonic generation driven by electron funneling in terahertz (THz) optical resonators, where ultrafast electron–surface scattering reduces the required field intensity by three to four orders of magnitude. This provides concrete design guidelines for low-field, geometrically tunable THz upconversion and rectification, spanning frequencies from sub-10 THz to tens of THz. More broadly, metals and semi-metals at room temperature can be viewed as cold quantum plasmas, naturally suited to PIC-based modeling. Our overarching goal is to bridge conventional electromagnetic simulations with the rich multiscale dynamics of quantum systems, offering a unified computational framework for advancing next-generation plasmonics and optoelectronics, including quantum materials, high-energy-density plasmas, optoelectronics, polariton physics, petahertz electronics, and symmetry-fusion topological photonics.

[1] Particle simulation of plasmons. Nanophotonics, Vol. 9, No. 10, 3303-3313, 2020. [2] Electron dynamics in plasmons. Nanoscale, Vol. 13, 2801-2810, 2021. [3] Nonlinear optical resonances from ballistic electron funnelling. ACS Nano, Vol. 19, No. 14, 14150–14160, 2025. [4] Particle-in-cell simulations of quantum plasmas. Computer Physics Communications (under review), arXiv:2501.07465.”

Investigation of Particle Deposition and Erosion in Airfoil-Fin Heat Exchangers for Enhanced Thermal System Performance

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Abstract

Heat exchangers are essential components in modern additive manufacturing thermal systems due to their superior heat transfer efficiency, compact design, and lightweight structure. Among the various configurations, airfoil-based heat exchangers have gained significant attention in recent years owing to their streamlined profiles, which effectively reduce flow separation and pressure losses while maintaining robust convective heat transfer performance. This unique combination of aerodynamic efficiency and thermal effectiveness makes airfoil-based designs highly desirable for advanced thermal applications. However, a critical challenge that remains underexplored is the behavior of particle deposition and erosion in airfoil-fin heat exchangers, particularly under particle-laden flow conditions. These phenomena are influenced by the complex interplay between aerodynamic flow structures and particle–surface interactions, which can significantly affect the long-term performance and reliability of these systems.

Motivated by these challenges, the present study systematically investigates particle deposition and erosion mechanisms in an airfoil-fin heat exchanger. A previously developed numerical framework is employed to simulate these phenomena in a coupled manner, enabling a detailed analysis of the interaction between particles and the surface of the heat exchanger. The study adopts a NACA airfoil geometry for the fin design, which offers an ideal balance of aerodynamic efficiency and structural feasibility. Key parameters, including the particle Peclet number, Damköhler number, erosion number, and the thermal diffusivity ratio between particles and the fluid, are systematically varied to evaluate their influence on the thermo-hydraulic performance of the heat exchanger. The results reveal critical insights into the mechanisms governing particle–surface interactions, highlighting the roles of aerodynamic flow patterns and particle dynamics in determining the extent of fouling and erosion. The findings have significant implications for advancing the performance, durability, and operational efficiency of heat exchangers in additive manufacturing and other high-performance thermal applications.

Fabrication and Application of a Physiological-Temperature-Triggered Shape-Memory Biodegradable Scaffold for Minimally Invasive Implantation

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Abstract

Conventional implantable devices commonly require open surgery, which is associated with considerable tissue trauma and a high risk of perioperative injury. Existing minimally invasive metallic stents reduce procedural invasiveness, yet their rigid expansion may still injure surrounding tissues. Their nondegradable nature also raises concerns regarding long-term implant-related complications. In this study, we developed a biodegradable polymer scaffold with body temperature-triggered self-expansion for minimally invasive implantation and adaptive defect repair. Poly(lactic acid), poly(trimethylene carbonate), and poly(glycolic acid), all FDA-recognized biodegradable polymers, were used to construct the material system. Precise regulation of the component ratio enabled tuning of the phase-transition temperature to the physiological range. The resulting ternary polymer scaffold could be flexibly folded and temporarily fixed ex vivo. Following implantation, the scaffold rapidly recovered its predefined configuration under physiological temperature and conformed to the target defect site. In vitro and in vivo studies demonstrated that the scaffold exhibited favorable mechanical compliance and a controllable degradation profile. Implantation-associated injury was significantly reduced, and no evident inflammatory toxicity was observed during degradation. These results establish a practical materials strategy for intelligent biodegradable implantable devices and support their potential applications in cardiovascular intervention, precision orthopedics, and other minimally invasive therapeutic settings.

Synergistic Control of Formability and Performance for Lattice Structures Fabricated via Full-Contour Scanning Strategy in Laser Powder Bed Fusion

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Abstract

The complex geometric configuration of lattice structures and the inherent physical characteristics of aluminum alloy powders pose significant challenges for the laser powder bed fusion process in fabricating high-precision lattice structures, thereby limiting the stable formation of extreme-dimension lattice structures and their applications in the aerospace sector. In this study, a Full-Contour Scanning Strategy (FCSS) was developed to fabricate AlMgScZr lattice structures with varying structural parameters (Volume Fraction, VF; Aspect Ratio, AR). The proposed strategy achieves superior forming accuracy (dimensional deviation of 1.51%) and near-full densification (relative density of 99.9%), successfully producing lattice structures with strut diameters of 100 μm. A systematic comparison was conducted between FCSS and Traditional Scanning Strategy (TSS) on forming accuracy, forming quality, surface morphology, microstructure, mechanical properties, and wettability. The results indicate that when the structural parameters satisfy VF < 40% or AR > 2.5, FCSS enhances forming accuracy by over 20% relative to TSS. In particular, at VF = 16.15% or AR = 5, the porosity is reduced to 0.01%, corresponding to a 75% decrease compared with TSS. Within the structural domain of VF < 25% or AR > 4, lattice structures fabricated via FCSS exhibit excellent energy absorption performance, with specific energy absorption improved by about 30% over TSS samples. Accordingly, an optimal structural parameter window suitable for FCSS (VF < 25% or AR > 4) is established, within which a synergistic enhancement of dimensional accuracy and energy absorption capability can be realized. FCSS also markedly improves the surface quality of the lattice structures. At VF = 16.15% or AR = 5, the surface roughness is reduced by 31% (to 21.74 μm), demonstrating superior hydrophobic characteristics. FCSS's contour-adaptive scan optimizes contour quality and elongates the path to boost heat input, suppressing defects without higher energy density, thus minimizing powder adhesion and dross. This strategy and its parameter window provide theoretical and technical support for high-quality manufacturing of extreme-dimension high-strength aluminum alloy lattices.

Tailoring laser absorption and multiscale strengthening in LPBF GH4169 through nano-Y2O3 modification

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Abstract

Achieving a concurrent improvement in strength and ductility remains a persistent issue for Ni-based superalloys processed by Laser Powder Bed Fusion (LPBF), primarily due to steep thermal gradients and rapid solidification kinetics. In this work, nano-scale Y2O3 particles (1 wt.%) were introduced into GH4169 to tailor the laser–powder interaction and subsequent solidification pathway. Rather than solely acting as a reinforcing phase, the Y2O3 addition alters the optical response of the powder bed, leading to a pronounced increase in laser absorptivity (exceeding 0.8). This modification intensifies energy deposition within the melt track, enlarges the effective interaction volume, and stabilizes melt pool behavior. As a consequence, the melt pool geometry evolves toward a lower aspect ratio, accompanied by a transition to a more refined and homogeneous solidification structure. At the microstructural level, the uniformly dispersed oxide nanoparticles act as effective obstacles to dislocation motion while simultaneously promoting dislocation storage, giving rise to a synergistic strengthening effect. The modified alloy demonstrates a substantial enhancement in yield and ultimate tensile strengths, while preserving tensile ductility above 20%, indicating that the conventional strength–ductility trade-off can be partially mitigated. Mechanistically, the strengthening increment is primarily governed by Orowan-type bypassing and dislocation-mediated interactions, which together dominate the overall strengthening contribution. More importantly, the results highlight a coupled pathway linking laser energy absorption, melt pool dynamics, and multiscale defect evolution. This study provides an alternative perspective for regulating LPBF process–structure–property relationships through compositional design, offering guidance for the development of high-performance additively manufactured Ni-based superalloys.

Graph-based structuring of digitalized P&ID

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Abstract

P&ID(Piping & Instrumentation Diagram)s are essential engineering drawings that contain equipment, piping, instrumentation, and control information for plant processes, but their complex structure makes it difficult for humans to intuitively understand them and quickly find the information they need. To address this issue, many studies have focused on the digitalization of P&IDs, and recent efforts have also explored structuring them using the standard format DEXPI. However, DEXPI still has limitations for direct object and relationship retrieval because its hierarchical structure is highly complex.

To overcome this limitation, this study proposes a method for transforming DEXPI-based P&ID information into a complete graph structure. For this purpose, the DEXPI structure was analyzed to define graph nodes and edges, and a transformation framework was designed to map the hierarchical structure into a graph. When applied to open-source P&ID data, the proposed method successfully represented not only physical objects such as equipment, instruments, and piping, but also relationships based on control logic within the same graph. This study provides a foundation for future graph-RAG-based object retrieval and question-answering systems, and future work will extend and validate the proposed approach using real industrial P&ID data.

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Laser additive manufacturing of a biomimetic active flexible metallic metamaterial with reconfigurable and programmable deformation capability

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Abstract

Metamaterials are excellent candidates for application in intelligent morphing aircraft owing to their high designability, excellent mechanical and functional properties. However, existing designs often rely on passive actuation and polymer-based materials, limiting the lightweight and strength of the morphing wings. Therefore, we proposed a novel active flexible metallic metamaterial inspired by the Portulaca oleracea seedcoat with tunable in-plane mechanical properties and large deformation recovery capability. The embedded characteristics and wavy interfaces of Portulaca oleracea epidermal cells form the network honeycomb configuration in its seedcoat. The network honeycomb sample with a minimum feature size of 0.3mm was precisely fabricated by laser powder bed fusion (LPBF) technology, achieving effective integration of biomimetic structure design and NiTi shape memory alloy (SMA) in the metamaterial. The formability, mechanical properties, deformation mechanisms, and the shape memory effect (SME) of network honeycombs were systematically investigated. By regulating the number of cell walls per junction, network honeycombs achieved tunable mechanical properties with the Poisson's ratio ranging from −0.21 to +0.47. The hexagonal network honeycombs (HNHs) exhibited excellent deformability (fracture strain of 38%), load-bearing capacity (specific strength of 35.0 N·m·Kg−1), and energy absorption property (specific energy absorption of 699.7 mJ·g−1). The HNHs demonstrated an excellent shape recovery ratio of 96.10% under thermal activation with 10% pre-programmed strain. Based on HNHs, a scaled model of the active deformation section of the wing rib was designed and fabricated. The reconfigurable deformation capability of the biomimetic metamaterial was demonstrated in morphing wings within a wide application temperature range, enabling smooth and continuous deformation within a range of −25◦ to 25◦. This study highlights the integration of shape memory alloy to endow metamaterials with active and reconfigurable properties, advancing the engineering applications of smart morphing aircrafts.

Unconventional Additive (Bio)Manufacturing Methods for Regenerative Medicine

Y. Shrike Zhang

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Abstract

Over the last decades, the field of three-dimensional (3D) printing, or additive manufacturing, has witnessed tremendous progress. 3D printing enables precise control over the composition, spatial distribution, and architecture of the printed constructs facilitating the recapitulation of the delicate shapes and structures of target patterns. More recently it has been further combined with cells and cell-laden biomaterials to offer the versatility to fabricate biomimetic volumetric tissues that are both structurally and functionally relevant. Nevertheless, conventional 3D printing and bioprinting techniques are limited in certain aspects. This talk will thus discuss our recent efforts in developing a series of advanced additive (bio)manufacturing strategies that take unconventional approaches to tackle some of these problems and improve their capacities towards diverse applications in biomedicine with a focus on regenerative medicine. These platform technologies will likely provide new opportunities in areas from constructing functional tissues and microtissue models for promoting personalizable medicine, all the way to minimally invasive surgical implications.

Metal Component Flexible Forming Technology and Equipment

Xunzhong Guo, Wenting Li

Nanjing University of Aeronautics and Astronautics

Abstract

The development of flexible, precise, and adaptive manufacturing technologies is pivotal for advancing high-performance aerospace, automotive, and defense systems. This keynote speech presents a comprehensive overview of the latest breakthroughs and a holistic framework in metal component flexible forming technology and equipment, as developed by the research team at Nanjing University of Aeronautics and Astronautics.

The presentation is structured around four core technological pillars that form a complete digital and intelligent manufacturing chain. First, we delve into 3D free bending forming, a revolutionary die-less technology enabling the precise fabrication of complex spatial tubular and profile components. The discussion covers the underlying mechanics, the development of China's first series of multi-axis computer-numerical-control equipment, and successful applications in critical aerospace fluid systems and lightweight automotive structures. Second, we explore digital incremental forming, a highly flexible die-less process for producing complex-curvature sheet metal parts. This segment highlights its advantages for low-volume, customized production, supported by robotic and gantry-type systems developed in-house.

The third pillar introduces solid-state additive manufacturing via friction stir deposition, a transformative approach for large-scale component integration, repair, and performance enhancement. This process offers significant benefits in microstructure control, material efficiency, and suitability for high-strength alloys. Finally, we unveil innovations in the design and fabrication of next-generation aerospace metamaterial structures, such as lightweight curved honeycomb cores with tailorable mechanical properties, manufactured using a novel rapid-forming process for ultra-thin foils.

This keynote speech will conclude by outlining the future roadmap, which converges on intelligent manufacturing systems for extreme environments and the expansion of a cross-disciplinary innovation ecosystem. The integrated vision presented herein demonstrates a fundamental shift towards more agile, sustainable, and high-performance manufacturing paradigms for the future.

Boosting the mechanical properties at 815 _ of laser directed energy deposited Inconel 625 alloy by introducing the Laves phase

Zuo Li, Xin Lin, Xin Hou, Zhiwei Hao, Wei Fan, Chongliang Zhong, Hua Tan, Yiyi Zhou, Yi Min Xie

No

Abstract

This study aims to enhance the high-temperature mechanical properties of laser directed energy deposited Inconel 625 alloy. Varied sizes, morphologies, and volume fractions of the Laves phase were effectively regulated, high–temperature tensile properties and stress rupture life were systematically investigated, and the underlying mechanisms were revealed thoroughly. Results demonstrate that when the Laves phase morphology transitions from long-striped to granular, with optimized dimensions (length: 1–2 μm, width: 0.2–0.6 μm) and a precise volume fraction of 1.2%, the alloy exhibits notable enhancement in mechanical performance: yield strength increases from 192.67 MPa to 217.33 MPa, tensile strength rises from 324.67 MPa to 348.33 MPa, and stress rupture life extends from 24 h to 31 h. On the one hand, the boosting in the high-temperature tensile strength was attributed to the precipitation of γ'' and δ phases near the Laves phase, or the pinning effect at the Laves/γ interface. On the other hand, the extended stress rupture life results from δ phases hindering dislocation motion while promoting dynamic recovery. This study confirmed that retaining a controlled amount of Laves phase significantly enhances the mechanical properties of Inconel 625 alloy, providing valuable insights for laser additive manufacturing and repaired nickel–based superalloy above 800 °C.

Process development in Microwave Plasma Additive Manufacturing of Aluminum Alloy

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Abstract

“This study presents a novel additive manufacturing process for AA7075 aluminum alloy using a 2.45 GHz coaxial microwave (MW) plasma jet. The wire is fed directly into the plasma core, where the interaction between the heat source and the material is systematically investigated. A series of experiments is conducted to determine the optimal process window, identifying wire feed speeds of 210-270 mm/min, microwave powers of 700-1000 W, and travel speeds of 100-150 mm/min as the essential parameters for stable energy coupling and precise droplet control. To facilitate complex fabrication, modifications to computer-aided manufacturing (CAM) data are automatically generated to create 3-D models. The thermal gradient and plasma pressure are analyzed using the finite element method (FEM), while high-speed camera imaging is employed to observe droplet formation and deposition. Experimental results confirm that these optimized settings effectively mitigate common defects, such as cracks. The printed components exhibit superior surface morphology and a refined, dense microstructure, confirming the efficacy of the microwave plasma additive manufacturing approach. This research offers a robust framework for the precision manufacturing of high-performance aluminum alloys, paving the way for their use in advanced industrial sectors such as aerospace.

Keywords: Additive manufacturing, AA7075 aluminum alloy, Microwave plasma, Process parameters, Microstructure.”

Laser-Induced Hydrothermal Growth of ZnO/MXene Heterostructures for On-Chip Multifunctional Sensors

Zang Tong

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Abstract

Achieving localized, controllable fabrication of functional nanomaterials and their integration into multifunctional on-chip devices remains a key challenge for next-generation micro-sensing systems. In this work, we propose a laser-induced hydrothermal growth (LIHG) strategy for the in situ construction of ZnO/$Ti_3C_2T_x$ MXene heterostructures, enabling integrated ultraviolet (UV) photodetection and NO_2 gas sensing on a single chip. The LIHG process generates a localized thermal field at the solid–liquid interface, allowing selective growth of well-defined ZnO nanowire arrays in predefined regions. Subsequent introduction of $Ti_3C_2T_x$ and laser annealing facilitates the formation of a robust heterointerface with enhanced electronic coupling.

Characterization results reveal that the incorporation of $Ti_3C_2T_x$ effectively modulates the interfacial electronic structure, suppresses carrier recombination, and promotes charge separation and transport. In terms of ultraviolet light detection, the optimized device achieves excellent photocurrent density under UV illumination and exhibits fast response and recovery characteristics. In gas sensing, the response of the device to NO_2 was significantly enhanced under UV-assisted conditions compared to the dark state. The improved sensing behavior is attributed to the synergistic effects of interfacial charge transfer and optimized adsorption/desorption dynamics.

This study highlights the effectiveness of LIHG-enabled heterointerface engineering for constructing multifunctional oxide/MXene microdevices and provides a scalable pathway toward integrated, high-performance sensing platforms for environmental monitoring and wearable electronics.

Transient Studies on the Irradiation of Metals and Semiconductors by Femtosecond Lasers

Yuewei Cui

Shandong University of Technology

Abstract

This study is based on the molecular dynamics method and constructs a dual-temperature model - molecular dynamics (TTM-MD) coupling simulation framework under femtosecond laser irradiation conditions. By introducing the electron temperature field and the electron-phonon coupling mechanism, it describes the non-equilibrium energy transfer process between the electronic system and the lattice system. Typical metal and semiconductor materials are selected as research objects. The laser energy deposition, temperature evolution, and structural change characteristics are systematically analyzed, and the competitive mechanism of non-thermal melting and thermal effects is explored, providing a theoretical basis for the mechanism research and process optimization of the femtosecond laser micro-nano processing process.

WAAM Propeller Certification process

Youssef Elkhouly, Siddharth Ganesh, Doron Teh, Wilson Lim

Singapore University of Technology and Design

Abstract

Wire Arc Additive Manufacturing (WAAM) has gained attention recently. This is because of its capability for the production and repair of medium- to large-scale metal parts, high deposition rate, and on-demand manufacturing. These advantages are especially relevant to the marine and offshore sectors, where spare parts such as propellers require maintenance, replacement, and significant inventory storage. This paper presents our certification journey for a WAAM-manufactured propeller. The propeller was fabricated using our variable-width, variable-height toolpath strategy, in which bead dimensions are adjusted along the toolpath to accommodate both thick and thin regions while compensating for cumulative height error. To demonstrate the process, a sacrificial blade was first printed for the extraction of test coupons, followed by the fabrication of the full four-blade propeller. This paper discusses the manufacturing and testing workflow used to support the propeller certification. It highlights the capabilities demonstrated in printing the propeller geometry and identifies the key gaps and challenges encountered during the certification process. Finally, possible directions for future work are outlined to support broader qualification and adoption of WAAM for marine components.

Characterisation of WAAM interpass temperature over varying bead widths for mechanical property

Doron Teh, Youssef Elkhouly, Siddharth Ganesh

Singapore University of Technology and Design

Abstract

Maintaining good mechanical properties for wire arc additive manufacturing (WAAM) products is crucial to demonstrate usability in industry. These mechanical properties are affected by many different factors during the printing process (toolpath strategy, bead dimensions, welding settings, temperature, etc.).

Our WAAM toolpath strategy utilises varying bead width to geometrically optimise printing non-uniform or difficult shapes. The variations in the bead width was suspected to be affecting some of the mechanical properties of the print. Additionally, we observed that the mechanical properties of WAAM printed parts varied when using fixed welding parameters but at different interpass temperatures.

Therefore, we propose that interpass temperature and bead width ranges both affect the mechanical properties for WAAM prints. To investigate and verify this, experiments were conducted on a series of test prints with fixed welding settings but using varying bead width toolpaths and different interpass temperatures for each print. Mechanical property tests of these test prints were later evaluated to determine working combinations of bead widths and interpass temperature ranges.

Data-Driven EDMDc Modelling for Pre-Pinch Droplet Dynamics in Inkjet 3D printing

Mandana Kariminejad, Dermot Brabazon, Marion McAfee

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Abstract

Drop-on-Demand inkjet 3D printing is increasingly important in the fabrication of flexible sensors, biological and pharmaceutical materials, and printed electronics, which require extremely precise layer-by-layer material deposition. Stable droplet generation is essential for print quality in Drop-on-Demand printing and relies on transient fluid dynamics driven by the piezoelectric actuation waveform. Given that inks are often of high value and have bespoke properties for specific applications, tuning the actuation waveform to give clean droplet ejection can be challenging, even with feedback from drop watcher systems. Computational Fluid Dynamics (CFD) allows for detailed virtual exploration of the effect of different actuation waveforms on inks with defined properties, but they are highly computationally expensive and cannot be used as real-time digital twins for process feedback and control. This work introduces a physics-informed data-driven modelling framework for real-time prediction of the fluid ejection dynamics using Extended Dynamic Mode Decomposition with control (EDMDc). This approach is founded on the Koopman operator principle, which offers a linear description of nonlinear dynamics when expressed through suitable observables. The EDMDc approach is applied to the CFD data to extract the essential dynamics of the system in a higher-dimensional state space where the dynamics are approximately linear.

In this study, the lifted state includes velocity history, pressure-memory states, and input delay terms, allowing the reduced-order model to capture inertia, delayed actuation effects, and transient nozzle-pressure dynamics. This framework is used to characterise different droplet-formation regimes, including satellite-producing behaviour and clean-drop behaviour. The approach has several advantages over Deep Learning approaches to generate surrogate models and digital twins, including low computational requirements and the ability to implement linear optimal control methods with guaranteed stability, robustness and performance.

Results show that regime-specific reduced-order models are suitable for integration with estimation, optimisation, and digital-twin workflows for waveform optimisation in DoD 3D printing.

Convergence of Computational Modelling, Deep Learning and Process Analytical Technologies for Pharmaceutical 3D Printing

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Abstract

3D printing offers many exciting opportunities for drug delivery applications, including the ability to use spatial geometry to tailor drug release profiles of oral dosage forms; combine multiple co-prescribed drugs into a single daily ‘polypill’; and to print drug delivery implants with personalised geometry, mechanical properties and drug release profile according to patient need. However, wider adoption of 3D printing in the pharmaceutical industry is hampered by problems in quality assurance and regulatory acceptance, requiring the advancement of technologies that ensure the quality of the (i) the design file, (ii) the printer set-up and (iiI) the printed product. In this work we explore computational modelling of Fused Deposition Modelling (FDM) of drug-loaded polymeric matrices for prediction of thermal cycling of the material and the resulting residual stresses and deformation in pharmaceutical 3D printing applications. Long Short Term Memory (LSTM) neural networks are used to develop real-time surrogate models of the spatio-temporal thermal profile in the printed part, producing thermal images and residual stress maps which are then used to train a second Deep Neural Network to predict warpage and deformation of the part. We propose the application of transfer learning to adapt the model-trained DNN to real-time thermal camera images and the measurement of residual stress using Raman spectroscopy.

The framework shows potential for not only initial screening of the design file to ensure feasibility for high fidelity 3D printing, but also recommendation of process conditions to minimise printing errors as well as real-time quality assurance of the pharmaceutical product. Future developments will relate the thermal profiles, residual stress maps and geometry to predict the drug release profile.

Bioprinted interfacial complex constructs for advanced healthcare applications

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Abstract

This paper reports on the biofabrication of functional, mechanoactive composite bioinks with encapsulated living cells (bone, adipose and Wharton jelly derived mesenchymal stem cells) via extrusion bioprinting for interfacial tissue engineering including vascularized bone and osteochondral grafts. We first designed and prepared bioinks containing an elastic, extrudable polymeric network matrix comprising biomimetic biomaterials including gelatin, elastin, gellan gum, methylcellulose combined with inorganic osteoinductive materials such as nanohydroxyapatite, functionalized bioactive glass, and laponite. The prepared hydrogel-based inks were examined for their printability, rheological properties, thermal behavior, crystallinity, water uptake and degradation rate. The constructs were assessed biologically in vitro for their osteogenic, osteoclastogenic, angiogenic and chondrogenic capacity, as well as for their antibacterial activity. The bioprinted constructs indicate printing accuracy values of up to 75%, with the composite bioinks being higher. The bioinks demonstrate excellent capability regarding extrusion printability at extrusion pressures of 30-100 kPa, favoring high cell survival rates. Rheological analysis of the bioinks reveals >90% viscosity recovery. The gene expression of relevant osteogenic, osteoclastogenic, angiogenic and chondrogenic markers, as well as the biochemical markers and the extracellular matrix collagen and glycosaminoglycans were significantly elevated in the composite bioinks. Mechanical stimulation of the cell-encapsulated constructs by means of a bioreactor demonstrated significantly increased cell activity, particularly towards osteogenesis, angiogenesis and antiosteoclastogenesis. The bioprinted constructs were implanted in a subcutaneous mouse model for two weeks, indicating the absence of adverse immunological reactions.

Wire-arc directed energy deposition for optimised and hybrid steel structures in construction

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Abstract

The construction sector has embraced wire-arc directed energy deposition (DED-Arc) since the opening of the world's first metal 3D printed footbridge – MX3D bridge in 2021. The relatively high deposition rate, lower cost, comparable mechanical properties to conventional structural steel, make DED-Arc the most suitable metal 3D printing method. On the other hand, the knowledge gap regarding its structural performance and the cost and productivity limitations remain the key barrier to wider implementation. In this presentation, a series of studies into the structural performance of DED-Arc steel elements subjected to axial compression, tension and combined loading, will be initially introduced. The findings have been encouraging – compared with conventional steel structures, DED-Arc steel components showed largely comparable performance; some weakening effects associated with the surface undulations, geometric imperfections and thermal residual stresses have also been highlighted. In terms of practical implementation in construction, the two key enablers are structural optimisation and hybrid construction. The example of a real-scale DED-Arc steel garden bridge will be first described, for which the main structure was fully optimised to harness the geometric freedom offered by 3D printing. The feasibility of combining DED-Arc with structural optimisation at the constructional scale was successfully proven, and the structural benefits were quantitatively revealed. Then the concept of hybrid construction, where DED-Arc is strategically used to complement conventional constructional work, is introduced. This is considered the most viable pathway towards wider adoption of DED-Arc in construction. A series of proof-of-concept studies will be introduced to demonstrate the benefits brought by introducing DED-Arc, as well as the practical viability in terms of cost, productivity and carbon footprint. We believe that metal 3D printing will undoubtedly be an integral part of future construction and a powerful tool to enhance construction automation, customisability and sustainability.

A Design-to-Process Framework for in-situ Polymerized Composite Couplers in Hydrogen Pipelines

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Abstract

The rapid expansion of hydrogen transmission infrastructure necessitates joining technologies that are leak-tight, pressure-resistant, manufacturable, and capable of supporting long-term service and repair. Conventional metallic couplers are increasingly limited by hydrogen embrittlement and fatigue-induced leakage, while existing electrofusion joints may not provide sufficient structural integrity for hydrogen applications. This study presents the engineering development of a high-performance fibre-reinforced thermoplastic (FRTP) composite coupler based on Elium®, a liquid thermoplastic resin that enables ambient-temperature in-situ polymerisation.

The work adopts an integrated design-to-process framework encompassing structural design, numerical simulation, surface engineering, and advanced manufacturing. Finite element analysis is employed to optimise the coupler architecture under representative loading conditions, with particular attention to stress redistribution, interfacial integrity, and deformation behaviour. In parallel, process modelling is used to predict resin flow, impregnation behaviour, and pressure evolution during in-situ polymerisation, thereby supporting process optimisation and void minimisation.

To enhance interfacial performance in the multi-material joining system, surface treatment strategies are implemented to tailor adhesion between the coupler and the mating components. The effects of surface condition on bonding quality are evaluated through coupon-level mechanical testing, and the results are used to inform prototype fabrication and joint design refinement. Based on the validated design and process parameters, a tubular composite coupler prototype is manufactured as a proof-of-concept for hydrogen pipeline connectivity.

This study demonstrates a systematic methodology for the development of composite couplers for hydrogen transmission, integrating mechanical design, process simulation, surface modification, and prototype validation. The proposed approach provides a pathway toward lightweight, corrosion-resistant, repairable, and scalable joining solutions for next-generation hydrogen infrastructure.

Off-Centered Rotational Stacking for Asymmetric 3D Rotational Stacking Lattices Fabricated by DLP 3D Printing

Seo Na Yoon, Young Tae Cho

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Abstract

Lightweight lattice materials are widely studied for their ability to achieve high mechanical performance at low density. In this study, we investigate 3D Rotational Stacking Lattices (3D RSL), which are generated by rotational stacking of monolithic unit structures. This stacking strategy introduces controlled aperiodicity into an otherwise periodic lattice while maintaining a deterministic and predictable architecture. Each rotational increment modifies the phase relationship between adjacent layers, producing variations in strut connectivity and length throughout the structure. These geometric variations reduce stress concentration and promote more uniform load transfer, resulting in improved strength and stiffness compared with conventional periodic lattices.

Previous studies on 3D RSL have primarily considered rotational stacking about the geometric center of the structure. However, such configurations retain a certain degree of structural symmetry, which limits the extent of aperiodicity. In this work, we explore an alternative design strategy in which the rotational axis is intentionally displaced from the center to introduce asymmetric structural features.

To evaluate this concept, 3D RSL structures were fabricated using polyurethane acrylate photocurable resin via DLP 3D printing. When the rotational axis was positioned near the lower-left corner of the structure, the compressive strength increased from approximately 900 kPa to 1100 kPa. Furthermore, the rotational axis location was systematically varied both inside and outside the lattice domain to examine its influence on compressive behavior. The proposed off-centered rotational stacking strategy expands the design space of 3D RSL and provides a new approach for designing lightweight polymer mechanical metamaterials.

From Material Design to Intelligent Construction: Advancing Spray-Based 3D Concrete Printing

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Abstract

Spray-based 3D concrete printing (S-3DCP) is emerging as a promising approach for enabling flexible onsite additive manufacturing in the built environment, particularly for complex geometries and non-horizontal surfaces. This study presents an integrated research framework that combines material design, process modelling, and functional integration to advance S-3DCP towards intelligent construction.

A series of experimental and analytical studies are conducted to investigate the relationships between rheological properties, spray parameters, and resulting structural morphology, as well as their implications for sustainability and functional performance.

On this basis, the integration of self-sensing capabilities within S-3DCP is explored for smart structural health monitoring. In parallel, the deposition process is further modelled using data-driven methods to improve prediction accuracy for automated construction, addressing the inherent variability of spray-based printing processes.

The overall objective is to move towards more reliable and performance-oriented digital construction, where material design, process control, and intelligent monitoring can be effectively integrated. This study highlights the potential of combining material science and intelligent systems to advance additive manufacturing in the built environment.

Multiscale microstructure engineering enables exceptional strength-ductility synergy in laser powder bed fusion processed AlSi10Mg

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Abstract

Conventional heat treatments typically compromise the strength-ductility synergy in laser powder bed fusion-processed AlSi10Mg alloys by coarsening the as-built microstructure. Here, we demonstrate that exceptional mechanical properties can be attained via multiscale microstructure engineering, facilitated by a rapid solution treatment followed by aging. The underlying mechanism involves preserving the fine as-built microstructure while converting the eutectic Si network into a discrete dispersion of sub-micrometer particles. Concurrently, this process induces the formation of sparse, coherent Guinier-Preston zones and inhibits gas-pore expansion. The optimized microstructure delivers a yield strength of 243 MPa, an ultimate tensile strength of 326 MPa, and an elongation of 16.2%. The exceptional mechanical synergy arises from the stabilized multiscale microstructural features. Overall, the proposed strategy provides a microstructure-informed framework for advancing the performance of additively manufactured aluminum alloys.

A Neural Network Framework for Geometric Characterization and Inverse Process Mapping in WAAM

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Singapore University of Technology and Design

Abstract

“Accurate control of bead geometry is critical in Wire Arc Additive Manufacturing (WAAM), where process parameters such as torch travel speed and wire feed rate exhibit strongly coupled, nonlinear relationships. This is useful especially when the additive process is a closed loop system, such that the parameters can be adjusted based on the required geometry. This study characterizes these interactions for a low-carbon steel (ER70S-6) using a robotic workstation comprising an ABB IRB 1600 industrial robot and a Fronius TPS/i 300 power source. A comprehensive experimental matrix was executed, depositing 100mm beads measured via high-precision blue laser scanning and manual calipers.

Previous approaches based on polynomial surface fitting (e.g. Poly33) often struggle to robustly capture the interdependence of welding variables across wide process windows. To overcome these limitations, a data-driven framework was developed using a shallow feedforward neural network (MATLAB fitnet). By optimizing the hidden layer architecture to capture the non-linear coupling, the model was trained iteratively to minimize worst-case prediction errors, successfully mapping the forward relationship between input parameters and bead geometry.

To enhance process toolpath planning, an inverse model was constructed to determine the required parameters for a target bead geometry. To avoid the instabilities of direct multi-valued mapping, the forward neural network was densely sampled to generate a high-resolution dataset. Continuous inverse surfaces were then generated via scattered interpolation, mapping desired width and height back to feasible torch speeds and wire feed rates.

Compared to conventional regression, this neural network approach demonstrates superior flexibility in capturing complex weld pool dynamics without predefined functional forms. The resulting framework facilitates the generation of precise lookup tables and the visualization of feasible process windows, providing a robust foundation for adaptive control systems and automated toolpath optimization in robotic WAAM.”

Bioinspired hetero-bilayer structures with dual-confinement effect for phase-change cooling

Yantong Zhu

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Abstract

Spray cooling offers exceptional heat-dissipation efficiency, its performance under time-varying thermal loads and complex gravitational conditions is limited by an inherent conflict: thin liquid film control and sufficient liquid supply. Here, a counterintuitive liquid film wetting behavior, i.e., superhydrophobic-to-superhydrophilic state spontaneous transition of micro droplets on Kallima inachus wing scales has been discovered. Motivated by this bioinspiration, we engineered a hetero-bilayer structure through the droplet adaptation strategy and achieve a gravity-insensitive and ultra-thin liquid film, enabling an ultra-high critical heat flux of 1057 W·cm-2 with a heat transfer coefficient of 49.5 $kW \cdot m^{-2} \cdot K^{-1}$ in spray cooling.

From Ti addition to Al3Ti nucleation: A dissolution-governed crack suppression in laser powder bed fused 7075 aluminum alloy

Kai Kang; Haiyang Fan; Qiuju Zheng; Yijun Wang; Bochao Li; Xijie Zhao; Liang Huang; Peng Li; Shoufeng Yang

Yantai Research Institute, Harbin Engineering University;Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences

Abstract

Solidification cracking severely impedes the laser powder bed fusion (LPBF) of high-strength 7075 aluminum alloy. Titanium addition suppresses cracking through grain refinement, but the nominal Ti content does not equal the amount that actively participates in nucleation. This study systematically investigates the effects of Ti additions (1.0-2.0 wt.%) and laser parameter on crack inhibition. It is revealed that 1.0 wt.% Ti represents the critical threshold for crack suppression, but its effectiveness is highly process-dependent, requiring low-power-low-speed conditions (200 W, 200 mm/s) to achieve a crack-free state. In contrast, Ti contents ≥1.5 wt.% enable robust, process-insensitive crack inhibition across a wide power range. Microstructural analysis demonstrates that the blended Ti nanoparticles dissolve under low-power-low-speed conditions optimized thermal conditions to form finely dispersed Al3Ti precipitates, which act as potent heterogeneous nucleation sites. This promotes a columnar-to-equiaxed transition, interrupts continuous liquid films, and significantly enhances hot-tearing resistance. This work validates the efficacy of low-Ti-alloying approach for crack suppression and elucidates its dependence on processing parameters, laying a foundation for the minimal yet effective compositional design of crack-resistant aluminum alloys for LPBF.

Achieving the strength-ductility trade-off of Ti-10Mo alloys by laser powder bed fusion via phase modulation

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Abstract

Titanium and its alloys produced by laser powder bed fusion (LPBF) are widely used in industries, such as aerospace components and biomedical implants. In comparison to α + β type Ti alloys, metastable β type Ti-10Mo alloys have many advantages, such as good biocompatibility, and lower Young's modulus, so that they are considered to be ideal alternative materials for biomedical implants. However, Ti-Mo alloys produced by LPBF from mixed powder usually exhibit insufficient Mo particle melting and inhomogeneous elemental distribution, leading to a deterioration in mechanical properties. To address this issue, we propose an strategy to regulate phase composition through process optimization, which enhances the strength-plasticity synergy. In this talk, we would like to present our latest work focusing on the effects of phase constituents on the evolution of microstructure, elemental distribution, and mechanical behavior of Ti-Mo alloys. In this study, laser powder bed fusion (LPBF) parameters were firstly optimised to fabricate highly dense metastable β Ti–10 Mo alloy with largely homogeneous structure from mixed powders. To thoroughly understand the deformation behavior and phase transformation mechanism of Ti-Mo alloys, the microstructural development will be analyzed, including the microstructural morphology, phase distribution, grain size and grain growing orientation. Moreover, the mechanical performance of yield strength, tensile strength, uniform elongation, microhardness and Young's modulus will be revealed to connect the micro-world to the macro-world. Eventually, some biomimetic structures will be mentioned in subsequent work. The results of this work are useful for the development of Ti-Mo alloys with lower Young's modulus and higher strength-ductility synergy for applications in the field of novel biomedical materials.

Physics-informed data-driven methods for inverse problems in advanced manufacturing

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Abstract

In advanced manufacturing, data-driven/machine learning (ML) techniques play a crucial role in solving inverse problems by identifying patterns in data and revealing hidden insights. Some examples include identifying material properties based on measured responses during testing, reconstructing the shape of a manufactured part from surface measurements, and estimating the optimal process parameters (such as laser power and scanning speed) in metal additive manufacturing by analyzing the final product's characteristics. However, the "black-box" nature of ML can make it difficult to understand how these models work and their results. Moreover, the effectiveness of ML predictions depends significantly on the quality and quantity of training data. To address these issues, a new approach called physics-informed machine learning (PIML) has emerged. PIML combines physical principles and domain knowledge with ML models, enhancing their interpretability and reliability. There are three main types of PIML techniques: hybrid models, physical loss-based models, and physics-embedded architectures, each with various integration methods. In this presentation, I will showcase several PIML architectures developed by our team, such as Physics-based Compressive Sensing, Physics-constrained Dictionary Learning, Physics-Informed Fully Convolutional Networks, and Finite Volume Physics-Informed U-Net, all designed to tackle inverse problems with limited data. Additionally, case studies will be provided to demonstrate the practical applications of these models in advanced manufacturing.

Harnessing additive manufacturing to architect microalloying-induced ($TiB + Y_2O_3$) nanodispersions for exceptional strengthening of near-α titanium alloy

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Abstract

Laser powder bed fusion (LPBF) offers a unique route to generate microalloying-induced nanodispersions unattainable by conventional processing. Here we harness LPBF to in-situ form hierarchical ($TiB + Y_2O_3$) nanodispersions through (0.05 wt% B + 0.07 wt% Y) microalloying in near-α TA15. The non-equilibrium solidification produces a distinctive architecture: TiB nanowhiskers distributed along primary-β grain boundaries forming a quasi-continuous network, together with Y_2O_3 nanoparticles dispersed within the grains. This architecture exhibits good thermal stability, surviving post-build heat treatment without coarsening or dissolution.

Despite totaling only 0.35 vol% ($TiB + Y_2O_3$) reinforcements, the resulting microalloy achieves strengthening comparable to conventional composites with several-fold higher reinforcement content: room-temperature strength improves by over 10% (attaining the highest UTS among all benchmarked materials) and, notably, 500°C strength enhances by 15% without ductility sacrifice. The enhanced performance originates from synergistic mechanisms including grain refinement, Orowan strengthening, load transfer, and CTE mismatch strengthening, all enabled by the thermally stable hierarchical nanodispersions. This work demonstrates that harnessing additive manufacturing to architect microalloying-induced nanodispersions provides an efficient strategy for developing high-performance titanium alloys with minimal alloying.

Programmable Design and Fabrication of Continuous Compositionally Gradient Interfaces in Multi-Material L-PBF Enabled by Custom Slicing Software

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Abstract

This report presents a multi-material laser powder bed fusion (L-PBF) method for fabricating compositionally gradient interfaces through programmable powder deposition, together with the secondary development of slicing software for the same machine. For the self-developed multi-material L-PBF system equipped with a nozzle array, slicing software was developed for multi-material interface design and coordinated process control. This software enhances spatial resolution, execution accuracy, and process controllability, providing support for the precise design and stable fabrication of complex interfaces. Using 316L stainless steel and IN718 superalloy as the model material pair, an interdigitated interface design with a layer-wise offset arrangement was implemented through programmable, high-precision powder deposition. During multi-material L-PBF, the alternating powder layout, together with melt-pool stirring, promoted material intermixing and gradually transformed the initially discrete material distribution into a continuous horizontal compositionally gradient interface about 1 mm wide. The interface showed smooth transitions in elemental distribution, grain growth, and microhardness, confirming the formation of a continuous gradient between the two materials. These results demonstrate a feasible route for the controllable fabrication of gradient heterogeneous structures in multi-material L-PBF. The successful fabrication also verifies the practical value and necessity of the slicing software for interface design, powder deposition, and coordinated process control.

Research on Powder Spreading Technology and Process optimization in Multi-material Laser Powder Bed Fusion Additive Manufacturing

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Abstract

Multi-material laser powder bed fusion (MM-LPBF) enables the integrated manufacturing of heterogeneous material components. However, the development of this technology consistently faces critical challenges such as powder cross-contamination and the regulation of dissimilar material interfaces. This study focuses on the research and process optimization of MM-LPBF powder spreading techniques to address the above issues. It firstly introduces the common key challenges currently faced by MM-LPBF powder spreading technologies, and discusses the fundamental principles, advantages, and disadvantages of four technical approaches:blade-based powder spreading, electrostatic powder spreading, gas aspirating-dispensing powder spreading,and ultrasonic vibration-assisted powder spreading. Relying on a self-developed MM-LPBF system equipped with a micro-nozzle array, an integrated and collaborative multi-material LPBF forming process was developed through iterative system modification, combining Venturi-based negative pressure powder removal, blade-based powder spreading, and ultrasonic vibration-assisted micro-nozzle powder spreading. The Venturi nozzle achieves a single-track powder removal width of less than 1 mm and enables uniform removal of powder in the target area with a small removal thickness (≤ 0.3 mm). This process demonstrates effectiveness and engineering applicability in improving powder utilization, enhancing forming efficiency, and optimizing interface forming quality.

Preliminary Design and Characterization of a Thermally Regulated Bifurcated Manifold for High-Throughput Pneumatic Multi-Nozzle Extrusion

Ong Zhi Xiang, Tay Jia Wei, Tan Qing Yang, Aakanksha Pant, An Jia, Professor Tan U-Xuan

Singapore University of Technology and Design

Abstract

Extrusion-based Additive Manufacturing (AM) for food and bio-inks is currently constrained by the low throughput of single-nozzle systems and rheological inconsistencies driven by temperature fluctuations. While transitioning to multi-nozzle arrays is essential for industrial scalability, maintaining uniform pressure and viscosity across multiple outlets remains a significant engineering hurdle in pneumatic systems.

The research proposes the development and characterisation of a specialised bifurcated manifold design for simultaneous 8-nozzle pneumatic extrusion. The design utilises a three-tier symmetric branching architecture (1->2->4->8) to distribute a single pneumatic feed into eight identical outlets. To maintain rheological stability, the manifold integrates a localized temperature control element designed to provide uniform thermal regulation across the internal flow paths. Initial characterisation focused on fluidic split efficiency and the synchronization of material discharge under constant pneumatic pressure.

This work introduces a preliminary framework for a multi-nozzle pneumatic system that offers potential for scalability. By demonstrating the feasibility of subdividing a single pressure source through a bifurcated architecture, this research suggests a modular pathway toward more complex, high-density arrays.

Additive Manufacturing System for Cell Laden Gelatin

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Singapore University of Technology and Design

Abstract

In an alternative approach to the standard cell culture techniques, which is to have a biocompatible scaffold and later seed cells onto said scaffold before culturing in a bioreactor, this study skips a step and directly seeds cells into the bio-ink used to print the scaffold.

Printing cell-laden gelatin has some unique challenges compared to printing gelatin conventionally. Living cells require certain conditions to survive and propagate, such as a sterile environment, shear stress limits and strict temperature ranges. For growing cell cultures intended for food purposes in particular, food-safe materials have to be used as well in the printer design.

This study is designed around printing a scaffold laden with fish cells for fish meat cultivation for food. The ink is a mixture of gelatin, sodium alginate and phosphate buffered saline with suspended fish cells. For gelatin, temperature has to be tightly controlled in order to print to the detail required for cell culture scaffolding. The design incorporates three separate temperature controls, to ensure the gelatin maintains a printable temperature while in the print head, a temperature low enough to be structurally stable on the print bed and in a range that ensures cells survive. To maintain a sterile environment, the setup is also equipped with UV lights for disinfection and all components in contact with the ink is food-safe. Additionally, extrusion nozzles and techniques are selected to minimise shear stress on cells, increasing their survival rate.

Impact of Wire Arc Additive Manufacturing on Inconel 718 Microstructure and Properties

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Abstract

Wire Arc Additive Manufacturing (WAAM) is increasingly recognised as an enabling technology for the next generation of large_scale marine components. This presentation highlights the key achievements of the Mencast project on WAAM_manufactured nickel aluminium bronze (NAB) marine propellers, with a focus on qualification approval and industrial readiness rather than detailed process disclosure.

The project demonstrates the successful transition of WAAM from laboratory_level development to a certification_oriented manufacturing route aligned with marine classification requirements. Emphasis is placed on the establishment of a qualification framework that enables repeatable production, material consistency, and regulatory confidence for safety_critical propeller applications. Through close collaboration with classification societies, including ABS and Lloyd's Register, the project achieved important qualification outcomes that represent a milestone for WAAM adoption in the marine sector.

The work showcases how additive manufacturing can be translated into certifiable and commercially viable solutions, and provides a strong reference for future deployment of WAAM in high-value marine and offshore applications.

Rapid image-based evaluation of conductive ink printability for AI-driven formulation selection

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Abstract

Printability assessment in extrusion-based additive manufacturing conventionally requires dedicated printer time, structured test geometries, and rheological characterisation. This work introduces manual dispensing image as a rapid printability pre-screen, combined with a transfer learning image classifier to remove subjectivity from the assessment and enable systematic evaluation of new ink candidates before any print trial is conducted. This work presents an AI-assisted decision support framework that integrates two independently trained models, both rooted in the same conductive ink formulation space, to guide conductive ink selection prior to print optimization.

The first component is a surrogate model trained for electrical conductivity prediction on formulations comprising acrylamide (PA), poly(ethylene glycol) diacrylate (PEGDA), hydroxyethyl cellulose (HEC), and PEDOT:PSS. The second component is an image classifier, trained on manual dispensing within the same ink system, labelled as extrudable or non-extrudable. The classifier provides rapid extrudability assessment of new formulations without requiring printer time. Both models are trained on overlapping subsets of the same dataset, ensuring the operation is within the same formulation space.

These components are integrated into a multi-objective decision support tool that screens new candidate formulations sequentially. First by filtering through predicted conductivity, then by assessing extrudability through manual dispensing images. Candidates are ranked using a combined score with user-adjustable weighting between the two objectives. Applied to new formulations beyond the training set, the framework enables data-driven ink selection prior to full experimental validation, reducing the trial-and-error burden in functional ink development.

Laser scan-based anomaly detection in metal additive manufacturing using multimodal ensemble learning

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Abstract

Metal additive manufacturing (AM) is gaining traction in product development as a general-purpose technology that is used to manufacture rapid prototypes, rapid tooling, and end-use products. However, concerns about reliably attaining stringent product specifications hinder its broader uptake. This study designs and evaluates a novel process for detecting laser scan-based defective regions very close to the nominal process caused by uncertainty in the powder bed fusion. A tailor-made test specimen (n=442) was designed for the experiment. The build parameters within the individual layers of each test specimen were manipulated to seed laser scan-based defective regions representing basic primitives, i.e., circle, triangle, square, and pentagon. The novelty also stems from the design that the laser power and/or laser scan speed fluctuate on the fly without having the laser switch ON/OFF within a single vector scan. This scan-based design represents a closer imitation of real process defects representative of primitive shapes as a function of laser scans rather than geometry of the parts. Volumetric energy density was varied to ±30% with an increment of 5% from the nominal. The size of the defective primitives ranged from 5 µm to 2000 µm. A late-fusion multimodal ensemble approach was developed and deployed based on datasets from both a near-infrared Scientific Complementary Metal-Oxide-Semiconductor (sCMOS)-based optical tomography (OT) system and a dual-photodiode-based meltpool monitoring (MPM) system. The results revealed the probability of detection using multimodal ensemble learning. The outcome aids designers and researchers in developing products in line with stringent specifications put forth by precision industries.

Robust thermochromic photothermal coating with ultraslippery anti-icing/de-icing and all-season temperature regulation performance

Shize Sun,Xiaolin Liu, Huawei Chen

Beihang University

Abstract

Photothermal materials with higher conversion efficiency are a promising approach to preventing ice accretion on infrastructures like wind turbines. However, the conflict between weak-light inefficiency in winter and overheating hazards in summer remains a challenge for composites. Herein, we develop a robust thermochromic photothermal icephobic coating with switchable solar-driven anti-/de-icing and anti-overheating modes for all-season demands. During freezing winter, a 0.05 W/cm2 weak solar irradiation can raise the black coating (solar absorbance >97%) temperature from -10 °C to 7.6 °C and facilitate rapid ice shedding from rotating rotor. During summer, the thermochromic coating turns white with strong reflection and limits coating temperature below 51 °C, inhibiting composites oxidation above 60 °C. Strikingly, the interpenetrating elasticity and ultra-slippage endow the coating with exceptional ice detachment properties, exhibiting an ultralow ice adhesion strength (<31 kPa) and sliding angle (<8.3°), which are maintained even after 200 Taber abrasion cycles. This study successfully addresses the critical challenge of regulating all-season temperatures of photothermal coatings, pioneering a new pathway for designing intelligent anti-icing coatings for wind turbines and low-altitude rotorcrafts.

Advanced crystalline-amorphous dual-phase nanostructured metals by additive manufacturing

Xusheng Yang

The Hong Kong Polytechnic University

Abstract

Metallic alloys with optimal strength-ductility synergy, wear resistance, and corrosion resistance are essential for extreme service conditions to ensure enhanced safety and longevity. Traditionally, crystalline metals are known for their ductility but suffer from low strength and wear resistance, whereas amorphous metals exhibit high strength but are prone to brittleness. This study introduces a novel crystalline-amorphous dual-phase nanostructure, synergistically combining these contrasting properties to produce ultra-strong metals without sacrificing ductility. The advanced nanostructure encapsulates nanocrystals within thick amorphous grain boundaries, promoting cooperative co-deformation and reducing the risk of localized or galvanic corrosion. Employing state-of-the-art additive manufacturing techniques such as laser surface processing and magnetron sputtering, we have fabricated these unique nanostructured metals. Their mechanical behaviors, including deformation and wear mechanisms, were thoroughly examined through in situ SEM micropillar compression tests, mechanical wear testing at varying temperatures, and comprehensive atomic-scale characterizations. Furthermore, this study utilized atomistic simulations and theoretical modeling to elucidate the underlying plasticity and wear pathways, offering insights into the enhanced performance of these materials. These combined properties make the developed materials highly suitable for applications requiring robust, durable, and corrosion-resistant materials, setting a new standard for the design of next-generation metallic materials. Acknowledgements: HK RGC grants (PolyU15210123 and PolyU15201424); Hong Kong Innovation and Technology Commission (ITC) Guangdong-Hong Kong Technology Cooperation Funding Scheme (Nos. GHP/088/23GD and GHP/088/23GD), Lai Yun Yin Second Charitable Foundation (N-ZHBK).

Development of a Machine Learning-Based Prediction Model for Bead and Deposition Geometry in WA-DED Using Laser Vision Data

Young Tae Cho

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Abstract

In wire arc directed energy deposition (WA-DED) processes, bead geometry is a key factor that determines the final shape of the deposited structure. However, bead geometry varies nonlinearly with heat input conditions, significantly influencing the mechanical properties, dimensional accuracy, and surface quality of the fabricated part. In multi-layer deposition, geometric deviations accumulate layer by layer, leading to amplified shape errors. Therefore, precise prediction and control of bead geometry prior to fabrication are essential for ensuring process reliability. Moreover, the inherent difficulty in predicting deposition geometry limits the applicability of coordinate-based post-processing.

This study aims to predict the geometry of WA-DED structures based on bead geometry prediction. Cross-sectional bead data were collected using a laser vision sensor (LVS) under various current and travel speed conditions, and a machine learning-based model was developed. The data were pre-processed and refined using spline-based correction, and multiple regression models were employed to learn nonlinear relationships between process parameters and bead geometry. The trained model reconstructs bead cross-sections under new conditions and predicts the final geometry by accumulating bead shapes along the deposition path. In addition, geometric features such as curvature (_) and inter-layer shape information were used to quantitatively analyze variations. Validation against LVS data demonstrated high prediction reliability in terms of RMSE and K-fold cross-validation. This approach enables prediction of irregular WA-DED geometries, improving the accuracy and efficiency of coordinate-based post-processing.

Keywords: WA-DED (Wire Arc Directed Energy Deposition); Bead Geometry Prediction; Machine Learning; Multi-layer Deposition; Shape Reconstruction

Acknowledgement: This work was supported by the Korea Institute for Advancement of Technology (KIAT) grant funded by the Ministry of Trade, Industry and Energy (MOTIE), Republic of Korea (No. RS-2023-KI002700), and by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (RS-2025-25396743).

Machine learning-assisted thickness prediction and 3D surface reconstruction for multi-material powder beds in micronozzle-controlled laser powder bed fusion

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Harbin Engineering University; Chongqing Institute of Green and Intelligent Technology; Chinese Academy of Sciences

Abstract

Micronozzle-controlled laser powder bed fusion (LPBF) innovates fabrication of multi-material structures, but also introduces a unique powder bed spreading mechanism and requires a technique for real-time in-situ monitoring of powder bed topography during process control. Existing thickness monitoring methods, such as those employing laser displacement sensors and high-resolution balances, are limited by lengthy measurement cycles and high instrumentation costs. This work develops a new pathway based on 4K imaging and supervised machine learning for powder bed thickness prediction and 3D topography reconstruction, which can be flexibly integrated onto a multi-material LPBF system. The results highlight the high accuracy of the powder bed thickness prediction using the developed multi-feature support vector regression (SVR) fitting. The prediction error remains within approximately 3.31 _m, with an average error of 1-2 _m (maximum absolute percentage error is 9.2%). The reconstructed topography exhibits excellent agreement with the measurements obtained by the laser displacement sensor. In the reconstruction of defected powder beds, the SVR-predicted errors in defect location and width are less than 1 _m. The defect depth errors are below 5 _m, typically remaining around 1 _m. Compared with traditional laser sensor approaches, the developed method is a rapid and cost-effective tool for in-line characterisation of powder bed thickness, reducing data acquisition time to 2 seconds. Importantly, the pathway can be further integrated into various additive manufacturing systems, and benefits the development of high-resolution closed-loop strategies for improving powder bed uniformity.

Voxel-Based Path Planning Method for Multi-Material Additive Manufacturing

Liangcheng Cao, Bo Wang, Jianbiao She, Shoufeng Yang

Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences

Abstract

To address the requirements of path planning and precise material assignment for heterogeneous structures in multi-material additive manufacturing (e.g., extrusion-based forming and jet deposition forming), a discrete modeling and path planning method based on the voxelization concept is proposed, enabling coordinated control of path and material distribution. The method specifically includes steps such as 3D modeling, path voxelization, material assignment, and process file output, achieving visual modeling of heterogeneous structures and ultimately generating G-code process files that contain dual information of spatial positions and material properties. By enabling fine-grained control at the voxel scale for both path and material, this method provides an effective path planning approach for the precise printing of multi-material heterogeneous structures, contributing to improved process flexibility and forming accuracy in multi-material additive manufacturing.

Laser-induced growth of ZnO/$CsPbBr_3$ heterostructure optoelectronic devices

Zhengwei Li

Shandong University of Technology

Abstract

This study constructs a ZnO nanowire/$CsPbBr_3$ quantum dot composite structure using laser-assisted hydrothermal method, successfully developing a high-performance ultraviolet-visible light photodetector. By utilizing laser growth technology to regulate the morphology and crystallization characteristics of ZnO nanoballs, excellent electron transport properties and specific surface area are imparted. The laser heating process achieves tight integration between $CsPbBr_3$ quantum dots and ZnO nanoballs, effectively optimizing the heterojunction interface contact. This not only leverages the advantages of $CsPbBr_3$ quantum dots, such as high light absorption coefficient and wide spectral response, but also relies on the n-type semiconductor characteristics of ZnO nanoballs to achieve efficient separation and transport of photogenerated carriers, while suppressing non-radiative recombination of carriers. The prepared Ag/ZnO nanoball/$CsPbBr_3$ quantum dot/Ag photodetector exhibits excellent photoelectric response performance in the ultraviolet-visible light range. Compared to pure ZnO-based detectors, its dark current is significantly reduced, achieving effective detection of a wide spectrum from ultraviolet to visible light regions. This study provides a new approach for the preparation of low-dimensional metal oxide/perovskite quantum dot composite photodetecting materials using laser technology. The adopted preparation method is both simple and controllable, and the composite structure photodetector prepared has good application prospects in the field of optoelectronic devices.

Enhanced resistance to H embrittlement of Ni-based alloy fabricated by laser powder bed fusion with crystallographic texture control

Ozkan Gokcekaya, Takayoshi Nakano

The University of Osaka

Abstract

Considering the transition to a carbon-neutral society and the shift from Society 4.0 to Society 5.0, suppressing hydrogen embrittlement in additive manufacturing, particularly in L-PBF, has become an urgent issue. Nickel (Ni)-based alloys are materials that combine high temperature properties, corrosion resistance, and excellent mechanical properties. However, there is concern about the deterioration of their functionality due to hydrogen embrittlement (HE) in a H environment. In this study, we aimed to enhance hydrogen embrittlement resistance by controlling crystallographic texture using Laser Powder Bed Fusion (L-PBF) in Ni based alloy. Laser-Powder Bed Fusion (L-PBF) process develops unique microstructure owing to its super thermal field (STF). By altering laser conditions such as the scan strategy, the shape of the solid-liquid interface and heat flow direction in the melt pool can be altered. This enables crystallographic texture control and results in different microstructural characteristics.

Thus, we achieved crystallographic lamellar microstructure (CLM) formation with major grains oriented in <110> and minor grains oriented in <100> in the build direction (BD), as well as a single-crystal-like microstructure (SCM) with <110> orientation along the BD and the hydrogen embrittlement susceptibility was investigated.

The behavior of HE changes with the state of the microstructure, such as lattice defects that have an affinity for H diffusion, therefore it is proposed that HE can be suppressed by controlling the microstructure that contributes to H diffusion and trap site by preventing the localization of hydrogen. Hence, L-PBF has the potential to suppress HE by utilizing changes in microstructural characteristics.

Multifunctional Flexible Strain Sensors Based on Ag@Graphene/Resin Composites for Motion Monitoring and Morse Code Communication

Lei Chen

Shandong University of Technology

Abstract

This work develops a flexible strain sensor based on an Ag-decorated graphene/photoradical resin composite for wearable applications and assistive human-machine interaction. By incorporating Ag-modified graphene into the resin matrix, the composite material achieves stable conductive networks while maintaining flexibility and exhibiting antibacterial properties. The fabricated sensor demonstrates sensitive and repeatable resistance responses to finger bending and other deformations, showing good stability under cyclic loading conditions. Based on distinguishable low- and high-amplitude signal peaks, Morse code encoding and recognition are successfully realized, showcasing its potential for assistive communication. This work offers a new approach for the design of intelligent wearable devices that integrate strain sensing, antibacterial functionality, and information transmission.

Adhesion Characteristics of a Slippery Interface and Analysis of the Maximum Printable Area Using Conical Structures for Large-Area Continuous DLP 3D Printing

Chae Hyeok Yoon[1], Woo Young Kim[2], Seong Min Yoon[1], Seo Rim Park[1], Seo Na Yoon[1], Young Tae Cho[1]*

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Abstract

In DLP-based continuous photopolymerization, interfacial resin dynamics critically govern printing speed, precision, and process stability. With high-viscosity resins, failure to rapidly replenish liquid resin in the micro-gap between the cured layer and window interface during build plate elevation leads to interlayer non-uniformity and reduced productivity. Here, we introduce a lubricant-infused organogel-based slippery interface to overcome large-area continuous printing limitations, and quantitatively analyze its interfacial adhesion and printing stability against FEP film, organogel, and PDMS interfaces. The slippery surface, featuring a PDMS brush layer via photo-induced grafting, exhibits 92.7% optical transmittance and contact angle hysteresis below 10°, with the fastest capillary-driven resin infiltration across all tested gap heights. Load cell measurements revealed that adhesion forces of FEP and PDMS interfaces were more than 1.5 times greater than those of the slippery surface. Scaling analysis confirmed that only the slippery surface exhibits nearly simultaneous separation across the entire contact region, in contrast to edge-initiated peeling on other interfaces. Conical structure printing experiments demonstrated that FEP and PDMS interfaces suffered structural failure even at low speeds due to sharp adhesion increases with expanding cross-sectional area, whereas the slippery surface maintained stable low-adhesion characteristics, suppressing structural defects. Complex large-scale structures were successfully fabricated at 0.1 mm/s, surpassing the printable area limits of conventional continuous DLP printing. These results demonstrate that the proposed interfacial strategy effectively ensures both productivity and reliability in large-area continuous 3D printing.

Acknowledgement This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT)(NRF 2023R1A2C3006499) This work was supported by the Korea Institute for Advancement of Technology (KIAT) grant funded by the Ministry of Trade, Industry and Energy (MOTIE), Republic of Korea (No. RS-2023-KI002700).

Acquiring strong yet ductile additive manufactured medium-entropy alloy at cryogenic temperatures through tuning local chemical ordering

Wenjie Lu, Xu-sheng Yang

The Hong Kong Polytechnic University

Abstract

Additive manufacturing (AM) produces net-shaped components with high complexity and low material waste, however limited ductility restrict their further application, especially for cryogenic application. The potential game changer high-/medium-entropy alloys (H/MEAs) are no exception.

In this study, we report a simple strategy, tuning local chemical ordering (LCO) domains (range from sub-nanometer scale to several nanometers scale) through proper microalloying and heat treatments, to achieve strong yet ductile AMed MEA for cryogenic application. Compared with the AMed Ni50Cr25Co25 MEA, the precisely tuned AlNb alloying together with post-processing heat treatment markedly promotes local ordering, boosting the tensile strengths while substantially improving ductility. The yield strength increment originates from superior ordering strength resulted from highly dispersed LCO domains with high anti-phase boundary energy and the strong solid solution-related friction stress originated from AlNb alloying, simultaneously, LCO domains with minimized lattice misfit facilitates the sequential activated stacking faults-mediated planar deformation characteristics, which promotes excellent high work-hardening capacity and ductility. Finally, our AMed MEA with elaborately regulated LCO domains (~2 nm diameter) through AlNb alloying and post heat treatments achieves ultrahigh cryogenic tensile strength up to ~2 gigapascal at a remarkable uniform elongation of ~42%. The outstanding strength and ductility synergy properties set our AMed MEA apart from reported AMed alloys, even batter than the well-established wrought alloys for cryogenic application.

The findings of this work not only establish a new paradigm for compositional design of AMed alloys, but also provide an innovative strategy for the cryogenic applications of such AMed high-performance alloys.

Large-Scale Metal AM in the Built Environment: A 11m WAAM Pedestrian Bridge at SUTD

Jiang Chenxi, Siddharth Ganesh, Doron Teh, Youssef Elkhouly, Stylianos Dritsas, Soh Gim Song

Singapore University of Technology and Design

Abstract

Wire Arc Additive Manufacturing (WAAM) is transforming the construction of large-scale, complex metal structures by combining high deposition rates with cost-effective production. This presentation details the design and fabrication of a landmark pedestrian steel bridge for the Singapore University of Technology and Design (SUTD) campus. Measuring 11.25m in length and over 3m in height, the bridge utilizes WAAM to modularly print curved exterior walls and handrails from AM316L stainless steel. By integrating printing substrates directly into the structural wall posts, the project optimizes material use and structural integrity. We demonstrate the technical viability of this large-scale application through rigorous overhang-angle evaluation, material-strength characterization, and the analysis of a full-scale partial modular prototype.

3D-Printed IP-DIP Hollow Core Micro-Waveguides for High-Speed Optical Interconnects

Hongwei Gao, Dawn Tan

Singapore University of Technology and Design

Abstract

The escalating demand for high-bandwidth, low-latency data transmission in photonic integrated circuits (PICs) necessitates advanced optical interconnects with minimal signal degradation. Hollow core fiber (HCF) architectures offer compelling advantages, including ultralow non-linearity and reduced material absorption, but their micro-scale integration remains a significant manufacturing challenge. In this study, we present the design, additive manufacturing, and characterization of a 100-µm-long hollow core waveguide fabricated utilizing high-resolution two-photon polymerization (TPP) 3D printing. The waveguide is printed using IP-DIP photoresist, capitalizing on the material's excellent structural fidelity and high resolution to precisely define the complex microstructured cladding required for robust modal confinement in the air core.

Optical characterization of the fabricated 100-µm structures at the 1550 nm telecom wavelength demonstrates notably low propagation losses, validating both the waveguide design and the exceptional surface quality achieved via the TPP process. Furthermore, high-speed data transmission testing at 1550 nm confirms the waveguide's ability to support high-bandwidth optical signals with excellent signal integrity and minimal dispersion. These findings successfully demonstrate the viability of 3D-printed IP-DIP hollow core micro-waveguides as a highly scalable, low-loss solution for next-generation optical interconnects, advanced photonic packaging, and high-speed datacom applications.

Design and Additive Manufacturing of Gyroid-Based Multifunctional Structures for Bone Implants

Dahyun Daniel Lim, Seok-Hyeon Kang, Beomjun Choi, Seok Chung

Korea University

Abstract

Recent advances in additive manufacturing have enabled the fabrication of titanium (Ti-6Al-4V) implants for biomedical applications such as spinal fusion cages and dental implants. In these applications, porous architectures play an important role not only in providing sufficient mechanical support, but also in influencing biological performance, including bone cell attachment, proliferation, and osseointegration. Therefore, the design of implant structures should consider multifunctionality rather than focusing solely on mechanical strength.

In this study, we explore gyroid-based porous structures as multifunctional implant architectures targeting both mechanical and biological performance. Specifically, sheet-based and strut-based gyroid designs are investigated under varying relative densities to examine how structural characteristics affect load-bearing capability as well as the potential for bone cell growth. By comparing these design variables, we aim to better understand the relationship between porous geometry, mechanical behavior, and bone regeneration-related performance.

The results of this study provide insights into the design of additively manufactured bone implants with enhanced multifunctionality, offering a framework for optimizing porous architectures for both structural integrity and biological compatibility.

Application of Stability Research in Additive Manufacturing and Robotics

xiaoyong, SUN

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Abstract

Stability serves as the core guarantee for additive manufacturing and robotic systems to achieve high-precision, high-reliability and long-service-life operation. Focusing on structural stability and in combination with my research interests, this report elaborates on the research progress in these two fields.

In the field of additive manufacturing, my research on stability mainly focuses on structural stability and motion accuracy. For space-based on-orbit additive manufacturing equipment, to resolve the issue of motion accuracy under the constraints of microgravity and overload, the coordinate axis constraint calibration method is adopted, enabling the motion accuracy to reach 0.1 mm.

In the field of robotics, my stability research is oriented toward motion smoothness, load robustness and adaptability to complex environments. Relying on dynamic modeling, attitude optimization and stability control algorithms, and aiming at the dynamic balance problem of robots under external impacts, the impact-constrained dynamic model method is utilized to realize stable gait locomotion of robots.

Rapid prototyping of an optically integrated microfluidic flow cytometry device for large-sample analysis

Takanobu Takenouchi, Yuta Iijima, Kazuyo Ito, Daisuke Yoshino

Tokyo University of Agriculture and Technology

Abstract

Flow cytometry is a powerful tool for analyzing cells, but conventional systems are often expensive, bulky, and difficult to customize. This study presents a rapid prototyping approach for developing an optically integrated microfluidic flow cytometry device capable of detecting forward-scatter and fluorescence signals. The device was fabricated using a combination of CNC micro-milling, soft lithography, and 3D printing to enable fast design iteration and low-cost manufacturing. A wide microchannel structure was employed for the analysis of large biological samples, such as circulating tumor cell (CTC) clusters. CTC clusters are important targets because they are closely associated with cancer progression and metastatic potential. While wide channels are advantageous for preventing clogging and reducing mechanical stress on large samples, they generally result in lower measurement precision due to less stable sample focusing and reduced signal collection efficiency. To address this issue, we attempted to improve the device's performance by optimizing the channel geometry. We evaluated the fabricated system using microbeads with different diameters and fluorescence intensities as model particles. Our results suggest that combining rapid prototyping with channel design optimization is a promising approach for developing customizable flow cytometry platforms for biological research and diagnostics.

Fusion of additive manufacturing and physical coating technologies for metamaterials

Jong-Chan Beom, Gideon Simon Mduma, Sung-Jun Lee, Chang-Lae Kim

Department of Mechanical Engineering, Chosun University

Abstract

There has been increasing research interest in the development of metamaterials aimed at enhancing mechanical, thermal, and permeability characteristics and optimizing overall performance. Design and fabrication technologies based on additive manufacturing are widely utilized for the development of metamaterials. This presentation aims to investigate the application of a fusion of additive manufacturing and physical coating technologies to the development of metamaterials for enhancing chemical and electromagnetic properties. A design and fabrication methodology for metamaterial frames based on DFAM (Design for additive manufacturing) and additive manufacturing processes is proposed. In addition. an approach for producing metamaterials by applying physical coatings to these frames is investigated. An evaluation method for the fabricated metamaterial is proposed, and their properties are examined using this approach. Finally, the potential applications of the fabricated metamaterials are discussed.

TPMS Lattice Structures of 7xxx Aluminium Alloy via LPBF: Enabling Crack-Free Fabrication and Optimizing Mechanical Performance

Jiani Huang, Xu-sheng Yang

The Hong Kong Polytechnic University

Abstract

Lattice structures have attracted significant interest in lightweight engineering due to their exceptional specific strength and energy absorption capacity. Laser powder bed fusion (LPBF) enables fabrication of such complex architectures with high precision. Among candidate materials, 7xxx series aluminium alloys (Al-Zn-Mg-Cu) are particularly attractive for aerospace and automotive lattice applications owing to their outstanding specific strength. However, their fabrication via LPBF remains challenging due to severe hot cracking caused by high solidification shrinkage and thermal stresses.

In this study, an in-situ microalloying strategy was adopted to refine the solidification microstructure and suppress hot cracking, enabling the successful fabrication of dense, crack-free 7xxx aluminium alloy by LPBF. Building on Sthis, four biomimetic triply periodic minimal surface (TPMS) lattice topologies — Gyroid, Diamond, I-WP, and Primitive — were designed and manufactured using the microalloyed powder. Quasi-static compression tests were performed to evaluate specific strength and specific energy absorption (SEA) across topologies, with systematic variation of unit cell size and relative density.

Results show that the Diamond topology achieves the highest SEA (up to 35.24 J/g), attributed to its mixed bending- and stretching-dominated deformation mode, while Diamond and I-WP structures offer the highest specific strength (0.0886 and 0.0856 MPa·m3/kg, respectively). Smaller unit cells generally improve structural integrity and SEA due to increased nodal constraint, while larger cells improve manufacturability and may extend plateau deformation; the optimal cell size is topology-dependent and subject to manufacturing accuracy. Relative density, controlled via wall thickness, was identified as the dominant factor, showing a strong positive correlation with both specific strength and SEA.

These findings bridge advanced alloy design and biomimetic topology optimization, offering practical guidance for high-performance lightweight structures in demanding engineering applications.

Designing Freeform Mechanisms for Exact 3D Path/Motion Generation

Peng Song

Singapore University of Technology and Design

Abstract

“In engineering, a mechanism is an assembly of moving parts interconnected by joints to transfer an input motion to a desired output motion. Traditional mechanisms are composed mechanical parts with standard shapes such as spur gears. Despite cheap to manufacture via mass production, mechanical parts with standard shapes have a finite number of design parameters, making them only able to approximate a user-prescribed path/motion. Thanks to advances in additive manufacturing, it is now possible to conveniently and affordably fabricate mechanisms with complex, arbitrary geometries.

To address the limitation of traditional mechanisms, we extended 3D freeform geometry modeling to the context of mechanisms, opening up a new research direction called Design of Freeform Mechanisms. Our key idea is to model and design mechanisms with 3D freeform geometry such that a user-prescribed 3D path/motion can be exactly encoded into the freeform geometry. In particular, we proposed two classes of freeform mechanisms: 1) 3D freeform cam mechanisms and 2) multi-point conjugation mechanisms, as well as techniques to modeling and designing these mechanisms. We have demonstrated the superiority of these freeform mechanisms via a variety of applications, including mechanical automaton, low-cost manipulator, and walking robot.”

A systematic study of disorder-connectivity coupling in mechanical metamaterials via dual-uncertainty-aware framework

Yinan Zhu, Dr. Yuman Zhu, Dr. Yunlong Tang*

Monash University

Abstract

Disordered mechanical metamaterials offer advantages including reduced anisotropy and resistance to localized collapse. Among the factors governing their mechanical behavior, nodal connectivity plays a critical role, yet how it interacts with structural disorder to influence post-yielding plasticity and anisotropy remains unclear. To address this challenge, this study employs perturbation-based metamaterials with different nodal connectivities by additive manufacturing. A dual-uncertainty-aware Gaussian process framework is also proposed to address uncertainty from both limited training data and structural randomness. Results show that asynchronous collapse induced by perturbation can mitigate plateau stress oscillations, while the framework can achieve prediction accuracy of $R^2 > 0.95$.

Versatile and Instructive Potentials of Nanobiomaterials as Smart Additives for 3D Bioprinting

Chuntae Kim, Yoon Ki Joung, Dong-Wook Han

Pusan National University (PNU)

Abstract

Three-dimensional (3D) bioprinting represents the next frontier in additive manufacturing, advancing beyond conventional fabrication toward the creation of living, functional tissue constructs. By integrating intelligent bioinks with precision bioprinting systems, this technology holds significant promise for addressing the global shortage of transplantable tissues and organs. However, the clinical translation of 3D bioprinting remains constrained by the limited functionality of traditional bioinks, particularly in achieving optimal printability, mechanical robustness, and biological performance. To address these challenges, nanobiomaterial-based hybrid bioinks have emerged as a key innovation in next-generation biofabrication. Incorporation of nanoscale building blocks—including filamentous M13 bacteriophages, graphene-family nanomaterials, carbon nanofibers, MXenes, and nanoclays—enables the design of multifunctional bioinks with enhanced rheological control, structural fidelity, and bioactivity. These nanobiomaterials impart unique physicochemical properties, such as electrical conductivity, high surface area, and tunable mechanical strength, thereby significantly improving the performance of bioprinted constructs. For instance, M13 bacteriophages function as programmable nanofibrous scaffolds capable of presenting bioactive peptides, while MXenes and graphene derivatives contribute superior electrical and thermal properties essential for electroactive tissue engineering. The integration of such two-dimensional (2D) nanomaterials transforms conventional bioinks into intelligent, stimuli-responsive systems that actively guide cellular behavior and tissue maturation. Our research demonstrates the application of these nanostructured hybrid bioinks in fabricating functional tissue constructs, including skin, skeletal muscle, bone, and neural tissue. These constructs exhibit enhanced cellular organization, mechanical integrity, and tissue-specific functionality compared to traditional systems. Overall, nanobiomaterial-enabled hybrid bioprinting represents a paradigm shift in additive manufacturing, paving the way for the development of bio-instructive, adaptive, and clinically translatable tissue constructs. This approach underscores the convergence of nanotechnology and biofabrication in shaping the future of regenerative medicine.

Physics-Guided Microstructure and Defect Engineering in LPBF of AA6061 via Laser Modulation and Substrate Preheating

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Abstract

High-strength aluminium alloy AA6061 remains challenging for laser powder bed fusion (LPBF) due to its susceptibility to solidification cracking and porosity under rapid solidification conditions. This work presents a physics-guided approach to microstructure and defect engineering by combining control of laser modulation and substrate temperatures. The effects of laser frequency, duty cycle, and elevated substrate temperature on melt pool dynamics, solidification behavior, and defect evolution are systematically investigated. Experimental results reveal two distinct melting regimes governed by modulation parameters. A remelting-cycle regime, characterized by multiple melt pool boundaries within a single track, refined grains, and reduced cracking; and a sustained-melting regime, in which continuous above-liquidus conditions promote deeper melt pools and coarser microstructures. The introduction of high-temperature substrate preheating alters these regimes by reducing thermal gradients and cooling rates and suppressing solidification cracking. To elucidate the underlying mechanisms, high-fidelity numerical simulations of transient melt pool and microstructure evolution are performed to quantify thermal cycling and solidification conditions under representative conditions. The simulations reveal that the interplay among modulation frequency, duty cycle, and substrate temperature governs the transition between remelting-driven cyclic solidification and sustained melting, thereby controlling grain structure, subgrain formation, and defect susceptibility. The findings provide a pathway toward application-specific material design, where microstructure and defect populations can be tailored through process modulation and thermal management.

In-situ observation of spattering during laser powder bed fusion: implications for defect prediction and powder degradation

Huaiyu Yang, Cheng Zhu, Ruihao Song, Zhuoer Chen

School of Metallic Materials and Advanced Manufacturing, Soochow University

Abstract

Spattering is an inevitable phenomenon in Laser Powder Bed Fusion (LPBF) process that can lead to the formation stochastic defects in the built part and degradation of the powder. The presentation is focused on the typical features of spattering observed through optical tomography during LPBF process with varied conditions in scan vector rotation, part geometry and layer thickness. Although the cause-effect between spattering and defect formation was previously found, the ability to predict the presence of such defects is complicated by the self-healing nature of the process. This work investigates the interplay between gas flow, spatter and self-healing process through the analysis of monitored data and defect quantification, and highlights the challenges of predicting stochastic, small defects that are associated with spattering. On the other hand, the spatter generated during the LPBF process are mixed with the feedstock powder that are to be reused for the following builds. A series of builds were designed to accelerate the powder degradation by building parts of high surface-to-volume ratio, where systematic collection and testing of powder samples were performed. The correlation between powder oxidation and the cumulative volume and surface area of the builds were established.

Large Knowledge Model-Assisted Bioprinting

Huang Xi, Yeong Wai Yee

Nanyang Technological University

Abstract

Bioprinting is a promising branch of additive manufacturing, but process setup often still relies on repeated trial-and-error, particularly when optimizing printing parameters for new materials, target geometries, or downstream applications. At the same time, valuable knowledge on formulations, printability, and operating conditions is distributed across a rapidly growing literature and is difficult to reuse efficiently in practical workflow design. In this work, we present a Large Knowledge Model (LKM) framework for bioprinting that combines literature retrieval with citation-grounded response generation to support evidence-based decision-making. The framework is designed to answer bioprinting-related questions with traceable source support and to provide literature-guided starting points for downstream parameter tuning. Building on our earlier work, we discuss ongoing efforts to extend the framework beyond the initial study, including improvements to retrieval quality, broader evaluation, integration of multimodal information such as figures and imaging data, and incorporation of user-generated experimental data for more adaptive workflow support. This work highlights the potential of Large Knowledge Models to complement additive manufacturing workflows by linking scattered literature evidence to practical process setup, with the longer-term goal of improving efficiency, traceability, and reproducibility in bioprinting research.

Co-optimization of Dielectric and Electroactive Performance in 3D Printed PVDF via Bottom-Up Electret Engineering

Xiaobing Dong, Ningyi Zhang, Shihui He, Chao Jiang*

College of Mechanical and Vehicle Engineering, Hunan University

Abstract

“Poly(vinylidene fluoride) (PVDF) is a cornerstone for wearable sensing and soft electronics, yet its electroactive performance is fundamentally constrained by traditional crystalline phase-based enhancement strategies. This work presents a transformative approach to surpass these limits through Bottom-Up Electret PVDF (BUE-PVDF) fabricated via electrohydrodynamic additive manufacturing.

To navigate the complex, multi-parameter process space of this emerging field, we developed a model–experiment synergistic optimization framework. This framework employs a surrogate model as a directional decision tool, iteratively refined through experimental feedback to enable efficient process exploration under limited predictive fidelity. Our findings reveal a mechanism distinct from conventional phase-structure modulation: identifying pore-trapped spatial charges, rather than β-phase fraction, as the dominant contributor to dielectric and electromechanical enhancement. Guided by this insight, coordinated parameter optimization yields an ultrahigh intrinsic dielectric constant of 60.3 (approximately 6 times that of commercial PVDF). Furthermore, this unique 3D electret structure fully exploits internal crystal benefits, achieving record-breaking electroactive properties. The optimized electrostrictive coefficient (M33) is 10,000 times that of normal PVDF films, while the piezoelectric constant (d33) reaches 10 times the traditional limit. This work establishes a physically interpretable pathway for “”printing the charge”” and provides a generalizable strategy for the high-performance additive manufacturing of functional polymers in next-generation smart systems.

Keywords: Additive Manufacturing, PVDF, Electret, Dielectric Properties, Soft Electronics”

In-situ Architecturing of 3D Microstructural Composites via Laser Additive Manufacturing for Synergistic Property Enhancement

Kaihao Zhang

The Hong Kong University of Science and Technology (Guangzhou)

Abstract

The pursuit of high-performance metallic materials, which necessitates simultaneously overcoming trade-offs between strength and toughness or between strength and conductivity, represents a fundamental challenge in materials engineering. Conventional manufacturing routes often struggle to architect microstructures at multiple scales to decouple these competing properties. This work presents a transformative paradigm that utilizes laser powder bed fusion (LPBF) additive manufacturing (AM) not merely as a shaping tool, but as a dynamic platform for in-situ architecturing 3D reinforcement networks and heterostructures within bulk metals. We demonstrate this concept through two distinct, yet philosophically aligned, material systems. First, we report a strategy to spontaneously architect a continuous 3D graphene network within a Ni matrix. By exploiting the rapid thermal cycles of LPBF, we drive the in-situ precipitation and growth of few-layer graphene from a Ni/polymer precursor during the printing process. This results in a conformal graphene wrap around an architectured Ni scaffold, which is subsequently densified into a bulk composite. This microstructure delivers an exceptional strength-ductility synergy, achieving a 72% enhancement in ultimate tensile strength (648 MPa) without sacrificing ductility (54% elongation), owing to the effective harnessing of graphene’s intrinsic properties and a decoupled strengthening-toughening mechanism. Second, we implement a microstructural composite strategy to resolve the property trilemma in CuCrZr alloy. LPBF is used to fabricate a honeycomb scaffold that intentionally encapsulates unmolten powder, forming a dual-phase “green” composite. Subsequent thermomechanical consolidation and aging create an architectured heterostructure where a hard, conductive laser-printed matrix and soft, ductile powder-derived regions coexist. This spatially differentiated microstructure yields an unprecedented combination of high strength (669 MPa), good ductility (20.6%), and high electrical conductivity (82.7% IACS). Both studies underscore a shift in the role of laser AM from geometric shaping to a potent method for in-situ microstructural architecturing.

Multi-Scale Engineering of Additively Manufactured Biodegradable Zinc

Yageng Li, Yixuan Shi, Chengcong Huang, Luning Wang

University of Science and Technology Beijing

Abstract

The rising incidence of musculoskeletal disorders worldwide has intensified clinical challenges such as bone defects, osteochondral damage, and fractures, highlighting the urgent need for advanced bone repair strategies. Owing to the hierarchical architecture and patient-specific variability of bone tissue, there is a growing demand for personalized implants with functionally graded properties. Conventional manufacturing techniques are inadequate for meeting these complex requirements, whereas additive manufacturing, particularly Laser Powder Bed Fusion (LPBF), offers unique capabilities for fabricating customized implants with precise structural control. Biodegradable metallic materials have recently emerged as promising candidates due to their favorable biocompatibility and controllable in vivo degradation. The integration of additive manufacturing with biodegradable metals provides a pathway to simultaneously tailor mechanical performance, degradation behavior, and biological functionality. However, this field remains in its early stage, with material performance governed by complex interactions across composition, microstructure, and macrostructure. In this study, LPBF was employed to fabricate biodegradable Zn-based alloys, combined with compositional design and process optimization to regulate microstructure and enhance mechanical properties. Porous and functionally graded architectures were further designed to systematically investigate their effects on mechanical performance, degradation, and biological responses. High-performance Zn-Mg eutectic alloys and Zn-Mn-Mg ternary alloys were developed, achieving a compressive yield strength of 600 MPa with over 60% strain, and a tensile strength of 290 MPa with elongation exceeding 20%, respectively—meeting the mechanical requirements for load-bearing bone implants. Functionally graded structures enabled regulation of fluid flow within porous scaffolds, decoupling the conventional correlation between porosity and degradation rate while improving fatigue resistance. Finally, a full-thickness bone defect model in Bama miniature pigs demonstrated that a porous Zn-hydrogel bilayer scaffold with dual gradients in mechanics and bioactivity effectively promoted simultaneous cartilage and bone regeneration. These findings provide a comprehensive strategy for the design of next-generation biodegradable metallic implants.

Oxygen-Regulated UV Crosslinking for Programmable Swelling-Driven Shape Morphing in Extrusion-Based 4D Bioprinting

Hu Renzhi, Yeong Wai Yee

Nanyang Technological University

Abstract

Shape morphing in hydrogel-based additive manufacturing is commonly achieved through geometric patterning, multi-material deposition, thickness gradients, or differential-swelling assemblies. While effective, these approaches introduce fabrication complexity and offer limited capacity to control microstructural heterogeneity within a single-material printed system.

This work proposes oxygen-regulated UV crosslinking as a process-level strategy for programming swelling-driven shape morphing in extrusion-based hydrogel additive manufacturing. Rather than treating the curing environment as a fixed boundary condition, oxygen exposure during photopolymerization is here treated as an active and tunable manufacturing parameter. Given that oxygen acts as a free-radical scavenger, modulating its local concentration during curing directly influences network formation, crosslink density, and pore-size distribution. The resulting microstructural gradients produce differential swelling upon hydration, driving predictable macroscopic deformation from monolithic printed constructs without recourse to compositional variation or geometric complexity.

To establish this methodology, oxygen content during UV curing will be systematically varied and correlated with network heterogeneity, swelling kinetics, and deformation response. The process-structure-response relationships derived from this investigation are intended to clarify the mechanistic basis by which curing-environment control governs shape change behavior. By relocating a portion of the morphing design space from external print architecture to the photopolymerization environment itself, this approach broadens the available strategies for extrusion-based 4D printing and presents a straightforward, scalable route to fabricating self-morphing hydrogel structures.

Toward Function-Oriented WAAM: Single-Material Behavior and Deposition-Order Effects in Bimetallic Structures

Ozan Can Ozaner, Abhay Sharma, Reza Talemi, Tegoeh Tjahjowidodo

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Abstract

Toward Function-Oriented WAAM: Single-Material Behavior and Deposition-Order Effects in Bimetallic Structures

In many high-performance engineering applications, components are still produced as monolithic parts even when the most expensive alloy is only required locally, leading to unnecessary material use and cost. This is particularly relevant for Inconel 625, whose superior high-temperature and corrosion-resistant properties are not always needed throughout the entire component. In such cases, Wire Arc Additive Manufacturing (WAAM) offers a promising route for producing monolithic functionally zoned structures by retaining Inconel 625 only in critical regions while introducing a lower-cost alternative such as SS309L in less demanding locations. However, the industrial use of this strategy requires a clear understanding of how process conditions influence both single-material behavior and bimetallic interface performance. This study therefore investigates WAAM-fabricated SS309L, IN625, and SS309L–IN625 structures through a unified process–thermal history–microstructure–mechanical response framework. In the single-material stage, the roles of process parameter selection and thermal-cycle engineering are examined in relation to surface integrity, heat accumulation, microstructural heterogeneity, anisotropy, and tensile/fatigue performance. In the bimetallic stage, deposition order is treated as a key design variable governing arc stability, dilution, transition-zone length, local microstructure, and damage localization. The results show that the same thermal and metallurgical mechanisms controlling distortion, surface irregularity, and anisotropy in single-material walls also govern interface formation once dissimilar deposition begins. Deposition order significantly alters elemental mixing and mechanical performance, with SS-first producing a shorter transition zone and IN-first generating a broader graded region together with markedly higher fatigue scatter. Overall, the findings demonstrate that WAAM can enable reliable material zoning in monolithic metallic components while reducing overdesign and preserving structural integrity.

Rheological transition driven core-skin architecture for transient thermal response in material-extruded copper systems

Taehyeob Im, Jeongho Yang

Nanyang Technological University

Abstract

“Compact thermal management is critical in high-power electronics, electrified transportation, and energy conversion systems, where volumetric constraints and limited pumping power restrict conventional heat exchanger design. In such systems, total thermal resistance arises from the coupled contributions of solid conduction and surface convection. Although additive manufacturing enables complex copper architectures with enlarged surface area and integrated flow paths, current strategies remain predominantly geometry-centric, leaving microstructure-enabled functionality largely unexplored.

In this study, binder-based material extrusion is employed to introduce rheology-controlled density gradients as a controllable thermal design parameter in copper systems.

Powder loading is systematically tuned across a rheological transition identified by torque slope variation during mixing, marking a shift from lubrication-dominated flow to particle interaction-dominated behavior. Compositions selected near this transition result in heterogeneous densification during sintering and produce an emergent core-skin architecture within a monolithic copper body. The dense core increases effective thermal conductivity and reduces conduction resistance, whereas the porous skin alters boundary-layer development and fluid-solid interaction, modifying convective resistance.

Transient thermal analysis under prescribed boundary conditions quantifies the cooling response of the monolithic copper architecture. The emergent core-skin density gradient redistributes effective conduction pathways and modulates surface heat release, thereby governing internal heat spreading and temperature decay. Cooling kinetics are characterized by the time-dependent evolution of volume-averaged and peak temperatures. These findings establish powder loading as an active thermal design parameter in material-extruded copper systems.”

4D printing of potato peels with pH- and thermal responsive transformations

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Abstract

The paper explores the potential of effecting time- dependent color and shape changes in 3D printed food through pH and heat stimuli. Potato peels were chosen as the base material for the experiments. Blue pea flower powder (BPFP) was mixed in the formulation at different percentages along with xanthan gum (XG) to develop three inks. BPFP was chosen as it contains potent antioxidants, anthocyanin like pigments, ternatins with high pH responsiveness having the ability to maintain blue color in neutral and weak acid environments. Plant based inks having potato peels as the base ingredient are a good starting material for 3D food printing owing to their high starch content. Utilizing peels also helps in reducing the waste component in processing of potatoes. Color change in 3D structures was shown at three different pH, neutral representing blue, acidic (pH < 3) turned the structures pink and alkaline (pH 11) effected green color over time. The paper also successfully established the shape morphing of the printed structures using heat as a stimulus. Flat ribbon, snail and flower structures were printed using 1% XG in the ink. Three temperatures (100°C, 150°C, 200°C) were tested on the printed shapes and all the temperatures caused upward curling of the printed ribbon shapes. Flower structures were also transformed due to the different moisture gradient in the printed structure as well as differential heating in the printed pattern over time. This work is significant as it establishes waste valorization 4D food printing using pH and heat stimuli benefitting sustainable food research.

Achieving heterogeneous interface uniformity in micronozzle-controlled laser powder bed fusion via Continuously Variable Transmission-inspired in-layer gradients of powder deposition

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Abstract

Horizontal gradient interfaces within each layer are essential for spatially tailored multi-material structures in laser powder bed fusion (LPBF), yet remain limited by current equipment and process design. This study proposes a micronozzle-controlled powder deposition strategy inspired by continuously variable transmission (CVT) to construct heterogeneous gradient interfaces via thickness docking of dissimilar powder layers. Without powder pre-mixing, the method enables flexible composition control between 316L and IN718 within ~100 μm layers, along with programmable vertical material arrangement. By stacking gradient layers in different sequences, three CVT-type architectures (CVT_IN/SS, CVT_SS/IN, and CVT_IN/SS/SS/IN) are achieved. The no-pre-mixing approach minimises cross-contamination and enables tunable melt and solidification behaviour. Among them, the CVT_SS/IN configuration exhibits the highest cooling rate (~1.9 × 10^6 K/s), producing smoother compositional transitions and refined grain structures. Consequently, enhanced interfacial integrity and mechanical continuity are obtained, with the mean absolute error reduced to 0.036 ± 0.02 GPa. This CVT-inspired strategy provides a scalable route for precise, layer-wise functional gradient design in multi-material LPBF.

XCT-Integrated Local-Global FEM Framework for Fatigue Crack Propagation in Additive Manufacturing Alloys

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Abstract

The accelerating adoption of additive manufacturing (AM) for critical components requires reliable fatigue assessment that accounts for inherent surface defects and porosity. However, conventional fatigue design approaches rely on smooth material properties without capturing the complex interactions between real surface geometry and fatigue crack behavior. This study addresses this gap by developing a local-global integrated simulation framework that combines X-ray computed tomography (XCT), finite element analysis (FEM), and fracture mechanics to predict fatigue crack propagation in AM-fabricated specimens. Our local-global approach preserves real surface defect geometry in a localized region while maintaining computational efficiency in the bulk domain. First, XCT scanning of specimens captures true surface topology, including roughness features and surface defects. High-resolution meshes extracted directly from XCT data are integrated into an idealized geometric model, creating a hybrid representation where the XCT-captured surface is stitched onto a bulk geometry, avoiding the computational cost of full-domain fine meshing. Static tensile analysis identifies local stress concentration zones on the XCT-captured surface, which serve as potential fatigue crack initiation sites. Fatigue crack growth simulation is then performed using Paris Law parameters derived from independent fatigue crack growth rate (FCGR) testing. Cyclic loading is defined by the applied stress from FEM and a stress ratio R = 0.1, simulating crack propagation from the identified stress concentration zone to critical failure. The results demonstrate strong agreement between simulated and observed crack paths, validating the effectiveness of the local-global XCT-FEM framework in capturing fatigue behavior. This study demonstrates that real surface geometry captured through advanced characterization can be meaningfully integrated into fracture mechanics simulations through a computationally efficient local-global framework. In the context of AM material qualification and damage assessment, this approach demonstrates the feasibility of integrating real surface characterization data into structural fatigue simulation, bridging microscale defect geometry and macroscale fracture mechanics prediction.

Harnessing Abundant Elements: A New Paradigm for Strong and Ductile Titanium Alloys via Additive Manufacturing

Zibin Chen

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Abstract

“For decades, the development of high-performance titanium alloys has been constrained by the embrittling effects of abundant elements like oxygen and the microsegregation issues of iron, limiting their combined use. This keynote presents a groundbreaking integration of alloy design with additive manufacturing (AM) process design that overcomes these long-standing metallurgical challenges. We demonstrate a new class of α-β titanium-oxygen-iron (Ti-O-Fe) alloys that achieve an exceptional combination of strength and ductility, rivaling and exceeding that of industry-standard Ti-6Al-4V.

By leveraging the high cooling rates, intrinsic heat treatment, and thermal cycling characteristic of directed energy deposition (DED), we successfully circumvent the detrimental effects of oxygen and iron. Our approach yields a unique multiscale microstructure comprising fine α-β lamellae within equiaxed prior-β grains. Critically, we reveal a novel atomic-scale nano-heterogeneity: a strong partitioning of oxygen to the α-phase lath rims and iron to the β-phase. This results in an oxygen-rich, ultra-strong α-phase rim adjacent to a ductile, oxygen-free α-phase interior, while the β-phase remains virtually oxygen-free, acting as a soft, dislocation-absorbing matrix. Combined with an energetically favorable crystallographic variant selection, this architecture enables unprecedented tensile properties, with ultimate tensile strengths exceeding 1,100 MPa and tensile ductility exceeding 20%.

This work not only establishes a new family of low-cost, high-performance titanium alloys using abundant oxygen and iron but also opens a new pathway for interstitial engineering in metals. Furthermore, it demonstrates the immense potential of using off-grade, high-oxygen sponge titanium—a current industrial waste product—as a valuable feedstock, offering a significant opportunity to reduce the carbon footprint of the energy-intensive titanium industry. The integration of simulation-informed AM process design with fundamental materials science provides a powerful blueprint for the discovery and development of next-generation structural materials.”

Phase extraction from interference fringe pattern – from conventional phase-shifting technique to recent machine learning method

Yangjin Kim, Kenichi Hibino, Naohiko Sugita, Mamoru Mitsuishi

Pusan National University (Yangjin Kim) National Institute of Advanced Industrial Science and Technology (Kenichi Hibino) The University of Tokyo (Naohiko Sugita, Mamoru Mitsuishi)

Abstract

The accurate extraction of phase information from these fringe patterns is vital to ensure high-precision measurements. Over the years, various methods have been developed to achieve this, ranging from conventional phase-shifting techniques to the more recent approaches leveraging machine learning. Conventional phase-shifting interferometry has long been the standard in optical metrology. These techniques involve capturing a series of interference fringe images at different phase shifts and then using mathematical algorithms to extract the phase distribution. While phase-shifting methods are widely used and offer high precision, they do have limitations. For instance, the necessity for multiple images can lead to longer measurement times, making them less suitable for real-time or dynamic applications. Furthermore, these techniques often require precise control over the phase shifts and can be sensitive to noise, especially when the fringe contrast is low or the system experiences mechanical vibrations. The limitations of conventional phase-shifting methods have prompted researchers to explore alternative techniques, including the integration of machine learning (ML) to improve phase extraction. Machine learning algorithms, particularly deep learning networks, have shown promise in overcoming some of the inherent challenges in traditional phase extraction. In ML-based phase extraction, deep neural networks or convolutional neural networks are trained on large datasets of interference fringe patterns to learn the underlying phase directly. These methods can handle noisy and incomplete data more robustly than conventional techniques. For instance, they can extract phase information from a single fringe image, eliminating the need for multiple phase-shifted images, which reduces measurement time and system complexity.

AI-Empowered Bone Organoid Fabrication: Principles and Applications

Long Bai, Changsheng Liu, Jiacan Su

Long Bai, Changsheng Liu, Jiacan Su

Abstract

Bone-related diseases such as osteoporosis and osteoarthritis pose serious threats to human health, and their high-quality repair remains a critical challenge in medicine. Our previous research, grounded in material-biological effects, developed engineered synthetic hydrogel matrices as replacements for traditional Matrigel, enabling the construction of highly biomimetic bone organoids with self-mineralization and vascularization characteristics. Nevertheless, bone organoid fabrication still faces key challenges: poor reproducibility due to the absence of standardized construction strategies, limited functional recapitulation caused by insufficient cell maturation, and low scalability efficiency resulting from reliance on manual operations. To address these bottlenecks, we focused on AI-empowered fabrication approaches by introducing an organoid-specific large model O-GPT and proposing the “AI Virtual Organoids (AIVOs)” framework. Machine learning algorithms were employed to achieve precise prediction of material properties and optimization of fabrication parameters. Through this digitalized system, we aim to overcome the major barriers in intelligent bone organoid manufacturing, thereby providing a scientific paradigm for bone regeneration research and clinical translational applications.

3D Printing of Eutectic Gallium-Indium for fabrication of soft biosensor

Jaw Wei Qi

Nanyang Technological University

Abstract

With the shift in emphasis towards advanced diagnosis and long-term health monitoring, wearable devices have become widely adopted for measuring vital signs. Previously, rigid electrodes like Ag/AgCl gelled electrodes were used to interface with the body to acquire biopotential signals. However, the rigid nature prevents good conformability with the organ of interest, resulting in poor signal quality. Here, Eutectic Gallium-Indium (EGaIn) was explored as an alternative electrode material owing to its high conductivity and fluid deformability. Additive Manufacturing of EGaIn presents a compelling pathway for fabricating highly conductive, deformable, and complex structures, but the low viscosity and high surface tension makes it challenging in depositing continuous uniform lines. This work presents the strategy explored in mitigating the low viscosity of EGaIn and the technique used to improve printability.

Tuning the adsorption of metal ions in 3D printed organogels via pKa modification

Samuel Lee Zhuo Han, Yeong Wai Yee

Nanyang Technological University

Abstract

Organogels play a key role in the vat polymerization (VP) precursor approach, whereby they act as a sacrificial template for selective infiltration of metal salts. These loaded organogels can then undergo calcination to form metal oxides or further heating with a reducing gas can allow for reduction to form dense metal structures. However, this process still suffers from a considerably low loading percentage of metal ions, which can lead to significant shrinkage upon thermal treatment. Here, we propose the use of a photoacid to selectively modify the pK¬a¬ during the printing process, which affects the polymerization process and thus the polymeric structure, leading to an increased uptake of metal cations and thus increase the loading percentage. The printed organogels were then characterized by various techniques, such as inductively coupled plasm-optical emission spectroscopy (ICP-OES), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC). The ICP-OES method was utilized to quantitatively determine the amount of metal cations adsorbed into the organogel, providing an accurate analysis on how different printing parameters, and thus pK¬a¬ values, can affect how much metal can be adsorbed. Thermal characterization, such as TGA and DSC, are also crucial in determining the changes in polymeric structure with the introduction or infiltration of metal cations. Overall, this study provides insights on the how pK¬a¬ can be controlled during the printing process and how the as-printed structures would be affected due to this pK¬a¬ change. The potential of these compounds in developing new materials for applications in catalysis, electronic devices and biomedical applications would likewise be discussed in future works.

Development of a Novel Method for Multi-Material 3D Food Printing via Single Inlet and Outlet

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Abstract

Three-dimensional food printing (3DFP) has become increasingly prominent due to its capacity to produce customized, three-dimensional (3D) meals. Most food inks described in the literature are composite formulations designed to balance printability and structural stability. Existing multi-material food printing systems use independently operated syringes or coaxial nozzles to create 3D edible food constructs. However, these printing systems are limited to two food inks and are highly inefficient due to prolonged material-switching times, increased equipment costs, and the need to precisely calibrate extruder offsets in multi-extruder printers. Therefore, there is a need to develop an approach that enables multi-material food printing through a single-inlet, single-outlet system, overcoming current inefficiencies and producing a seamless, continuous food ink from more than two separate inks.

The novel single-inlet, single-outlet printing system is achieved using 3D-printed removable inserts that allow two or more separate food inks to be extruded simultaneously. Experimental results have shown that the 3D-printed removable inserts enable up to four different food materials to be extruded concurrently using a Foodini 3D food printer. Although the food ink output is determined by the toolpath, there was still some control over the pattern before printing. Experimental validation using dyed mashed potato purées demonstrated the feasibility of 3D-printed inserts and the single-inlet, single-outlet approach for creating multi-material 3D edible constructs. In addition, the capabilities of the 3D-printed inserts and the single-inlet, single-outlet approach have also been demonstrated using nozzles of different sizes (1.5 mm and 4.0 mm) and different food inks.

Micro-Scale structure Control and Property Optimization Enabled by Precise Laser Energy Input in LPBF

Yang YANG, Chuyang LIU, Ziliang YAN, Haofa Liang

Guangdong University of Technology

Abstract

Laser powder bed fusion (LPBF) fabricated Ti6Al4V alloys typically suffer from a strength–ductility trade-off, characterized by high strength but limited ductility. This behavior is primarily attributed to the formation of acicular __ martensite, high dislocation density, and significant residual stresses induced by the extremely high cooling rates. Leveraging the intrinsic capability of laser beams to deliver highly localized energy input at the microscale, the microstructure and properties of metallic materials involving solid-state phase transformations can be precisely and locally tailored to meet specific engineering demands. In this work, in-situ laser heat treatment and defocusing strategies are proposed to achieve localized performance enhancement in LPBF Ti6Al4V alloys. The underlying microstructural mechanisms governing the property evolution are systematically elucidated. A distinctive bimodal microstructure is identified as the key contributor to the enhanced strength–ductility synergy. A change of crystallographic orientation for parental phase and multi-step structural evolution results to prominent strengthening. These findings enable precise microscale structural regulation without the addition of alloying elements, highlighting their significant potential for advanced manufacturing and engineering applications.

Creating novel texture through novel nozzle design and robotic arm

Goh Guo Dong, Yeong Wai Yee

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Abstract

The creation of novel food textures is an important direction in food additive manufacturing, as texture strongly influences sensory perception, consumer acceptance, and the ability to design personalized foods. In this work, we explore the development of novel textures through the combined use of custom nozzle design and robotic arm-based 3D food printing. Unlike conventional extrusion systems that rely on standard circular nozzles and fixed 3-axis toolpaths, the proposed approach leverages specially designed nozzle geometries together with the enhanced freedom of motion provided by a robotic arm to manipulate material deposition, filament orientation, and internal architecture during printing.

Custom nozzle designs are developed to influence the flow behavior of food paste during extrusion, with the aim of generating unique surface features, internal anisotropy, and fibrous or layered structures that are difficult to achieve using traditional nozzles. At the same time, the robotic arm enables non-planar and spatially varied printing paths, allowing greater flexibility in controlling how material is placed and structured. By integrating these two strategies, the printing process can be tailored to create food constructs with distinctive mechanical properties and mouthfeel.

Machine Learning–Guided Optimization of Sodium Alginate/ Methylcellulose–PEDOT Composites for Shape-Morphing Bioelectronic Systems

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Abstract

Shape-morphing bioelectronic materials are emerging as a promising platform for next-generation soft robotics, biomedical devices, and adaptive interfaces, where mechanical adaptability and electrical functionality must be simultaneously achieved. Among candidate materials, sodium alginate (SA) and methylcellulose (MC) hydrogels offer excellent biocompatibility, tunable swelling behavior, and facile processability, making them suitable for programmable shape transformation. Meanwhile, poly(3,4-ethylenedioxythiophene) (PEDOT) provides high electrical conductivity and electrochemical stability, enabling integration of sensing and actuation functionalities within the same material system. However, combining these components into a unified composite introduces inherent trade-offs: increased swelling capacity enhances morphing capability but reduces structural stiffness and compromises electrical percolation pathways, while higher conductive filler content improves electrical performance at the expense of mechanical compliance and swelling responsiveness.

In this work, we investigate the formulation space of SA/MC–PEDOT composites to systematically understand and optimize the competing relationships between swelling ratio, mechanical stiffness, and electrical conductivity. Given the high-dimensional and nonlinear interactions among material composition, processing parameters, and resulting properties, conventional trial-and-error approaches are inefficient and insufficient. To address this, a machine learning–guided framework is proposed to map the composition–property landscape and identify optimal formulations that balance morphing performance with electrical functionality. Experimental datasets are generated across varying polymer ratios and conductive loadings, and surrogate models are trained to predict multi-objective performance metrics.

This study establishes a data-driven pathway for the rational design of multifunctional hydrogel-based bioelectronic materials. The proposed framework not only accelerates material discovery but also provides insights into the underlying structure–property relationships governing shape-morphing conductive systems. Future work will focus on validating the predicted optimal formulations and demonstrating their performance in programmable morphing and bioelectronic device applications.

Stable-keyhole laser fusion additive manufacturing

Cang Zhao, Bo Shi, Shuailei Chen, Dong Du

Tsinghua University

Abstract

We will introduce our work on laser melting in this talk. Here are three key points:
1. The process-based definitions are more strict and physically sound; 2. Stable-keyhole laser melting enables efficient, sustainable, and robust AM; 3. The realization of this scenario demands the development of multiphysics models, signal translations from morphology to other feasible signals, and in-process metrology across platforms and scales.

A Multigrid Path Optimization Scheme for Computationally Tractable Thermal Path Planning in Metal Additive Manufacturing

Ruozhou Du; Yufan Zheng; Rafiq Ahmad

University of Alberta; Xi'an Jiaotong-Liverpool University; University of Alberta

Abstract

“Model-based path optimization is a promising strategy for thermal management in metal additive manufacturing, yet its application to large-scale and multi-layer builds remains computationally prohibitive due to the rapid growth of thermal simulation cost and path search space. This challenge becomes more severe in multi-layer fabrication, where continuous inter-layer heat accumulation further compounds the thermal history and increases optimization complexity.

To address this limitation, this study proposes a multigrid-based path optimization framework for computationally tractable thermal planning in metal additive manufacturing. Inspired by multigrid methods in numerical analysis, the framework evaluates thermal responses at grid resolutions commensurate with their characteristic spatial frequencies. To ensure physical consistency across hierarchical levels, a frequency-domain-based artificial diffusion time is introduced within a recursive evaluation scheme. Acting as a physics-informed low-pass filter, this mechanism removes unresolved high-frequency thermal responses at coarse levels while preserving dominant large-scale thermal evolution. Building on this foundation, a multilayer coupling scheme is further developed to incorporate inter-layer heat accumulation by transferring the residual thermal field from the previous layer as the initial condition for current-layer optimization.

Numerical studies on both single-layer complex geometries and multi-layer builds show that the proposed framework generates scan paths with improved thermal uniformity compared with conventional zigzag and chessboard strategies while maintaining strong computational tractability. For geometrically repetitive large-scale domains, the method achieves speedups of up to three orders of magnitude relative to traditional single-grid optimization, reducing the planning time for a 300 × 300 mm² area to the order of minutes. Although the hierarchical approximation introduces a quantified optimality loss of 10.4%–25.9%, the resulting toolpaths consistently outperform standard fixed patterns in thermal uniformity.”

Processing–Microstructure–Property Relationships in Fe–Cu Biodegradable Alloys Fabricated by Laser-based Powder Bed Fusion of Metals

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Abstract

Artificial bone implants are widely used in clinical practice; however, permanent metallic implants, despite their high strength and biocompatibility, are associated with long-term complications that may require secondary removal surgery. Iron-based biodegradable alloys offer superior mechanical reliability for load-bearing applications but are limited by excessively slow degradation under physiological conditions. Copper addition has been reported to accelerate corrosion; nevertheless, the processing-dependent microstructural origins of mechanical and degradation behaviour in laser-based powder bed fusion of metals (PBF-LB/M)-fabricated Fe–Cu alloys remain insufficiently understood. Furthermore, although Cu contents of 5 wt.% and 8 wt.% have both been identified as promising, a systematic comparison under controlled processing conditions is still lacking.

In this work, Fe, Fe–5Cu, and Fe–8Cu alloys were fabricated by PBF-LB/M using controlled volumetric energy densities. The influence of processing parameters on relative density, defect characteristics, Cu distribution, and microstructural evolution was systematically characterised by SEM, XRD, and EBSD. Mechanical properties were evaluated through microindentation, ultrasonic testing, and compression testing, while degradation behaviour was assessed via electrochemical and long-term immersion experiments.

The results demonstrate that volumetric energy density strongly influences defect formation and Cu distribution, resulting in distinct mechanical performance and corrosion behaviour. These findings indicate that the corrosion kinetics of Fe–Cu alloys is governed not only by composition but also by process-induced microstructural heterogeneity. Under optimised processing conditions, Fe–8Cu exhibited a compressive yield strength more than twice that of pure Fe, while its degradation rate increased by 105% in electrochemical testing and 44% in immersion experiments.

This study clarifies the processing–microstructure–property relationships in PBF-LB/M-fabricated Fe–Cu alloys, contributing to a better understanding of composition and parameter optimisation for biodegradable implant applications.

Coaxial printing of liquid metal based soft and highly conductive bioelectrodes

Gao Xinchao; Yeong Wai Yee

Nanyang Technological University

Abstract

The integration of bioelectronics with engineered tissue constructs has shown great promise for functional tissue regeneration, particularly in electroactive tissues. However, conventional metal electrodes, although highly conductive, are rigid, dry, and mechanically mismatched with native tissues, which are inherently soft and highly hydrated. Gallium-based liquid metals (LMs), which remain liquid at room temperature and exhibit excellent electrical conductivity, are attractive candidates for bioelectronic applications. Yet, their high surface tension and low viscosity limit their direct use in extrusion-based 3D printing. Existing strategies typically disperse LM particles in hydrogel matrices to enable printability through interactions between the gallium oxide layer and the hydrogel network. However, such LM–hydrogel composites are usually dielectric and often require additional post-processing, such as drying or sintering, to become conductive.

Here, we report a semi-liquid conductive ink for extrusion-based printing by incorporating Ag-plated copper particles into liquid metal. Through coaxial extrusion, conductive electrodes were fabricated using the LM composite as the core and a biocompatible conductive hydrogel as the shell. This core–shell design preserves the high conductivity of the liquid metal while introducing a hydrated and mechanically compliant interface that more closely matches the surrounding tissue environment. This approach provides a promising strategy for the fabrication of soft, tissue-compatible bioelectronic platforms and may advance future applications in tissue regeneration and repair.

Enhancing the sensitivity of in-situ monitoring data for porosity identification during the L-PBF Printing of spinal cage devices

Akram Zarchinia, Andrea Villano, Fatemeh Golpayegania

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Abstract

The properties of metal alloy parts printed by L-PBF are hard to predict and control, due to high levels of process variability. This is particularly the case for the printing of geometrically complex parts, such as those with tapered edges and overhang structures. Data from in-process monitoring techniques can be used to assist operators identify optimum L-PBF processing conditions. For some print conditions however, the monitoring data can be insensitive to the generation of print defects. This study investigates an example of this; it involved the generation of localised keyhole porosity at the tapered edges of printed Ti-6Al-4V sawtooth geometries, printed as part of a spinal cage medical device. Based on µCT scans, porosity was only observed at the sawtooth edges and not the spinal cage bulk. In-situ photodiode monitoring data measurements were found to be insensitive to the presence of the process anomalies, due to the high level of signal 'noise'. In order to address this sensitivity issue, a mathematical formula called the Emission Accumulation Index (EAI) was devised. This provides an indication of localised overheating within a given location of a print layer, based on a combination of photodiode emission intensity, localised laser exposure time data, as well as the temporal distance of neighbouring scan points, within a defined radius along the scan path. Analysis of the spinal cage prints showed that the vast majority of the excess energy EAI points were located at the sawtooth edges, correlating with the location of keyhole porosity observed in the µCT scans. Informed by the EAI approach the laser processing conditions were adjusted in the region around the sawtooth geometries, compared with those used in the bulk alloy, in order to reduce the localised energy level density, by selectively changing the laser power and thus reduce the potential for localised overheating.

New ideas for the preparation of gradient materials based on additive manufacturing technology

Baicheng Zhang

Institute for Advanced Materials and Technology

Abstract

Professor Zhang Baicheng's team at University of Science and Technology Beijing has proposed a novel approach for gradient functional materials fabrication based on additive manufacturing technology to address the bottleneck of conventional homogeneous materials with limited performance in complex service environments. Centering on LPBF technology, the team innovatively developed a multi-material coaxial feeding system and intelligent path planning algorithm. By precisely controlling laser energy input, scanning strategies, and powder ratios, continuous gradient distributions of material composition, microstructure, and mechanical properties in three-dimensional space have been achieved. This technology overcomes the limitations of traditional welding and powder metallurgy methods regarding gradient layers, interfacial bonding, and geometric complexity. Performance gradients including hardness, wear resistance, corrosion resistance, and biocompatibility can be customized on demand from one-dimensional to three-dimensional scales. The research findings have been successfully applied to aerospace hot-end components, personalized biomedical implants, and high-performance molds, providing theoretical foundations and technical support for integrated "material-structure-performance" design and manufacturing of complex components, thereby promoting the development of additive manufacturing technology toward multi-material and intelligent directions.

Development of NiTi shape memory alloy using a unique in-house developed twin wire arc additive manufacturing system

Rajendra Goud and Dan Sathiaraj

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Abstract

Because of its near-net manufacturing, design flexibility, and rapid production, additive manufacturing has seen significant popularity over the last few years. Wire-based additive manufacturing techniques enable the fabrication of metal components with high deposition speeds, cheap material and equipment costs, and excellent structural integrity. In the current investigation, two Gas Metal Arc Welding (GMAW) systems were used to create the Twin-wire Arc Additive Manufacturing (T-WAAM) system. This technique was chosen over alternative wire-based techniques due to its higher deposition rates, simplicity of welding, and reduced cost. To encourage contact, melting, and alloy formation, the two GMAW systems were physically connected, and the torches were positioned 60 degrees apart. A NiTi shape memory alloy sample was deposited under optimal conditions, and its microstructure, phases, phase transformation temperatures, and mechanical properties were examined. An outstanding uniform bead was produced by deposition under ideal settings. Results from X-ray diffraction (XRD) and scanning electron microscopy (SEM) verified the increased concentration of the Ni3Ti phase, which increases hardness and fracture stress while lowering ductility. According to Diffraction Scanning Calorimetry (DSC), the martensite phase and some austenite are both preserved at normal temperature. The grains are fully crystallised and equiaxed, as determined by Electron Backscatter Diffraction (EBSD) measurements. The texture obtained from the orientation map was found to be random.

Direct Ink Writing of Electrostatic Devices for Soft Robotic Systems

Wang Yifan

School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore

Abstract

Direct ink writing (DIW) has emerged as a powerful additive manufacturing technique for fabricating soft functional systems with integrated material and structural complexity. In this talk, I will present recent advances in DIW-based manufacturing of multi-material electrostatic devices, with a focus on their applications in soft robotics and adaptive systems. We introduce a coaxial DIW strategy for printing electrostatic fibers with integrated conductive cores and high-dielectric shells, enabling precise control over geometry, material composition, and interfacial properties . This approach overcomes key limitations of conventional layer-by-layer fabrication by enabling the direct creation of complex three-dimensional architectures with tunable cross-sections and enhanced electrostatic performance.

By leveraging structural and material design, the printed electrostatic systems exhibit programmable force generation, controllable adhesion, and reversible actuation, enabling functionalities such as electrostatic clutches, shape morphing structures, and wearable actuation interfaces. We further show how architectural design at the fiber and system levels can significantly enhance force output and functional efficiency without increasing device size or operating voltage.

This work demonstrates how DIW can transform the manufacturing of electrostatic devices from planar assembly to fully printed, integrated soft systems, and highlights new opportunities for scalable production of soft robotic actuators, wearable interfaces, and intelligent adaptive materials

3D Bioceramic Bone Graft Implants: Technological Breakthroughs, Clinical Applications, and Market Opportunities

Chih-Kuang Wang, Chih-Yun Lee, Yu-Feng Su, Sung-Yen Lin, Yen-Han Lai

Kaohsiung Medical University

Abstract

The global orthopedic biomaterials market was valued at USD 21.16 billion in 2023 and is projected to reach USD 35.90 billion by 2030, driven by population aging, the growing burden of musculoskeletal disorders and fractures, increasing trauma and revision procedures, and the persistent limitations of autografts and allografts. 3D-printed bioceramic bone graft implants are emerging as a promising platform for next-generation orthopedic reconstruction because they can combine bioactivity, patient-specific geometry, and defect-directed regeneration. An ideal scaffold must satisfy both mechanical and architectural requirements, including cancellous-bone-level compressive support, resistance to handling and early fixation failure, controllable biodegradation synchronized with host bone remodeling, and a highly interconnected porous network that supports cell infiltration, nutrient transport, vascularization, and osseointegration. In our three pilot studies, digital light processing combined with a photo-cured and negative thermo-responsive biocearic slurry enabled _-TCP-based scaffolds with dense ceramic struts (~94–95% relative density), clinically relevant pore architectures (300–800 _m), and compressive strengths ranging from ~11 MPa to ~38 MPa, depending on the indication-specific design. Preclinical animal evidence demonstrated promising performance in cranial burr-hole reconstruction, hybrid long-bone segmental defect repair with Ti6Al4V fixation, and bilayer osteochondral regeneration. Importantly, current academic and early translational studies increasingly recognize triply periodic minimal surface (TPMS) architectures as a key direction of development because their continuous-curvature porous networks more closely resemble human cancellous bone and may offer advantages in stress distribution, permeability, and bone ingrowth over conventional orthogonal channel structures. Guided by this trend, our team has established a start-up company to optimize clinically translatable 3D bioceramic products, with the expectation of advancing future patient-specific implants for cranio-maxillofacial, trauma-related, and joint-preserving orthopedic applications.

Nanoscale Transport and Mechanics in Energy and Biomedical Applications

Jingjie Yeo

Cornell University

Abstract

This talk highlights our mechanistic, computational studies of nanoscale transport and mechanics across energy, electronics, and biomedical systems. We develop multiscale molecular simulations and machine_learned potentials to connect atomic interactions to macroscopic performance. In fused macrocycle_cage porous crystals, we reveal ultrafast, anomalous subdiffusive lithium transport, optimal Li loading, and strong thickness and solvent effects on conductivity. In related supramolecular ion conductors and __W thin films, we quantify thermal expansion, elastic constants, and entropy_ driven ion migration pathways. For soft and biological media, coarse_grained models and trajectory_ level machine learning uncover size_dependent nanoparticle hopping diffusion in gut mucus and mechanistic rules for mucus_penetrating drug carriers. These advances provide predictive, experimentally validated design principles for solid electrolytes, metals in high-energy applications, and mucosal drug delivery platforms.

Two-Photon Polymerization Fabrication of Micro-Scale TPMS Scaffolds and Their Effects on Cell Morphology and Differentiation

Zheyu Yao, Wenhui Yu, Hongyu Zheng

Shandong University of Technology

Abstract

The microphysical environment is believed to have a significant influence on cell fate. Recreating the microphysical environment at the cellular scale is crucial for studying cell-matrix interactions. Triply periodic minimal surfaces (TPMS) have garnered significant attention in the fields of biomedicine and additive manufacturing due to their continuous curvature, high surface-to-volume ratio, and tunable mechanical properties. Two-photon polymerization (TPP) 3D printing technology enables the fabrication of TPMS structures with sub-micron precision, thereby facilitating the study of cell-structure interactions at the micro-scale. In this study, the porosity and surface area of TPMS structures with different configurations were designed and compared, and high-resolution TPMS scaffolds were fabricated using TPP technology. It investigated the effects of TPMS type and unit cell size on the proliferation, morphology, alignment, and osteogenic differentiation of human mesenchymal stem cells (hMSCs). The results indicate that hMSCs cultured on TPMS scaffolds exhibit higher proliferation rates. The structural features of TPMS scaffolds influence cell morphology, with cells on the scaffolds exhibiting reduced nuclear area and roundness. Cells on TPMS scaffolds exhibited alignment along specific directions, forming an ordered arrangement. Furthermore, the TPMS structure influenced the expression of osteogenic differentiation. This work reveals the application potential of combining TPMS design with TPP additive manufacturing technology in the fields of advanced tissue engineering and biofunctional materials.

Logistics and Additive Manufacturing in Industries

Shaligram Pokharel

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Abstract

Additive manufacturing (AM) is becoming a way to develop and supply spare parts logistics. This avoids stocking and managing spare parts, reducing inventory, warehouse space, and transportation costs. The growth in digital design technologies, increasing quality of raw materials, and decreasing cost of technology and materials is causing a shift in logistics control, from central manufacturing and transporting to spare parts printing hubs in the industry, which cuts the lead time, increases response time, enhances efficiency, and makes the supply chain more resilient. In this keynote, the current development in AM and logistics, and the possibility of adopting hybrid supply chain models that facilitate AM would be presented.

In-situ high-speed X-ray imaging of crack formation in 3D printed 7075 alloy with Er and Zr modification during laser remelting

Wenhui Yu, Xunxiang Yin, Hongyu Zheng

Shandong University of Technology

Abstract

Due to the high susceptibility to hot cracking, AA7075 alloy faces significant challenges during laser powder bed fusion (LPBF), limiting its widespread application in the aerospace and automotive industries. Composition modification is a commonly adopted strategy; however, the melt pool dynamics of the modified alloy remain unclear. In this study, in-situ high-speed X-ray imaging was employed to characterize the crack formation and elimination behaviors during laser remelting of an LPBF-fabricated AA7075-Er-Zr substrate. This remelting process resembles the scanning of previously deposited layers in LPBF. It was found that high-density particles, enriched with Er and Zr, existed in the as-printed specimens. During remelting, these particles moved with melt convection and pore expansion, were eventually absorbed into the molten pool, and promoted microstructure refinement. Based on the X-ray imaging results, a remelting strategy was adopted to process the modified powder, yielding specimens with significantly refined microstructures and further reduced crack density, thereby establishing an optimized processing route. These findings provide valuable insights into crack reduction and elimination in LPBF processes.

Inkjet-printed Spherical Microwells for Sustainable Multicellular Structure Engineering

Yuxuan Tang, Changjin Huang

Nanyang Technological University

Abstract

Three-dimensional (3D) multicellular structures such as spheroids and organoids are key building blocks for regenerative engineering, disease modeling, and drug screening. However, many existing fabrication platforms rely heavily on disposable plastic consumables and complex processing steps, leading to high material use and limited sustainability. In this talk, I will present an inkjet-printing-based strategy for the generation of spherical microwells that enables efficient 3D multicellular structure formation and manipulation while significantly reducing plastic consumption. Our approach leverages the controlled deposition of liquid droplets onto partially cured elastomer substrates, where interfacial tension and substrate mechanics drive the spontaneous formation of spherical microwells without molds, photolithography, or sacrificial templates. By tuning printing and curing parameters, we achieve precise control over microwell size and arrangement, enabling high-throughput production of uniform multicellular spheroids across a wide range of cell types. Importantly, the elastomer substrates are reusable and mechanically tunable. Simple stretching of the substrate enlarges microwell openings, allowing gentle, enzyme-free release of spheroids and facilitating downstream handling and transport. By eliminating single-use plastic well plates and minimizing consumables, this platform supports more sustainable biofabrication practices. Overall, this inkjet-printed spherical microwell technology provides a scalable, material-efficient, and environmentally conscious solution for 3D multicellular structure generation, contributing to bio-innovations that support a greener, carbon-reduced future in regenerative engineering.

Fabrication of AgNP-AuNP-Embedded PEI/PAA Polyelectrolyte Multilayers on Ti-Alloy Substrates for Bio-Tribology

Yaling Deng, Yu Xu, Tao Liu, Ziye Wang, Jiayi Xiong

College of Intelligent Science and Control Engineering, Jinling Institute of Technology

Abstract

Titanium alloy is a prevalent metallic material in biomedical field due to its excellent characteristics. However, the poor wear resistance hinders its clinical applications of titanium alloy. To establish efficient lubrication interfaces on Ti6Al4V, novel polyethyleneimine/polyacrylic acid (PEI/PAA) polyelectrolyte multilayer (PEM) films embedded with silver nanoparticles (AgNPs) were fabricated via an eco-friendl strategy. The coatings were constructed using layer-by-layer assembly, following by the in-situ incorporation of AgNPs through UV irradiation reduction. This modification significantly enhanced the mechanical properties, specifically Young's modulus and hardness. Tribological tests revealed that the coating achieved a low friction coefficient of approximately 0.053, with negligible wear observed on both the polymer interface and the counterpart steel ball. Furthermore, the AgNP-embedded coatings demonstrated enhanced antibacterial activity against Escherichia coli and Staphylococcus aureus while maintaining excellent. Consequently, these nanocomposite films show great potential as bio-tribological interfaces for artificial joints and implant prostheses.

Additive Manufacturing of Advanced Ceramics for Various Applications

Piao Qu, Chongyu Long, Fang Su, Yu Liu, Changyong Liu, Zhangwei Chen*

Additive Manufacturing Institute, Shenzhen University

Abstract

Advanced ceramic components possess excellent chemical stability and superior physical properties, and have been widely applied in fields such as mechanical electronics, energy and environmental protection, aerospace, etc. Here we first review the principles, advantages, and disadvantages of various ceramic 3D printing technologies, and discusses the performance of printed parts. We also report the latest progress in ceramic additive manufacturing at the Additive Manufacturing Institute of Shenzhen University (AMI-SZU), highlighting application research explorations in energy fields such as lithium batteries, fuel cells, and nuclear fusion energy, as well as in environmental fields such as catalytic carriers, using techniques including vat photopolymerization, inkjet printing, and direct ink writing 3D printing. Furthermore, an integrated shaping and material-forming ceramic additive manufacturing approach based on organic/inorganic precursors is proposed, which has achieved promising research results.

Solidification behavior regulation and strengthening-toughening mechanism of green laser additively manufactured particle-reinforced 7075 aluminum alloy

Chaolin Tan

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Abstract

Infra laser additive manufacturing high-strength 7××× series aluminum (Al) alloys are challenging due to poor laser absorptivity, high cracking susceptibility, and insufficient precipitation strengthening. Herein, we investigate a new approach to process high-performance 7075 Al alloy by integrating green laser directed energy deposited (DED) with nano-TiC embedded composite AA7075 powder. The green laser exhibits superior energy-material coupling efficiency, facilitating high-quality deposition with a 40-45% lower laser power than using conventional infrared laser. Additionally, green laser DED features a stable melt pool with reduced thermal gradient and less elemental evaporations, facilitating a more uniform grain size and a lower dislocation density in the deposited Al alloy. Following heat treatment, the Al alloy achieves an ultra-high density of nano-scale η' precipitates and GP zones (number density ~2.13×1016 m-2), owing to the preserved solute content and accelerated precipitation kinetics. The GL-DED-processed Al alloy achieves a tensile yield strength of about 600 MPa, which is higher than forged AA7075 and almost all DED-processed Al alloys hitherto reported. This work showcases how hard-printing materials can achieve excellent performance by integrating material design and novel additive manufacturing process with short-wavelength laser, which could be generally applied to other hot crack-susceptible and highly reflective materials.

Efficient simulation of SMA morphing wings using physics-informed neural networks

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Abstract

Smart morphing wings with shape memory alloy (SMA) components are promising for a wide range of aerospace applications due to their programmability, high energy density, and lightweight nature. However, accurate prediction of their functional behaviour remains challenging because of the complex, thermally dependent phase transformation of SMAs. Classical finite element analysis (FEA) can accurately model the constitutive behaviour of SMAs and the mechanical deformation of smart morphing structures. Nevertheless, its low computational efficiency and reliance on trial-and-error for convergence constitute a major research gap, limiting its applicability to computationally intensive tasks such as system-level design, simulation, and optimization.

This paper presents a physics-informed neural network (PINN)–based framework for the efficient simulation of SMA-driven morphing wings. By embedding governing equations, phase-transformation evolution constraints, and boundary conditions into the training loss, the underlying SMA physics, including the highly nonlinear, temperature-dependent stress-strain hysteresis, is consistently preserved in the PINN model. The proposed framework is further applied to structural topology optimization while avoiding the mesh distortion issues that commonly arise in FEA-based optimization. Moreover, the model is inherently differentiable with respect to the design parameters, greatly simplifying sensitivity computation.

The effectiveness of the proposed method is validated through numerical benchmarks of wing leading and trailing edges under aerodynamic and thermal loading conditions. The results demonstrate that the method maintains both robustness and predictive accuracy even in large-deformation regimes. The PINN-based surrogate model thus offers a promising tool for the structural optimization of SMA-driven morphing wings.

Topology optimization design and deformation behavior control of SMA-actuated bistable structures

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Abstract

“Bistable structures, characterized by their ability to maintain two distinct stable configurations without continuous energy input, hold significant promise for applications in space deployable mechanisms and morphing structures. The thermal responsiveness of shape memory alloys (SMAs) endows bistable structures with self-actuation capabilities, enabling them to function simultaneously as both supporting and driving components. However, the precise design of SMA-actuated bistable structures and effective control over their deformation behavior remain challenging. This paper proposes a topology optimization framework tailored for SMA-actuated bistable structures, aiming to synergistically enhance lightweight design and actuation performance.

First, an isogeometric mechanical model incorporating hyperelastic material constitutive behavior and geometric nonlinearity is established to accurately capture the snap-through behavior under mechanical loading. Second, within the solid isotropic material with penalization (SIMP) framework, a multi-objective topology optimization model is formulated to maximize actuation displacement while minimizing structural compliance. The adjoint method is employed to derive sensitivities, addressing challenges associated with nonlinear convergence. Leveraging this optimization framework, the critical snapping state is treated as a design variable to proactively tailor the snap-through behavior, enabling precise shape–performance control.

Optimization results demonstrate that the resulting bistable configurations allow tailored triggering energy and deformation displacement. By adjusting the weighting factors in the optimization objectives, effective control over the critical snap-through force and deformation amplitude is achieved. These tailored configurations significantly enhance the actuation efficiency of SMAs by lowering the energy barrier for self-actuation. The proposed method validates the feasibility of designing SMA-actuated bistable structures and offers a new approach for active deformation design in 4D-printed smart structures.”

Isogeometric concurrent optimization of continuous fiber paths and structural topology for additive manufacturing

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Abstract

“Continuous fiber-reinforced additive manufacturing provides a promising route for fabricating lightweight composite structures with enhanced mechanical performance. However, the structural efficiency of printed components strongly depends on the coordinated design of fiber trajectories and structural topology. This work proposes an isogeometric framework for the concurrent optimization of continuous fiber paths and material layout in additively manufactured composite structures.

In the proposed method, the continuous fiber path field and the structural topology field are represented within a unified isogeometric formulation, enabling smooth geometric description, accurate structural analysis, and consistent optimization on complex curved surfaces. To improve practical manufacturability, multiple additive manufacturing constraints are incorporated, including constraints on the local fiber content and the curvature of fiber paths. Stress constraints are further introduced to enhance the load-bearing capability and reliability of the optimized designs.

The proposed framework enables the simultaneous tailoring of fiber steering and topology distribution, allowing the fiber architecture to align more effectively with load-transfer paths while maintaining manufacturable structural forms. This study demonstrates that isogeometric concurrent optimization provides an effective computational design strategy for high-performance continuous fiber composite structures and offers new opportunities for advanced structural design in additive manufacturing.

High performance plain carbon steels obtained through 3D-printing

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Abstract

Over the last century, improvement in mechanical performance of structural metals has primarily been achieved by creating more and more complex chemical compositions. Such compositional complexity raises costs, creates supply vulnerability, and complicates recycling. As a relatively new metal processing technique, metal 3D-printing provides a possibility to revisit and simplify alloy compositions, achieving alloy plainification, which enables simpler materials to be used versatilely. Here, we demonstrate that high performance simple plain carbon steels can be produced through 3D-printing. Our 3D-printed plain carbon steels achieve tensile and impact properties comparable, or even superior to those of ultra-high strength alloy steels such as Maraging steels. The sequential micro-scale melting and solidification intrinsic to 3D-printing provides sufficient cooling to directly form martensite and/or bainite, strengthening the steels while maintaining microstructural and property homogeneity without dimensional limitations or heat treatment distortion and cracking. By manipulating 3D-printing parameters, we can tailor the microstructure, thereby control the properties for customized applications. This offers a scalable approach to reduce alloy complexity without compromising mechanical performance and highlights the opportunities for the 3D-printing to help drive alloy plainification.

Support-enabled in-situ heat treatment for microstructure programming in additive manufacturing of high-strength aluminum alloys

Cherq Chua, Ali Ghasemi, Jia An, JunHua Luan, Chee Kai Chua, Swee Leong Sing

National University of Singapore (NUS), Singapore University of Technology and Design (SUTD)

Abstract

In additive manufacturing, support structures are conventionally used to prevent distortion and anchor parts with complex overhangs to the substrate plate. In this work, we show that engineered control of heat-dissipation pathways through support structures can instead be exploited to harness intrinsic process heat and activate microstructural evolution during laser powder bed fusion (LPBF). Using Scalmalloy® as a model system, low-area-fraction supports (LAFS) were found to significantly enhance heat retention within the part and prolong high-temperature exposure during layer-by-layer fabrication, thereby promoting substantial in-situ heat treatment (IHT) and mechanical strengthening. By coupling LAFS with interlayer time control, the cumulative thermal exposure could be spatially tailored to produce either graded or near-uniform hardness distributions along the build direction. Tensile testing showed that the combined use of LAFS and a graded interlayer time strategy yielded a strength of 453 MPa and an ultimate tensile strength of 479 MPa in the as-built state, approaching the performance of conventionally peak-aged Scalmalloy®. Atom probe tomography further revealed a high number density of Sc-rich solute clusters with an average radius of ~1.9 nm, identified as the dominant strengthening feature. Multiscale thermal simulations established a quantitative link between local thermal histories and mechanical response through an equivalent aging framework. These results demonstrate a process-integrated strategy for microstructure and property control in LPBF precipitation-hardenable alloys, enabling programmable in-situ heat treatment during fabrication and potentially eliminating the need for post-processing heat treatment.

Grain boundary α and its effects on mechanical properties of additively manufactured titanium alloys

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Abstract

Grain boundary a-phase (GB-α) in titanium alloys is the vulnerable site for failure, while its formation and evolution mechanisms in additively manufactured titanium alloys, along with its correlation with deformation behavior and local dislocation motion, is still ambiguous. GB-α precipitation and coarsening behavior in additively manufactured titanium alloys during fabrication and post heat treatment process were investigated. GB-α tended to precipitate at the triple junctions (TJs) of the β-phase grain. Kinetic analysis showed that the coarsening mechanisms vary with different heat treatment process. For instance, with different annealing temperatures, the coarsening behavior of LPBF Ti64 could be different: bulk diffusion at 750 °C and interface reaction at both 850 and 950 °C. In the meantime, the deformation-induced dislocations were found severely accumulated within the continuous GB-a with the transverse tensile loading direction, which corresponds to the strain localization, while uniformly distributed between the continuous GB-a and surrounding grains with the perpendicular tensile loading. In contrast, discontinuous GB-a could fully accommodate uniform deformation with the matrix microstructure under both loading directions.

Difference in motivation, process, and performance in horizontal and vertical interfacial interfaces of multi-material laser powder bed fusion: an interesting interface case inspired by Continuously Variable Transmission (CVT) mechanics

SHI Qimin (石齐民); YANG Shoufeng (杨守峰)

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Abstract

Multi-Material Laser Powder Bed Fusion (MM-LPBF) is showing promising capabilities to achieve all-in-one fabrication of multiple materials onto a single part, with high manufacturing precision, thereby combining the required properties and/or functions. Understanding the bonding behaviours between two materials under laser radiation is fundamental for MM-LPBF. Because of the layer-by-layer nature of LPBF, any complex 3D multi-material structure can be simplified to the interfacial bonding of two dissimilar materials, both horizontally and vertically. This talk would like to present our latest work on the interfacial bonding of dissimilar metal materials in MM-LPBF, including both horizontal and vertical interfaces. The story will cover the different bonding strategies we developed when bonding the horizontal and vertical interfaces of dissimilar metal materials. To thoroughly understand the interfacial bonding behaviours and the underlying mechanisms, the material redistribution at the interface under liquid convection will be analysed. The microstructural development across the interface will be compared. Eventually, the mechanical performance of bonding strength, microhardness, and micro-modulus across the interface will be revealed, connecting the micro-world to the macro-world. To complete the above study, the model material combinations Steel/IN718/Copper, Steel/IN718, and IN718/Copper are selected to reveal the basic theories and mechanisms for vertical and horizontal interfacial bonding. In particular, we will share a micronozzle-controlled powder bed layout strategy, inspired by Continuously Variable Transmission (CVT) mechanics, to fabricate heterogeneous gradient interfaces by docking thickness gradients of two dissimilar powder layers. This approach, for the first time worldwide, enables flexible composition adjustment without powder pre-mixing between the model materials 316L and IN718, even within each ~100 _m-thick powder layer, while allowing programmable vertical spatial arrangement of the two materials within a powder layer. The data and printing experience from these studies would be welcomed and transferable to other metal combinations in MM-LPBF.

Harnessing Golden Ratio in Metamaterial Design: Enhanced Fracture Resistance through Delocalized Deformation

Deng Junjie, Wang Xinxin

Central South University

Abstract

Architected metamaterials are destinguished by their exceptional mechanical properties, reliant on ideal, defect-free microarchitectures. However, unavoidable defects introduced during manufacturing and in-service conditions compromise structural integrity, rendering fracture resistance a critical challenge. To concurrently enhance strength and toughness, we incorporate the golden ratio, a motif of structural and aesthetic harmony, into the design of architected aperiodic metamaterials. Employing dual-material PolyJet additive manufacturing, we constructed and fabricated conventional, hierarchical periodic, and golden-ratio-guided aperiodic truss microlattices and interpenetrating phase composite (IPC) metamaterials. Compared to periodic counterparts, the aperiodic architectures exhibit significantly enhanced damage tolerance under both monotonic and cyclic tensile loading. This superior performance is attributed to the inherent geometric heterogeneity of aperiodic designs, which mitigates stress concentrations and enables the spatial delocalization of damage-tolerant regions. Consequently, crack propagation exhibits increased complexity and self-adaptive behavior, resulting in highly tortuous fracture paths and enhanced energy dissipation. These findings underscore the significant potential of golden-ratio-inspired aperiodic architectures in advancing damage-tolerant metamaterials.

Integrating Computer-aided Design, Computational Simulations and Additive Manufacturing for Developing Advanced Tissue Engineering Scaffolds

Min Wang, Prof. Dr.

The University of Hong Kong

Abstract

Bone tissue engineering (BTE) was one of the earliest intensively investigated areas in the field of tissue engineering (TE) and regenerative medicine and over the past three decades, many strategies and products have been developed for BTE. Among the three main approaches for TE, namely, cell-, growth factor-, or scaffold-based TE, scaffold-based BTE has dominated, with many efforts being made to combine these three approaches so as to effectively regenerate bone in human bodies and overcome major difficulties in bone tissue repair. Despite their success, traditional scaffold fabrication techniques, such as solvent-casting-and-progen-leaching, freeze-drying, and electrospinning, have limitations which hinder the development of advanced TE scaffolds with desired porous structures and biological properties. Increasingly, additive manufacturing (AM, i.e., 3D printing) is investigated for TE owing to its unmatchable capability. For a long time now, our industries have benefitted greatly from computer-aided design (CAD) and computer-aided manufacturing (CAM). AM, which belongs to CAM, has revolutionized the industries. AM technologies and bioprinting enable us to fabricate complicated (pore size-graded, functional gradient, etc.) and customized (i.e., patient-specific) TE scaffolds, as well as tissue-engineered products (TEPs), for meeting demanding clinical needs. Furthermore, computational simulations (CS: mechanical, fluidic, etc.) can assist us hugely in developing advanced TE scaffolds. By integrating CAD, CS and 3D printing, advanced TE scaffolds can be developed effectively and efficiently, minimizing the cost, time and efforts. For bone regeneration, bioactive ceramics are commonly used to construct BTE scaffolds. Owing to its osteoconductivity and osteoinductivity and controllable biodegradation rate, the biphasic calcium phosphate (BCP) bioceramic is among best materials for BTE scaffolds. In this keynote talk, our research on integrating CAD, CS and 3D printing in developing pore-graded BCP scaffolds is introduced. These advanced BCP scaffolds have shown excellent in vivo performance in regenerating bone in an animal model.

AI-based Defect Detection and Localization in Laser Powder Bed Fusion

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Abstract

“Metal additive manufacturing (AM), particularly laser-based powder bed fusion (PBF-LB), enables the production of complex, high-value components. However, layer-wise manual supervision remains time-consuming and costly, limiting large-scale industrial adoption. This study investigates artificial intelligence (AI)-based defect detection using in-situ monitoring data from both EOSTATE PowderBed and Exposure Optical Tomography (OT) systems.

A manually annotated dataset was constructed from multiple PBF-LB builds, including layer-wise powder bed images and OT thermal signatures. Four widely used convolutional neural network (CNN) architectures—ResNet50, EfficientNetV2B0, YOLOv5, and Faster R-CNN—were trained via transfer learning to evaluate classification and localization performance.

For defect classification, ResNet50 and EfficientNetV2B0 achieved robust performance, with EfficientNetV2B0 offering improved computational efficiency. For defect localization, YOLOv5 outperformed Faster R-CNN in both detection accuracy and inference speed, demonstrating strong capability in handling multi-scale and irregular defect morphologies. Lower average precision in object detection was primarily associated with defect size variability and annotation boundary uncertainty.

The results confirm the feasibility of AI-driven defect identification using both powder bed morphology and optical tomography data. The findings highlight YOLOv5 as a practical solution for real-time monitoring and demonstrate the industrial potential of integrating AI into EOS PBF-LB systems for automated quality control and reduced material waste.
Future work will focus on expanding dataset diversity and improving annotation consistency to enhance model robustness for deployment in industrial AM environments.”

In-situ alloying design of high-performance crack-free superalloy by additive manufacturing

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Abstract

A novel approach based on in-situ alloying via laser powder bed fusion (LPBF) provides a new idea for design and fabrication of crack-free superalloys with high γ’ content. This study investigates effect of in-situ alloying and specifically designed heat treatment on microstructure morphology, crack control, and mechanical properties, demonstrating their advantages in crack inhibition and performance enhancement. By mixing mature crack-free superalloy powders (IN718) as matrix and single-crystal superalloy powders (DD6), containing a high content of high-temperature strengthening elements such as Al, Ta, and W, at a mass ratio of 4:1, crack-free AMS14 alloy was successfully prepared. Swirl-like micrometer-scale concentration modulations (microCMs) rich in high-temperature strengthening elements with a thickness of only ~5 μm are introduced in as-built state. Crack inhibition is achieved through matrix element liquid feeding and dispersion of thermal tensile stress by matrix region with high plasticity. Specially designed heat treatment enables release of high-temperature strengthening elements in microCMs and sufficient precipitation of strengthening phases, resulting in a multi-level strengthened microstructure with a relatively high content of γ’ precipitates, and achieving excellent comprehensive mechanical properties at elevated temperature. Ultimate tensile strength at 650°C reaches 1252.77 ± 22.31 MPa, while elongation reaches 13.82 ± 0.89%. Design concept in this study, which combines in-situ alloying for crack inhibition and heat treatment for release of high-temperature strengthening elements, provides a new approach for designing new high-performance superalloys for additive manufacturing.

A multi-stimulus 4D-printed hygromorphic–SMP Façade for climate-adaptive architecture

Huynh Thu Hang, Yi Hwang

Korea University, ARTS Lab, South Korea

Abstract

This study presents a simulation-based analysis of a 4D-printed, multi-stimulus-responsive building façade panel that integrates a reversible hygromorphic layer with a shape memory polymer (SMP) as a novel smart material façade system. Compared with classical unimodal bilayer systems, the proposed trilayer architecture enables more dynamic and tunable climate-adaptive responses. However, its more complex deformation behavior makes it challenging to predict mechanical performance and to optimize the thermo-hygromorphic design. To address this, we employ a unified Finite Element Analysis (FEA) framework to capture curvature evolution, stress redistribution, and neutral axis shift under varying thickness ratios, stiffness combinations, fiber orientations, and SMP softening behaviors. The simulation results are validated against small-scale prototypes to confirm the accuracy of the thermo-hygromorphic response. We demonstrate that moisture-driven swelling, coupled with temperature-dependent stiffness modulation, enables programmable and reversible curvature control in the façade panel. This work provides a computational design strategy for multi-stimulus 4D printed envelopes and highlights the potential of hybrid hygromorphic-SMP systems for energy-efficient, climate-responsive architecture.

3D printing of ZnO-modified hydroxyapatite scaffolds with directional pore microstructure for enhanced mechanical properties and biocompatibility

Xianglin Zhou

Jiangsu Key Laboratory for Design and Manufacturing of Precision Medicine Equipment, School of Mechanical Engineering, Southeast University, Nanjing, 211189, China

Abstract

Hydroxyapatite (HA) exhibits multifunctionality and wide applications in biological tissues such as vertebrate bones and teeth, due to facial element substitutions and chemical modifications of active surfaces in crystal structures with various inorganic or organic additives. It is a challenge to achieve biocompatible scaffolds that combine both high strength and toughness for the repair and regeneration of bone and tooth defects. In this study, we developed ZnO-modified hydroxyapatite 3D scaffolds with microscopic directional pore structures (~20 _m) using a directional freezing-assisted direct-ink-writing (DIW) 3D printing technique. The directional pore microstructure significantly enhanced the mechanical properties compared to the non-directional scaffolds. Moreover, both experimental and molecular dynamics simulation results demonstrated that the incorporation of ZnO nanoparticles improved the sintering process, maintaining the directional pore microstructure while significantly increasing the mechanical strength. Notably, the coated hydroxyapatite scaffolds demonstrated excellent antimicrobial activity with ~99% antimicrobial resistance and biocompatibility with ~89.96% cell survival. This study presents an innovative approach for constructing directional porous hydroxyapatite scaffolds with multifunctionality and high mechanical properties, providing a promising foundation for advancements in dental restoration, implantable medical devices, and bone tissue engineering.

Fast Laser Processing of Silicon Carbide Ceramic Materials

Jie YIN, Zhengren HUANG

Shanghai Institute of Ceramics, Chinese Academy of Sciences

Abstract

SiC-based Ceramic composites are promising for usages as various large-scale and complex-shaped components. However, the intrinsic brittle nature of SiC ceramics inhibited their wide application. Incorporation of chopped carbon fiber as a reinforcing phase could enhance its reliability. During recent years, efforts have been devoted to fast forming techniques to reduce excess carbon reduction. Additive manufacturing of SiC-based ceramics by adopting various techniques, including digital light processing, direct ink writing, selective laser sintering, and et al were emerged. In previous study, our group conducted investigation on direct ink writing of C/SiC ceramic composites. The critical point was the preparation of homogenous C/SiC green bodies. In recent study, we combined selective sintering and liquid silicon infiltration for a higher-efficiency and higher-performance-component fabrication. We prepared complex-structured composites therefrom. The relationship between microstructure tailoring and mechanical performance was investigated.

Design and Additive Manufacturing of Structural Batteries

Zhiyang Lyu

Southeast University

Abstract

As electronic devices continue to evolve toward miniaturization, intelligence, and high integration, their power sources, batteries, are increasingly required to meet demanding criteria such as miniaturization, customization, and high specific energy. However, conventional electrode manufacturing processes struggle to simultaneously satisfy these complex and stringent requirements. Leveraging its capability for precise control of electrode architectures at the micro/nanoscale, 3D printing enables the fabrication of 3D electrode structures with adjustable thickness and width, effectively enhancing the areal loading of active materials and shortening ion transport pathways, thereby significantly improving both specific energy and power density. Moreover, 3D printing facilitates the design and accurate construction of complex micro/nanostructured electrodes, offering innovative solutions to critical scientific and technological challenges in next-generation batteries. This report focuses on the theme of “Design and Additive Manufacturing of Structural Batteries,” presenting recent research progress in the design and fabrication of micro/nanostructured materials and architected devices based on direct-ink-writing technology.

Generative AI-Driven High-Fidelity Digital Twin Environment Construction and Sim-to-Real Transfer Technology for Smart Construction

Rushi DAI

Thrust of Urban Governance and Design, Thrust of Smart Manufacturing, The Hong Kong University of Science and Technology (Guangzhou)

Abstract

While the construction industry remains a cornerstone of the real economy, its intelligent transformation is consistently hindered by fragmented digital-physical data, complex environmental variables, and the inherent difficulty of supervising diverse on-site scenarios. This research addresses these bottlenecks by proposing a framework centered on the AI+ building construction concept, leveraging domain-specific AI models and high-fidelity digital twin (DT) technology to bridge the gap between virtual simulation and physical execution.

The methodology focuses on two critical technical pillars. First, the study develops high-fidelity multi-dimensional digital twin construction technology, utilizing generative AI to assist the creation of complex 3D scenarios. This process targets technical breakthroughs in accurate spatial mapping and the real-time synchronization of multi-source dynamic data. Second, the research tackles Sim-to-Real Transfer technology, establishing a robust transformation channel that allows digital optimizations, including process simulations and autonomous machinery training, to be deployed effectively within physical construction and operation process.

By establishing an integrated digital-physical technology platform, this study mitigates the industry pain points of high simulation training costs and disjointed data streams. The proposed system provides standardized digital scenarios for training on-site automation through the simulation of core construction processes. Ultimately, this research demonstrates how the deep integration of generative AI and digital twin environments can enhance construction efficiency, strengthen safety risk prevention, and realize the practical value of AI technology within the broader smart manufacturing and advanced construction sectors.

AI-Based Line Recognition in Piping and Instrumentation Diagrams

Yoochan Moon, Ji-Beob Kim, Sangwook Park, Seung-Tae Han, Duhwan Mun

Professor

Abstract

“A Piping and Instrumentation Diagram (P&ID) is a fundamental engineering document that represents the interconnections among piping, valves, instruments, and control devices in process plants. It plays a critical role throughout the plant lifecycle, including design, operation, and maintenance, by providing essential information on process flow and control logic. From the perspective of information representation, the elements of a P&ID can be categorized into symbols, text, and lines. Symbols denote components such as valves, instruments, and controllers, while lines represent pipelines and signal connections. The digitization of unstructured P&IDs typically involves three main stages: object recognition, topological reconstruction, and digital P&ID generation. This paper reviews recent advances in line recognition techniques for P&ID digitization and introduces the line recognition approach developed by the research group of Prof. Duhwan Mun. Finally, future research directions are discussed.

Acknowledgment: This research was supported by the Machinery and Equipment Industry Technology Development Program (RS-2025-25449384) funded by the Ministry of Trade Industry & Energy (MOTIE, Korea) and by the Design Industry Technology Development Program (No. RS-2025-04752997) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea).”

Swelling-Programmed Topography for Scalable and Size-Controlled Spheroid Manufacturing

Seon Yeong Chae, Dong-Wook Han, Suck Won Hong

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Abstract

Precise and reproducible three-dimensional (3D) cell culture is a core requirement in advanced biomanufacturing; however, achieving uniform spheroid formation across diverse cell types, particularly those with weak intrinsic cohesion, remains a significant challenge. In this study, we present an integrated manufacturing pipeline that combines a dynamic micropatterned hydrogel substrate with a portable microfluidic system to enable controlled spheroid formation and size regulation for standardized tumor modeling. We developed a micropatterned interpenetrating polymer network (IPN) hydrogel engineered as a mechanochemical niche. This platform utilizes swelling-mediated topographical evolution, in which line-patterned grooves progressively narrow upon hydration. This dynamic transformation enhances local cell–cell interactions while preserving sufficient space for cell migration. As a result, robust and uniform spheroid self-assembly was achieved in both weakly aggregating L929 fibroblasts and HCT116 colorectal cancer cells. Mechanistic analysis revealed that these topographical cues promote collective compaction and upregulate extracellular matrix (ECM) and adhesion-related gene expression, thereby enhancing structural integrity and physiological relevance. Transcriptomic profiling and drug sensitivity analysis further demonstrated that the resulting spheroids recapitulate in vivo-like drug resistance, including reduced sensitivity to chemotherapeutic agents such as doxorubicin and paclitaxel. To address size heterogeneity, we also developed a hand-powered centrifugal microfluidic platform that selectively enriches spheroids within a defined size range (150–250 _m) without motors or electronic components, enabling high-throughput and reproducible processing. Therefore, this integrated system highlights the potential of swelling-responsive hydrogels as programmable materials for advanced manufacturing of functional cellular assemblies and engineered microenvironments. Also, it can serve as a powerful tool for future drug screening and the transition to organoid-based industries, and can be scaled into a functional bio-interface.

Analysis and optimization of load-bearing performance of various lattice materials fabricated by additive manufacturing

Xiaocui Yang, Qi Shi, Haichao Song

Nanjing University of Industry Technology

Abstract

In this study, 6 lattice structures were selected as the research objects, which included body-centered cubic, diamond, kelvin, octahedron, octet truss, and primitive cubic. The finite element simulation models were constructed, and the load-bearing performance of various lattice structure was analyzed under the uniform conditions for structural size and material property. It could be concluded form the distribution of stress that for the tensile strength, the diamond lattice structure can yield best result because of its highest covalent bond strength; for the compressive strength, the octet truss lattice structure is the best, since the generated deformation in it during compression process was dispersed throughout the whole structure rather than concentrated locally; for the flexural strength, the best result was also gained by the octet truss lattice structure for its high specific stiffness, which made the distribution of stress more uniform during bending; for the torsional strength, the performance of octet truss lattice structure is the best as well because of the axial arrangement of its members, and the distribution of shear stress was uniform and less prone to shear failure during torsion; for the shear strength, the body-centered cubic lattice structure can achieve the best result because of its multiple slip systems, and the distribution of the stress was more uniform during shear. Based on the bearing performance requirements of a certain application scenario, the optimal parameters of composite structure of these 6 lattice structures were obtained by joint optimization by particle swarm algorithm and finite element simulation model. The actual sample with photopolymer material was fabricated by using stereolithography technology, and its load-bearing performance was tested with the universal material testing machine. The experimental data showed good consistency with the simulation results, which proved the accuracy of simulation model and the effectiveness of optimization algorithm.

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3D-Printed Multichannel Scaffolds Enable Guided Neural Regeneration through Integrated Structural and Molecular Design

Jingjia Ye, Fenglu Li, Jin Zhang, Wei Wei

The Fourth Affiliated Hospital, International School of Medicine, Zhejiang University

Abstract

Additive manufacturing provides unprecedented opportunities to create complex biological structures; however, achieving precise control over both structural organization and biological function remains a significant challenge. Here, we present a multichannel 3D-printed scaffold that combines structural guidance with bioactive and molecular regulation for directed neural regeneration. The scaffold includes parallel microchannels fabricated through high-resolution printing, along with a bioactive hydrogel and a small interfering RNA (siRNA) delivery system. This integrated approach enables simultaneous modulation of the injury environment, enhancement of intrinsic axonal growth capacity, and precise topographical guidance of regenerating axons. In a spinal cord injury model, the engineered construct facilitated strong and aligned axonal regeneration, reduced inflammation, and markedly improved functional recovery. Importantly, the multichannel structure played a critical role in guiding axons along defined trajectories, demonstrating how manufacturing-designed structures can influence biological organization and function. This work showcases a versatile strategy for integrating material design, structural engineering, and molecular regulation, offering new insights into precision biofabrication for complex tissue regeneration.

Rethinking Design for Multi-Material Printing: Bridging Digital Models and Fabrication with OpenVCAD

Charles Wade and Robert MacCurdy

University of Colorado Boulder

Abstract

Additive manufacturing has rapidly advanced to enable the precise deposition of multiple materials within a single part, offering unprecedented opportunities for functionally graded and multi-material designs. As these capabilities expand, there is growing demand for software tools that allow engineers and researchers to design objects where composition, color, or mechanical properties vary continuously through space. However, current computer-aided design and slicing workflows are largely surface-based, describing shapes with discrete boundaries rather than continuous volumetric data. Surface-based design makes it difficult to specify, visualize, and fabricate functionally graded components. An additional challenge with volumetric design is supporting diverse printing modalities such as material jetting and material extrusion. This talk introduces OpenVCAD, an open-source, Python-based library for volumetric multi-material design and fabrication. OpenVCAD allows users to define both geometry and material distributions as implicit functions, supporting complex, continuous gradients that can be realized on a range of additive manufacturing systems. The framework supports inkjet printing, material extrusion (including mixing and functionally graded process parameters), import and export with simulation packages, and mesh export. Support for a variety of export types connects volumetric design to real-world fabrication workflows. Through a series of demonstrations, we will highlight applications that span soft robotics, 3D-printed pre-surgical planning models, functionally graded materials, and compliant mechanisms. OpenVCAD is designed to be modular and extensible, encouraging community contributions that expand its capabilities through new modules, workflows, and applications. Attendees will learn how to get started using OpenVCAD in their own workflows and gain practical insights into applying volumetric design to real-world multi-material printing challenges. These examples showcase how OpenVCAD unifies design intent and fabrication and empowers users to generate functionally and physically sophisticated volumetric objects. By lowering the barrier to volumetric design, OpenVCAD enables the additive manufacturing community to fully leverage the multi-material potential of modern 3D printing systems.

Electrolyte-Defined Metal Growth for Confined Electrochemical Additive Manufacturing

Daniel Jee Seng GOH, Wai Yee YEONG

School of Mechanical and Aerospace Engineering, Nanyang Technological University

Abstract

Electrochemical additive manufacturing (ECAM) approaches typically initiate growth from conductive interfaces and require dynamically formed deposition pathways throughout fabrication, limiting their use in embedded or structured environments. In this work, we explore an alternative approach where metallic structures form through directed propagation within confined electrolyte pathways, reducing reliance on a continuous seed layer along the intended growth path. We investigate the dynamics of copper growth under controlled electrical excitation. Time-resolved observations reveal a characteristic transition from an initial induction stage to sustained directional propagation of a conductive filament toward the counter electrode. The process is found to be sensitive to electrical and physicochemical conditions, with distinct regimes of stable growth and instability emerging depending on the operating parameters.

Beyond kinetics, the morphology of the deposited structures is found to transition between filamentary and path-filling regimes depending on electrolyte composition and waveform conditions. The incorporation of polymeric additives enables control over growth trajectory and confinement, suggesting a route toward soft manufacturing environments. These findings highlight electrolyte-defined metal propagation as a new mode of ECAM, distinct from conventional seeded-path approaches, and provide a framework for future translation toward embedded and gel-based fabrication systems.

Enhanced mechanical properties of laser directed energy deposition (LDED) pure titanium with trace interstitial oxygen solute

Ziheng Tang, Xiaotong Pang, Yulei Feng, Kaiming Wang, Xixi Ji, Xiaofei Luo, Jian Zhang, Mingjun Zhang, Ling Tang, Taiqi Yan

Changsha University of Science and Technology

Abstract

Laser directed energy deposition (LDED) commercially pure titanium (CP-Ti) is frequently limited by a relatively lower strength. The introduction of more interstitial oxygen (O) solute has enabled significant improvement in strength but leads to reduced plasticity. This study systematically investigates the effect of trace oxygen addition (~0-495 ppm) on the microstructure and mechanical behavior of LDED Ti-O alloys via in-situ powder blending. The results revealed that the as-deposited samples exhibited refined prior- _ grains and acicular _-lath with increasing oxygen addition. Yield strength (YS) and ultimate tensile strength (UTS) increased monotonically with oxygen addition, whereas elongation (EL) exhibited a non-monotonic dependence. LDED Ti-O alloy at an intermediate oxygen addition (~165 ppm, named Ti2) possessed the optimal strength-ductility synergy with an UTS of 568 MPa and an EL of 27.9%, compared with LDED CP-Ti with an UTS of 463 MPa and an EL of 18.7%. A quantitative strengthening analysis elucidated that _-lath refinement and solid-solution strengthening dominated the improvement of strength. EBSD analysis of fractures indicated that the ductility improvement of LDED Ti2 alloy was associated with the activation of {10-12} deformation twining that enhanced strain hardening and delayed the necking. At higher oxygen addition (~495 ppm), twinning was suppressed and dislocation mobility became more constrained, promoting strain localization and reducing ductility. These results provide guidance for designing LDED Ti-O alloys with enhanced mechanical properties for structural and biomedical applications.

Enhanced High-Temperature Strength of Additively Manufactured Al-La-Sc-Zr Alloy via a Stable Nanoscale Eutectic Cellular Network

Mingliang Wang

Shanghai Jiao Tong University

Abstract

Metallic materials generally undergo substantial strength degradation at elevated temperatures. Traditional strengthening approaches, which depend on the dispersion of thermally stable particles, show limited efficacy due to the difficulty in inhibiting thermally activated dislocation motion. In this study, a novel strategy is proposed to achieve exceptional high-temperature strength by constructing a thermally stable nanoscale eutectic cellular network (ECN) through additive manufacturing. A near-eutectic Al-La-Sc-Zr alloy was developed specifically for laser powder bed fusion, featuring an Al-La nanoscale ECN and dense intracellular nanoprecipitates. This alloy exhibits excellent printability and remarkable high-temperature yield strength above 0.6Tm (~250 MPa at 300 °C), which is 2–5 times higher than that of conventional aluminum alloys, with minimal strength degradation after long-term annealing. In contrast to the traditional particle dispersion structure, the nanoscale ECN architecture improves load-bearing capacity and reinforces the aluminum matrix by confining dislocation motion within ultrafine cells (~200 nm), thereby effectively alleviating intrinsic high-temperature softening. This transformative method opens up new avenues for the design of next-generation heat-resistant alloys and expands the application potential of additive manufacturing in high-temperature scenarios.

Grayscale Digital Light Process 3D Printing as a Platform for Shape-Morphing Structures and 4D Printing

Farzad Gholami, H. Jerry Qi

Georgia Institute of Technology

Abstract

3D printing (additive manufacturing, AM), where materials are deposited in a layer-by-layer manner to form a 3D solid, has seen significant advances in recent decades. Multimaterial 3D printing has attracted significant research efforts in recent years, especially in the domain of multifunctional and shape-morphing structures, as these structures typically require the integration of heterogeneous materials. In this talk, we present our recent progress in developing grayscale digital light processing (g-DLP) 3D printing as a platform for multimaterial additive manufacturing methods, which can serve as a platform for multifunctional and shape-morphing structures. In g-DLP, we use light intensity to control local properties, thereby creating structures with gradient material properties, including stiffness and conductivity. This enables to rapidly fabricate parts with built-in sensing capability. We further investigate how to use machine learn to help the inverse design of 4D printing of shape-morphing structures with multimaterial additive manufacturing. At the end, we also discuss future work on g-DLP 3D printing.

Organoid Pan-omics Mechanism of Osteoporosis Caused by irregular rhythm Combined with Mechanical Unloading

Chong Yin, Kaiyuan Zheng, Guilin Luo, Hongqi Han

Affiliated Hospital of North Sichuan Medical College, Nanchong, Sichuan, 637000, P.R.China North Sichuan Medical College, Nanchong, Sichuan, 637000, P.R.China

Abstract

Osteoporosis poses a major threat to human health. Investigations have revealed that in populations with certain special occupations and lifestyles, mechanical unloading accompanied by disrupted circadian rhythms can lead to osteoporosis, with some key molecules may play important roles in this physiological process. Our preliminary research also found that in a mouse model of mechanical unloading induced by tail suspension, irregular circadian rhythms could exacerbate osteoporosis symptoms. In this process, the cytoskeleton molecule PLEC promoted osteogenesis through the circadian clock signaling pathway via liquid–liquid phase separation. However, its underlying molecular mechanism remains to be elucidated.

To further elucidate its mechanism, we performed single-cell RNA-seq, single-cell transposase-accessible chromatin sequencing (ATAC-seq), and proteomics analysis on bone marrow mesenchymal stem cells (BMSCs) extracted from Hind limb unloading (HLU) mice with circadian rhythm disruption, along with metagenomic sequencing of mice gut microbiota. RNA-seq and proteomics analyses were performed on osteoblast treated with RPM mechanical unloading. Single-cell RNA-seq, single-cell ATAC-seq, and proteomics analyses were also made on osteoblast cultured in organoids with different mechanical strength. We further conducted investigations on the regulatory mechanisms of PLEC phase separation on osteogenic differentiation during mechanical unloading. The results showed expression of PLEC, belonging to the plakin family, was decreased by mechanical unloading. Both mechanical unloading and circadian irregular rhythm can inhibit PLEC phase separation, which presented a synergistic effect. PLEC enhances bone formation via its phase separation, and the location of PLEC phase separation in osteoblast was proved as ribosome by Co-IP-LC/MS and duolinker-PLA staining. We further analysed the binding mRNA of PLEC by RIP-seq, and multiple circadian signaling factors, including CLOCK, Arntl, Period1-3, CRY1/2, ect. The mRNA expression of circadian signaling factors was not affected by PLEC expression or phase separation, while protein level and transcription activity was significantly enhanced, suggested PLEC phase separation facilitated circadian signaling factor translation. Moreover, the functional region of amino acid (aa) 1967-2185 in PLEC demonstrated therapeutic effect on mechanical unloading/irregular rhythm osteoporosis mice and also enhanced protein level and transcription activity of circadian signaling pathway.

This study have discovered a novel regulatory mechanism combining mechanical unloading and irregular rhythm. The study also provided new insights for potential therapeutic strategies of osteoporosis.

Fundamental Research and Technological Exploration of Food 3D Printing

Nana Zhang, Zilong Zhao, Yu Liu, Daming Fan

Jiangnan University

Abstract

Food 3D printing is recognized as one of the essential pathways for driving the transformation of the food industry from “traditional large-scale supply” to “personalized nutrition and flexible manufacturing”. However, current food 3D printing technology still lags behind mainstream 3D printing technologies such as stereolithography and fused deposition modeling in terms of materials and technological maturity. To address these challenges, our team has conducted systematic and in-depth research on the raw materials, technologies, and equipment used in food 3D printing. Initially, we systematically investigated the printability of various ingredients, including proteins, starches, and microalgae, and established a database and machine learning models for food 3D printing materials, enabling precise prediction of printing parameters. Furthermore, we developed several pioneering technologies for food applications, including microwave-assisted in-situ solidification, multi-material continuous precise switching printing, and high-throughput biomimetic fabrication. Building on these innovations, we explored printing pathways, online information collection, and feedback systems, achieving preliminary success in flexible adaptive control during the printing process. These efforts contribute to the development of intelligent food 3D printing systems, thereby advancing the engineering processes of food 3D printing.

Investigating and mitigating protrusion-induced powder bed anomalies in laser powder bed fusion

Kanishka Chamod [a, b], Yunlong Tang [a, b, c], Chun kit sit [a, c], Qiong Wu [a]

a: Monash Center for Additive Manufacturing (MCAM), Monash University, Victoria, Australia, b: Department of mechanical and aerospace engineering, Monash University, Victoria, Australia, c: Department of material science and engineering, Monash University, Victoria, Australia

Abstract

This study investigates the influence of protrusions, typical in-process defects arising on features like thin walls, overhangs, and lattices on powder spreading quality in Laser Powder Bed Fusion (LPBF). The work aims to understand how surface irregularities from previous layers affect powder uniformity and packing, ultimately impacting part quality. A parametric simplification model is proposed to geometrically characterize protrusions and analyze their effects on powder bed quality indicators. The Discrete Element Method (DEM) is employed to validate the model and explore the relationship between protrusion parameters (height, shape) and powder distribution metrics. Additionally, physical experiments are conducted to support simulation results and observe powder spreading with recoater-protrusion interactions. The study reveals that protrusions significantly disrupt powder packing, leading to localized anomalies during spreading. Geometric parameters, particularly protrusion height and peak width play a dominant role in influencing these disruptions. Reducing the recoating speed effectively diminishes the extent and severity of anomalous zones, especially for lower-height protrusions, thereby improving powder coverage and packing density. These enhancements contribute to minimizing downstream defects such as keyhole porosity during laser melting. This research uniquely highlights the critical role of underlying surface defects on powder spreading. By combining parametric modeling, DEM simulation, and experimental validation, the study offers actionable insights for in-situ control strategies to adapt recoating speed and enhance build quality in LPBF.

3D printing forerunning futuristic spinal implant material research

Naresh Kumar, Si Jian Hui, Lionel Yan Jin Lee, Gabriel Zi Hui Leow, Jerry Ying Hsi Fuh, A. Senthil Kumar

Department of Orthopaedic Surgery, National University of Singapore

Abstract

The global aging population has led to an increasing detection of osteoporosis and metastatic spine disease necessitating the exploration of advanced spinal implants with strong synergy in mechanical, biological, radiological, and processible properties. We present our studies on an advanced spinal implant material that has benefited from the versatility of 3D printing at material iteration and prototype fabrication.

A pellet-based extrusion printing system was utilized to process our mix of materials involving Polyetheretherketone (PEEK) as the base coupled with hydroxyapatite (HAp) and magnesium orthosilicate (Mg2SiO4) additives. This allowed for the iterative design of several implant material compositions that balance the key desired properties of spinal implants, particularly mechanical and biological.

Mechanical feasibility of the materials was assessed through tensile, compression, and flexion, while biocompatibility was assessed through cell-culturing evaluations. In addition, prototype pedicle screws of our advanced materials were fabricated by 3D printing and subjected to standard mechanical tests of ASTM F543. Radiological imaging with computed tomography (CT) and magnetic resonance (MR) imaging, and radiotherapeutic accuracy were also assessed in alignment with the growing need for radiolucent implants in metastatic patients.

Our findings show the expected increase in biological activity with the bioactive additives, but the increase in additives generally reduced failure strength. HAp delivers stable responsiveness to biological performance while Mg2SiO4 exhibits interesting trends between total additive and Mg2SiO4 compositions. Radiological evaluations showcase massive benefits of our composite with superior dosimetric accuracy during radiotherapy and clearer imaging quality during CT and MR scanning.

Through this study, we showcase the advantages of employing 3D printing at efficiently designing materials for futuristic implants that possess key mechanical designs, biological viability, radiological compatibility, and material processibility. As we continue to refine the adoption of additive manufacturing into biomaterial development, we anticipate greater fidelity in replicating complex structures and improved scalability.

AI-Based Line Recognition in Piping and Instrumentation Diagrams

Yoochan Moon, Ji-Beob Kim, Sangwook Park, Seung-Tae Han, Duhwan Mun

Korea University

Abstract

“A Piping and Instrumentation Diagram (P&ID) is a fundamental engineering document that represents the interconnections among piping, valves, instruments, and control devices in process plants. It plays a critical role throughout the plant lifecycle, including design, operation, and maintenance, by providing essential information on process flow and control logic. From the perspective of information representation, the elements of a P&ID can be categorized into symbols, text, and lines. Symbols denote components such as valves, instruments, and controllers, while lines represent pipelines and signal connections. The digitization of unstructured P&IDs typically involves three main stages: object recognition, topological reconstruction, and digital P&ID generation. This paper reviews recent advances in line recognition techniques for P&ID digitization and introduces the line recognition approach developed by the research group of Prof. Duhwan Mun. Finally, future research directions are discussed.

Acknowledgment: This research was supported by the Machinery and Equipment Industry Technology Development Program (RS-2025-25449384) funded by the Ministry of Trade Industry & Energy (MOTIE, Korea) and by the Design Industry Technology Development Program (No. RS-2025-04752997) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea).”

Harnessing Biofabrication to Engineer Skeletal Tissue Microenvironments and Control Stem Cell Function

Gildacio Filho, Patricia dos Santos, Fraser Shields, Marco Domingos

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Abstract

Skeletal tissues such as bone, cartilage and meniscus are characterised by highly organised extracellular matrix (ECM) microenvironments that regulate cell behaviour and maintain tissue function. Replicating these complex and hierarchical environments remains a major challenge in musculoskeletal research and regenerative medicine. Recent advances in biofabrication are enabling the engineering of tissue microenvironments with controlled structural, mechanical and biochemical properties, offering new routes to direct stem cell function and, ultimately, tissue ingrowth. In this talk, I will present our group's work on the development of tunable biomaterials and bioinks designed to recapitulate key features of the native ECM, enabling precise control over cell-material interactions and guiding stem cell differentiation and matrix production in skeletal tissues. By integrating multiple manufacturing approaches - including extrusion-based bioprinting, melt electrowriting and material jetting - we demonstrate how constructs with defined architectural and functional organisation can be fabricated to better replicate tissue complexity. These hybrid biofabrication strategies open new opportunities to develop physiologically relevant models for studying skeletal tissue development and regeneration. I will also discuss emerging directions aimed at improving the scalability and translational potential of these technologies, including the development of storable, off-the-shelf bioinks. Ultimately, this talk demonstrates how biofabrication - and bioprinting in particular - can be harnessed as powerful manufacturing platforms to support the development of next-generation regenerative therapies for skeletal applications and beyond.

Leaf Biowaste–Derived Conductive Platforms for Biodegradable Wearable Electronics and Direct-Current Triboelectric Energy Harvesting toward Sustainable Circular Electronics

Min-Hsuan Lee

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Abstract

Electronic waste (e-waste) and agricultural biomass burning represent two major environmental challenges, contributing to toxic contamination, carbon emissions, and severe air pollution. Developing biodegradable electronic systems based on circular economy principles offers a promising strategy to mitigate these issues. In this work, we present a sustainable and multifunctional platform based on biomass-derived leaf skeletons (Ficus religiosa), serving simultaneously as a biodegradable substrate, conductive electrode, and triboelectric active layer. A high-performance conductive network was established by integrating poly(3,4-ethylenedioxythiophene):polystyre ne sulfonate (PEDOT:PSS)-based nanocomposites onto the hierarchical leaf vein structure via a simple and scalable drop-casting process. The resulting biodegradable conductor exhibits a low sheet resistance of 2.4 ± 0.6 Ω sq^{-1} with a single coating step. Raman spectroscopy reveals that the enhanced electrical conductivity originates from the increased proportion of the quinoid structure in PEDOT chains, facilitating efficient charge transport. Leveraging the intrinsic micro/nano-porous architecture of the leaf veins, the conductive leaf was further utilized to construct a direct-current triboelectric nanogenerator (DC-TENG). The device achieves a peak output current of 330 μA and an open-circuit voltage of 1.2 V, demonstrating competitive energy harvesting performance. The naturally evolved vein network provides abundant contact electrification sites while ensuring mechanical flexibility and environmental compatibility. Beyond energy harvesting, the conductive leaf platform also enables multifunctional applications, including electrocardiogram (ECG) electrodes and flexible strain sensors, highlighting its versatility for wearable bioelectronics. As a proof of concept, the leaf-based DC-TENG was integrated into a smart human–computer interface system (computer mouse), demonstrating effective biomechanical energy harvesting during sliding motion. This work establishes a unified strategy for transforming agricultural leaf waste into high-value biodegradable electronic systems, offering a scalable, low-cost, and environmentally responsible pathway toward battery-free wearable devices and next-generation green electronics. The proposed platform directly supports the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 12 (Responsible Consumption and Production).

Effects of femtosecond laser texturing on the corrosion resistance of 316L austenitic stainless steel fabricated by binder jetting

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Abstract

Binder jetting (BJT) is a sinter-based additive manufacturing (AM) process with a low machine cost and high manufacturability. However, BJT-printed materials exhibit a high porosity compared to beam-based AM-printed materials, resulting in low mechanical properties and corrosion resistance. To improve the corrosion resistance, superhydrophobic surfaces inspired by nature have attracted great attention. To achieve super-hydrophobicity, femtosecond laser treatment (FLT) has emerged as a precise, controllable, and environmentally friendly approach for creating micro/nano structures with minimal thermal damage. This study focuses on the impact of FLT on BJT-printed 316L austenitic stainless steel, as-printed and after hot isostatic pressing (HIP), and compares them with conventionally manufactured (CM) 316L. Hierarchical micro-nano surface architectures were produced by FLT through alternating horizontal and vertical scanning patterns, with total scanning cycles of 200, 400, and 800 laser passes, corresponding to low-, medium-, and high-depth textures, respectively. As a result, the contact angle of untreated samples was 105 degrees and increased to over 150 degrees through the femtosecond laser treatment, resulting in surfaces considered superhydrophobic. Corrosion rates correlated directly with increasing surface roughness, following the order low-depth < medium-depth < high-depth. With the rapid and continuous development of bionic theory and technology, this superhydrophobic surface fabricated by femtosecond laser treatment is expected to provide a new and effective approach for metal corrosion protection.

A toolpath-driven digital framework for 3D concrete printing of bio-inspired TPMS breakwater blocks for sustainable coastal protection

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Abstract

Additive manufacturing is enabling the fabrication of architectured concrete structures with geometries that are unattainable using conventional construction methods. In coastal protection, bio-inspired triply periodic minimal surface (TPMS) structures offer high porosity, favourable strength-to-weight ratios, and improved wave energy dissipation, making them promising candidates for next-generation breakwater systems. However, the reliable fabrication of such complex geometries using 3D concrete printing (3DCP) remains challenging due to toolpath-dependent loading and the time-dependent mechanical behaviour of freshly printed materials. This study proposes a toolpath-driven digital design-to-fabrication framework that integrates parametric geometry generation, hydrodynamic performance evaluation, and automated modelling of the 3DCP process. TPMS geometries are first parametrically designed and configured into modular breakwater units, and their hydrodynamic performance is assessed using computational fluid dynamics simulations. To bridge the gap between digital design and physical fabrication, the actual printing toolpath extracted from G-code generated by slicing software is directly incorporated into a finite element modelling framework to simulate the sequential layer-by-layer deposition process. The framework accurately predicts buildability and failure mechanisms, including elastic buckling and plastic collapse, in representative printed geometries, while parametric analyses reveal the critical influence of printing parameters such as printing speed and extrusion width on structural stability. The feasibility of the workflow is further demonstrated through the successful fabrication of TPMS breakwater prototypes, validating the transition from computational toolpath modelling to physical production. The proposed approach establishes a robust digital pipeline for the design and fabrication of complex architectured concrete structures and highlights the importance of toolpath-informed modelling in advancing large-scale concrete additive manufacturing for sustainable coastal protection infrastructure.

Keywords: 3D concrete printing; additive manufacturing; toolpath-based modelling; TPMS; bio-inspired breakwater; coastal protection.

Generative Design and LPBF Manufacturing of a Patient Specific Bone Plate for High Tibial Osteotomy

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Abstract

Varus malalignment is a major mechanical factor in medial compartment knee osteoarthritis, increasing medial joint loading and accelerating cartilage degeneration, pain, and functional decline. High tibial osteotomy (HTO) is commonly used to correct this malalignment and shift load away from the affected compartment. In open wedge HTO, a bone plate is required to stabilise the osteotomy gap and provide a suitable mechanical environment for bone healing. Patient-specific bone plates have shown potential to improve surgical outcomes, including reduced operation time, less blood loss, and better anatomical fit. However, current design approaches usually depend on 3D reconstruction and prolonged collaboration between surgeons and engineers, which can be time-consuming and costly. This study proposes a generative design based workflow for patient-specific bone plates for HTO. In this workflow, surgeons define key design features, such as screw hole positions and plate geometry, and these inputs are used as constraints for the generative design process to produce feasible plate designs automatically. The proposed workflow aims to reduce dependence on repeated engineering input while increasing surgeon involvement in the design process, improving both efficiency and clinical trust. The final patient-specific plate will be manufactured using laser powder bed fusion (LPBF). Its mechanical and clinical potential will then be evaluated through comparison with a standard commercial plate. This study demonstrates the potential of generative design and metal additive manufacturing to enable efficient development of patient-specific HTO plates, and may provide a useful pathway for other orthopaedic fixation applications.

Microstructure-Driven Strain Hardening and Strength in Additively Manufactured Titanium Alloys

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Abstract

Strain hardening is a critical property of metals and alloys, governing their mechanical processability, structural reliability, and long-term durability in service. However, conventional titanium alloys widely used in structural applications typically exhibit limited strain-hardening capacity, which constrains their broader implementation in demanding engineering environments. In this talk, we show that additive manufacturing (AM) can enable the simultaneous achievement of strong strain hardening and high strength in a commercially available titanium alloy. These exceptional properties originate from a martensitic microstructure formed during the AM process. The microstructure consists of nanoscale martensite plates containing ultrafine triple-twinned substructures. During tensile deformation, the dominant mechanism is detwinning rather than conventional dislocation slip. This process progressively transforms the initial structure into single-twinned lamellae with twin boundary spacings of ~10 nm and embedded stacking faults. The gradual microstructural evolution requires increasing applied stress, thereby generating pronounced strain hardening. These findings highlight a pathway for designing high-performance titanium alloys through additive manufacturing–enabled microstructural control.

Multi-scale Multi-physics Numerical Simulation Study of Laser Powder Bed Fusion Process

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Abstract

Laser Powder Bed Fusion (LPBF) stands as one of the most promising metal additive manufacturing technologies for directly forming complex precision metal parts. It achieves part densities exceeding 99.9%, surface roughnesses of 20-30_m, and dimensional accuracies within ±50_m. However, ensuring the repeatability of the forming process and the reliability of part quality has remained the greatest challenge facing LPBF, becoming the primary bottleneck constraining the large-scale application of LPBF technology. Numerical simulation technology, as a quantitative and visual research tool, can assist in revealing the evolution patterns and control mechanisms of LPBF. To this end, our research team has pursued four key research directions centered on LPBF technology: 1) At the mesoscale, we have conducted in-depth investigations into the effects of powder spreading, molten pool flow, process parameters, scanning strategies, multi-laser systems, and multi-material configurations on build quality, with a particular focus on defect evolution such as porosity, spatter, and powder bed erosion; 2) At the macroscale, we simulate thermo-mechanical coupling behavior to reveal deformation and residual stress distribution in full-scale components during fabrication; 3) At the microscale, we predict 2D/3D microstructure evolution using phase field-finite element coupling; 4) In cutting-edge methodologies, we introduce Physically Informed Neural Networks (PINNs) for rapid real-time prediction of molten pool thermal-fluid behavior. The four research directions above are mutually reinforcing, aiming to systematically reveal the complex physical mechanisms and defect evolution patterns during the LPBF forming process through the deep integration of multi-scale, multi-physics numerical simulations with cutting-edge artificial intelligence technologies. This approach provides robust support for advancing LPBF technology from an “empirical trial-and-error” approach toward intelligent precision forming that is both predictable and controllable.

Advanced manufacturing of metal matrix composites for thermal management applications

Asuka Suzuki, Tsubasa Aoki, Yuya Masuda, Kazuki Nakamura, Mizuki Hasegawa, Konatsu Hayashi, Makoto Kobashi

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Abstract

Thermal management is a critical issue for emerging artificial intelligence (AI) data centers and electric automobiles. Materials with high thermal conductivity are required for these applications. Carbon fiber (CF) and diamond exhibit high thermal conductivity. Therefore, metal matrix composites reinforced by CF or diamond are promising thermal management materials. However, these composites exhibit poor deformability and are difficult to form into complex shapes. Additive manufacturing (AM) has emerged as an advanced manufacturing process for producing complex-shaped parts through layer-by-layer fabrication. AM processes enable the fabrication of complex-shaped composites. In this presentation, strategies for producing metal-matrix CF- or diamond-reinforced composites will be introduced. Laser powder bed fusion (L-PBF), which is the most representative AM process, repeats the powder bedding and laser scanning. The L-PBF of CF/Al composites has been attempted but is difficult due to the high reactivity between CF and Al, as well as the sublimation of CF with a high laser absorptivity. To solve these problems, we coated a TiC layer on CF through the molten salt method. Subsequently, single laser scan experiments and L-PBF processing were carried out. As a result, it was demonstrated that a process window for fabricating the CF/Al composite was opened by the TiC coating. Binder jetting (BJT) involves powder spreading and binder injection onto the powder bed. To impart sufficient strength, BJT-built parts are subsequently degreased and sintered at elevated temperatures. However, the green body consisting of diamond particles is difficult to sinter. Therefore, we focused on a pressureless melt infiltration process, in which a metal melt is spontaneously infiltrated into green bodies by capillary force. In this study, Mg melt was infiltrated into a diamond/Ti powder mixture to produce Diamond/Mg composites. It was clarified that the addition of Ti forms TiC at the diamond/Mg interface, supporting the Mg melt infiltration.

Microalloying during Laser Powder Bed Fusion and Laser Metal Deposition: Key technologies to a sustainable production of Shape Memory Alloy devices.

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Abstract

Shape memory alloys (SMA) exhibit the specific properties of shape memory and superelasticity, thanks to a thermoelastic martensitic transformation, and have found number of applications as sensors and actuators in many industrial sectors from robotic and biomedical to aeronautic and aerospace, for instance. Nowadays, the new technologies of additive manufacturing (AM) offer new capabilities for the production of near-net-shape active devices, being also envisaged as a promising technology for the future production of SMA actuators directly in the space.
However, the extremely high sensitivity of the SMA transformation temperatures to the alloy composition makes difficult the control of the final performances of the SMA component and prevents a good industrial productivity.

To solve this challenging problem, in the present work a new methodology of microalloying the SMA powders is introduced in two key technologies: at the melt-pool during AM by Laser Powder Bed Fusion (LPBF) and in the injection gun during Laser metal Deposition (LMD). Starting from the atomization of the SMA powders, the LPBF and LMD are optimized through the production parameters and post-processing treatments. The microstructure is characterized along the different steps of the complete process and the functional properties of shape memory and superelasticity are tested to evaluate the final performances of the AM produced component. The presented methodology has been successfully applied to the production of Cu-Al-based SMA, but it could be applied to any other SMA family.

The use of this microalloying technology allows a precise control of the final transformation temperatures of the SMA to fulfil the required specifications of the targeted applications. In addition, it offers a noticeable increase of the industrial productivity and, thinking on the next future of AM, it paves the road for the sustainable production of SMA components in the space.

Generative Design of Heat Exchangers for Additive Manufacturing with Manufacturability and Performance Awareness

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Abstract

Additively manufactured (AM) heat exchangers offer unprecedented geometric freedom for achieving high thermal efficiency, reduced weight, and compact form factors. However, designing high-performance heat exchanger geometries that are simultaneously manufacturable remains a major challenge due to complex thermal–hydraulic interactions and AM-specific constraints such as minimum feature sizes, overhang angles, and enclosed cavities. This paper presents a manufacturability- and performance-aware generative design framework for heat exchangers in AM. The proposed framework integrates surrogate modelling and diffusion-based generative modelling to automate the creation of high-performing and manufacturable heat exchanger geometries.

The workflow begins by constructing a large dataset of heat exchanger structures generated through parametric sampling of triply periodic minimal surface (TPMS) representations. Each design is evaluated through physic-based simulation in terms of thermal performance an manufacturability, such as thermal efficiency, pressure drop, along with manufacturability metrics relevant to AM processes. Surrogate models are then trained to approximate these metrics with near real-time inference while maintaining high predictive accuracy. These models are incorporated as guidance mechanisms within a diffusion-based generative model, enabling the performance-aware generation of novel heat exchanger geometries. Importantly, while the training dataset is derived from TPMS parameterizations, the generative model is not restricted to TPMS structures, allowing exploration of a broader design space. Manufacturability constraints are further enforced through geometry-aware filters and gradient-based penalties to ensure AM feasibility.

Results demonstrate that the proposed framework can (i) generate heat exchanger geometries with improved surface-to-volume ratios while maintaining manufacturability feasibility, and (ii) support multi-objective design exploration. Comparative studies show clear advantages over unguided generative baselines and conventional parametric design approaches. Overall, this work provides a generalizable AI-driven framework for the scalable, manufacturable, and high-performance design of heat exchangers for AM, offering a promising pathway toward next-generation thermal management solutions.

Alloy Design Paradigms in Additive Manufacturing

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Abstract

The advancement of alloys for Additive Manufacturing (AM) is critical to further boost the applications of AM for frontier areas. The first-generation alloys for AM largely rely on conventional commercial alloys that were originally developed under the assumption of near-equilibrium solidification. However, these materials are incompatible with the non-equilibrium metallurgical behavior of AM, which may face issues like high crack susceptibility. Hence, the second-generation alloy design for AM builds upon conventional alloy systems by inoculation treatments with alloying elements (e.g., Zr) or ceramic reinforcements (e.g., TiC) to achieve better material printability and properties. The third-generation empirical approach for material design adopts a knowledge-driven strategy by leveraging established metallurgical principles and empirical correlations to guide targeted composition optimization. Such trial-and-error strategies for discovering new materials face substantial bottlenecks like long development cycles and high costs. Hence, it has propelled research toward the fourth-generation paradigm—data-driven artificial intelligence (AI) assisted materials design for AM, which is an effective and innovative material solution guided by AM-specific metallurgical features. Advances in AI and robotics will shift the future paradigm of AM-specific alloy design toward an autonomous AI-Lab, which leverages an intelligent AM agent and automated high-throughput AM printing and testing for materials discovery.

Simple Chemistries for the Vat Photopolymerization of Advanced Materials

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Abstract

Additive manufacturing (AM) is one of the most powerful materials design tools available today. However, its utility in materials design is fundamentally limited by the materials that are compatible with it. There is thus incredible opportunity to think about how we can leverage chemical synthesis and materials science to expand the library of advanced materials compatible with additive manufacturing. Importantly, given the broad accessibility of AM, by designing chemistries and processes that are equally accessible, we can empower both the public and the larger scientific community with the advanced materials and devices needed to solve their own challenges. In this talk, I will discuss our approaches to materials design for vat photopolymerization (VP) additive manufacturing and highlight how simple chemistries can address some long-standing challenges in VP. In particular, I will show our recent advances in the field of polymer-derived materials and our emerging work on chemistry-driven reconfigurable structures. Together, these demonstrations underscore how the combination of chemistry and advanced manufacturing can enable substantial innovations in materials design, fabrication, and application.

Engineering Multifunctional Biomedical Scaffolds via Extrusion-Based Additive Manufacturing

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Abstract

“Additive manufacturing (AM) is enabling a shift in biomedical engineering from standardised implants toward patient-specific devices with precisely engineered structural and functional performance. This talk presents several of our studies investigating extrusion-based additive manufacturing, specifically fused deposition modelling (FDM) and direct ink writing (DIW), of polymer and composite biomaterials. The work establishes quantitative relationships between material formulation, processing parameters, microstructural architecture, and functional behaviour, while contributing to the foundation for future AI-assisted scaffold design.

Extrusion-based AM was used to fabricate scaffolds from biocompatible polymers including polycaprolactone (PCL) and polyvinyl alcohol (PVA) with controlled pore geometries and architectural gradients. Optimisation of processing parameters enabled scaffolds to achieve Young’s moduli exceeding 1 GPa while maintaining physiologically relevant porosity, demonstrating the importance of architectural control in balancing mechanical strength and biological transport. Direct ink writing was further applied to develop composite scaffolds composed of PCL, polyethylene oxide (PEO), and hydroxyapatite (HAp). Ink formulations exhibiting shear-thinning behaviour and rapid viscosity recovery enabled stable filament deposition and reliable fabrication of complex porous structures. These scaffolds showed tunable mechanical properties and supported incorporation of vancomycin, demonstrating the feasibility of combining structural support with localised drug delivery. Complementary development of physically cross-linked PVA double-network hydrogels enabled fabrication of soft biomaterials with tunable rheological and mechanical properties suitable for extrusion-based manufacturing. Systematic variation of microstructural parameters including porosity, pore size, and filament alignment demonstrated their direct influence on mass transport and drug release behaviour. Increased porosity enhanced release rates, while structural alignment governed diffusion pathways.

Collectively, these studies establish formulation-process-structure-property relationships across multiple AM platforms. The resulting datasets provide a foundation for AI-assisted optimisation and autonomous design of personalised biomedical devices for regenerative medicine and implantable drug delivery.”

Developing an in-situ process monitoring framework using acoustic signals and optical emission spectroscopy in Wire Arc Additive Manufacturing (WAAM)

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Abstract

Wire Arc Additive Manufacturing (WAAM) is a metal additive manufacturing technique that is capable of fabricating large-scale components efficiently, with minimal material waste and high deposition rates. However, the high deposition rates of WAAM demand high heat input to melt significant amounts of material, which can potentially result in flaws, such as pores. A porosity detection model, named Sparse-Wavelet Network (SWaN) was developed in the prior study. The model combined wavelet scattering with sparse principal component analysis (s-PCA) to predict porosity generated by turning off the shielding gas throughout the deposition process. Nonetheless, the model performed poorly in predicting unintended porosities simulated by partially choking the shielding gas flow. To address this challenge, the present study proposes an improved model: SWaN-λ. The improved model achieved better performance by integrating supplementary data obtained from optical emission spectroscopy (OES). The utilization of OES was designed to estimate the actual shielding gas condition during the process. In addition, the analytical results were benchmarked against images acquired through radiographic testing (X-ray computed tomography), thereby strengthening the robustness of the research findings. As a result, the newly developed SWaN-λ model demonstrated high prediction accuracy across various conditions. Moreover, the model offers interpretable results, as it is capable of indicating the important spectra lines of the OES data.

Laser powder bed fusion of NiTi: Shape memory effect

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Abstract

Additive manufacturing (AM) of nitinol shape memory alloys (SMAs) has gained increasing attention due to its geometric design freedom, which aligns well with the complex structural requirements of aerospace applications where SMAs are widely utilized. Laser powder bed fusion (LPBF) of Nitinol has been extensively investigated within this framework. Nevertheless, research efforts have predominantly focused on superelasticity, while the shape memory effect (SME) has received comparatively less attention. In this work, the SME has been systematically investigated. LPBF-fabricated equiatomic Nitinol specimens with a total elongation exceeding 10% were subjected to different levels of pre-strain. A total recovery strain of ~7% was achieved with a pre-strain of 8%. With increasing pre-strain, the total recovery strain upon heating increased correspondingly. The one-way SME was enhanced with higher pre-strain levels, while the residual strain remained approximately 1%, independent of the applied pre-strain when the pre-strain is larger than 6%. The high dislocation density generated during the LPBF process contributes to the observed irrecoverable strain. The two-way SME can be enhanced by the full cycle training but not the thermal cycle training. Both tensile and bending specimens showed a progressive increase in two-way SME with cycling, before reaching a stable value. The fact that the two-way SME develops only when a load is applied during training implies that an external driving force is necessary to facilitate the martensitic transformation.

4D Printing of Gastroretentive Drug Delivery Systems Using Sustainable PVA–Natural Cellulose Composites

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Abstract

Despite growing interest in four-dimensional (4D) printing for pharmaceutical applications, most reported gastroretentive drug delivery systems (GRDDS) remain limited in practical performance. Many shape-transformable GRDDS exhibit short gastric residence times and frequently rely on external devices, such as capsules, to enable oral administration. To address these limitations, this study developed a shape-memory composite based on poly(vinyl alcohol) (PVA) and bamboo-derived natural cellulose as the primary structural matrix for fused deposition modelling (FDM). Bamboo cellulose functioned as a mechanical modifier, markedly improving filament flexibility and printability, required for reliable 3D printing.

A novel “turbine-to-tablet” dosage form was designed with a turbine-like permanent geometry and thermally programmed into a compact tablet configuration suitable for oral administration. The base matrix, comprising PVA and 15% w/w bamboo cellulose, was optimised with 5% w/w mannitol as a plasticiser and 10% w/w propranolol hydrochloride as a model drug. Drug release was further modulated by incorporating 10% w/w of sustained-release agents, namely Eudragit® L100 or hydroxypropyl methylcellulose phthalate (HPMCP). Under simulated gastric conditions, the optimised systems successfully transformed from a compact tablet into their permanent turbine geometry. HPMCP-containing formulations exhibited superior shape recovery (52.34% within 30 min) compared with Eudragit® L100 (39.35% within 30 min). Both systems maintained buoyancy for up to 6 h, enabling dual gastroretention through initial floating–controlled by an 80% infill density–followed by geometry-based retention via expansion beyond the pyloric sphincter diameter. Drug release followed a biphasic profile, with approximately 80% released within 3 h and sustained release up to 24 h. Kinetic analysis (Korsmeyer-Peppas model, $R^2 > 0.999$) indicated Super Case II transport ($n = 0.90$-1.27).

Overall, this work demonstrates how design-driven 4D printing combined with sustainable composite materials can enable shape-transformable dosage forms with enhanced gastric retention and controlled drug release.

Waveform Optimization and Grayscale Binder Compensation for Furan-Resin Jetting Using an SG1024 Printhead in a Self-Built Sand-Mold Binder Jetting System

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Abstract

This study investigates how printhead driving waveforms govern the effectiveness of grayscale printing in sand-mold Binder Jetting and proposes a practical workflow to ensure grayscale commands correspond to predictable deposition outcomes. Despite the widespread industrial adoption of oil-based furan binders for sand casting, the proprietary and machine-specific nature of commercial BJ platforms leaves the waveform–droplet–powder interaction largely unquantified and difficult to reproduce; therefore, a self-built SG1024 system is required to systematically reveal a transferable process window for stable jetting and reliable grayscale-to-deposition mapping. Experiments were conducted on a self-built BJ platform equipped with a Fujifilm Dimatix StarFire SG1024 piezoelectric printhead, using an oil-based furan resin binder and a silica-sand powder bed (70–200 _m) blended with 50/30/10 _m fines. In grayscale printing, pixel intensity is intended to represent a controlled change in drop density / firing probability; however, this mapping collapses when the waveform produces unstable droplets. Typical failure modes include satellite droplets, missing/deflected drops, and drop-volume drift, which introduce nozzle-to-nozzle variation and nonlinearity between commanded grayscale levels and printed geometry (e.g., line broadening and corner rounding). To address this, the waveform design space of single-, double-, and triple-pulse excitations was explored using a screening-and-refinement strategy over key parameters (amplitude, rise/fall time, dwell time, pulse interval, and pulse count). Jetting quality was quantified by primary-drop velocity, drop-volume repeatability, satellite metrics, and missing-drop rate, and a feasible jetting window was identified for robust operation. With a stabilized waveform, grayscale printing becomes a more reliable, monotonic mapping from grayscale level to effective deposition, improving grayscale-step separability and dimensional repeatability across nozzles and builds.

Controlling Co-efficient of Thermal Expansion through Print Temperature in 4D Printing Applications

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Abstract

In many thermally activated 4D printing systems, programmed shape change is achieved by combining materials with distinct coefficients of thermal expansion (CTE) or by embedding anisotropic material behavior into structural designs to generate predictable deformation under thermal stimuli. However, these strategies typically require multi-material integration, complex design architectures, or post-processing steps. In this study, we present a novel single-material, single-step approach to CTE modulation by tuning the extrusion temperature during fused deposition modeling (FDM). Using foamable polylactic acid (PLA) filament, we printed specimens at 200 °C, 220 °C, and 240 °C. At 200 °C, negligible internal foaming was observed, while 220 °C produced moderate foam expansion, and 240 °C resulted in extensive foaming. Thermal expansion analysis revealed a systematic variation in CTE across these specimens, confirming that print temperature directly influences thermomechanical expansion behavior. Automated, high-throughput imaging quantified foam morphology and correlated extensive foaming results in significant CTE reduction, suggesting that internal architecture plays a key role in thermal response. Shape performance testing further demonstrated significant differences in actuation behavior corresponding to print temperature and resultant CTE values. Unlike conventional multi-material 4D strategies, this approach enables predictable and programmable shape transformation using a single feedstock and simple process parameter tuning, offering a cost-effective and scalable actuation mechanism for 4D printing applications.

Interfacial Phase Regulation and Bonding Strength in L-PBF Steel/Al Multi-Material Components

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Abstract

Laser beam powder bed fusion (L-PBF) additive manufacturing has emerged as a versatile approach for producing multi-material components with complex geometries and tunable interfacial properties. Achieving strong and reliable interfaces between dissimilar metals remains a critical challenge due to the formation of brittle intermetallic compounds and uneven elemental mixing. In this study, carbon steel/Al3Si1Mn alloy composites were fabricated via L-PBF by deliberately regulating intermetallic compound formation at the liquid/solid interface. Machine learning techniques were employed to optimize process parameters, enabling defect-minimized fabrication and consistent microstructure control of both constituent materials.

The interfacial mixing behavior and phase evolution were systematically investigated by varying the scanning speed, combining experimental characterization with numerical simulations. Results show that higher scanning speeds modify interfacial growth kinetics, effectively suppressing the formation of brittle intermetallic compounds, thereby significantly enhancing interfacial bonding strength. Furthermore, the in situ alloying mechanism of the carbon steel/Al composite was explored, providing insight into elemental transport and phase evolution at the interface. These findings demonstrate that precise regulation of the liquid/solid interface during L-PBF enables fabrication of carbon steel/Al multi-material components with optimized interfacial properties. This work provides a promising strategy for phase control and bonding strength optimization in additive manufacturing of multi-material systems, offering guidance for high-performance engineering applications.

KEYWORDS
Multi-materials; Additive manufacturing; Intermetallic compounds; Process optimization; Machine learning

3D-Printed Electromagnetic Systems via Multi-Material Extrusion

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Massachusetts Institute of Technology

Abstract

One of the most promising aspects of additive manufacturing is its ability to synthesize complex hardware architectures that are diSicult, costly, or even impractical to realize using traditional fabrication techniques. Conventional manufacturing often relies on subtractive processes and sequential assembly, which can limit geometric freedom and complicate the integration of multiple functional materials. In contrast, additive manufacturing enables precise control over geometry, composition, and spatial material distribution, opening new possibilities for highly integrated systems. Many of these devices require the coordinated use of multiple materials with distinct electrical, magnetic, mechanical, or thermal properties. Fabricating such devices typically involves complex assembly steps and specialized facilities. By enabling the patterned deposition of diSerent materials within a single build process, monolithic multi-material additive manufacturing presents a compelling approach to implement these devices more eSiciently and with greater design flexibility.

In this talk, we will highlight recent research from the Velásquez Group at MIT on additively manufactured electromagnetic systems, focusing on multi-material extrusion-based 3D printing. By leveraging highly doped thermoplastic composites and modifying commercial 3D printing platforms, we have demonstrated a range of exciting, innovative devices. These demonstrations include semiconductor-free logic, pumps for both gases and liquids, magnetic devices for sensing, energy harvesting, and origami-inspired assembly, and electric motors. Often, the performance of these 3D-printed systems surpasses the current state of the art or enables entirely new capabilities. Collectively, this work represents a significant step toward the fabrication of smart, multifunctional hardware via decentralized, advanced manufacturing beyond traditional manufacturing hubs.

Hybrid additive and pressure assisted manufacturing of thin Fe-6.5Si metal–insulator–metal composite soft magnetic cores

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Abstract

“Electric motors are critical components in electric vehicles, robotic actuators, and unmanned systems, where high frequency operation is required to increase power density. Silicon steel (Fe-xSi alloys) is widely used in stator cores. Fe-6.5 wt.% Si (Fe-6.5Si) exhibits low magnetostriction and high electrical resistivity, which are advantageous for high frequency applications. However, eddy current loss scales with the square of frequency and effective magnetic thickness, requiring substantial reduction of lamination thickness.

Ordered phase formation in Fe-6.5Si results in near zero tensile ductility at room temperature, severely limiting pressure-based forming. Thickness reduction below 300 μm by conventional rolling is restricted by cracking, creating a processing bottleneck for high frequency laminated cores. In this research, hybrid additive and pressure assisted manufacturing is implemented through sequential material extrusion (MEX), boron nitride spray coating, and spark plasma sintering (SPS). MEX enables crack free shaping of thin Fe 6.5Si green bodies. Boron nitride spray coating is introduced a ceramic insulation layer to reduce effective magnetic thickness. Subsequent SPS is applied to control pressure for densification while preserving geometric integrity. In situ formation of Fe 6.5Si and boron nitride layers are enabled to fabricate multilayer metal–insulator–metal composite cores within a single integrated manufacturing sequence.

Processing optimization resulted in a minimum Fe-6.5Si layer thickness of 190 μm. Permeability at 50 Hz and 1 kHz was 1285 and1246, respectively. Core loss at 50 Hz and 1 kHz measured 3.9 W/kg and 111.1 W/kg, respectively. Despite kilohertz excitation, hysteresis loss remained the primary loss component, consistent with reduced effective magnetic thickness.

A radial flux motor incorporating the multilayer metal-insulator-metal composite cores was fabricated using the proposed manufacturing process. Hybrid additive and pressure assisted processing of brittle Fe-6.5Si with integrated insulation establishes a manufacturing framework for three dimensional composite soft magnetic cores in high frequency motor applications.”

Tolerance-Aware Topology Matching for ID-Free STEP Models

Seungbeen Hyun, Duhwan Mun

School of Mechanical Engineering, Korea University

Abstract

In STEP-based CAD models, persistent topology identifiers are not reliably preserved during modeling operations, making it difficult to associate externally defined feature information with specific geometric entities. This presents a critical challenge in automated detailed design workflows, where target edges and faces must be identified consistently without stable IDs. Conventional ID-based mapping approaches are often inadequate in boundary representation environments, particularly when geometric modifications alter topology. To address this issue, this study formulates the ID-free topology matching problem and proposes a tolerance-aware geometric verification method for robust entity identification. The method utilizes reference point sets and geometric proximity evaluation to determine corresponding edges and faces while accommodating uncertainty in input coordinates. By incorporating tolerance-based reasoning, stable matching is achieved even when reference data contains moderate perturbations or inconsistencies. The algorithm is implemented in OpenCASCADE and integrated into an automated feature application pipeline for STEP models. Experimental validation on CAD models with varying geometric complexity demonstrates reliable topology identification across diverse configurations. Robustness analyses under perturbed reference conditions further confirm consistent matching performance, establishing a practical and scalable foundation for ID-free topology matching in automated detailed design applications.

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Digital Transformation and Content Enhancement for Engineering Documents

Sangwook Park, Junho Kim, Duhwan Mun

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Abstract

“Engineering documents contain mission-critical information in narrative form, yet their vast quantity and weak structure make manual data collection time-consuming. General-purpose parsing pipelines often fail due to complex layouts and frequent revisions, such as annotations and strikethroughs, which lead to inconsistent extraction and misinterpreted structures.

To address these challenges, this study presents a text extraction methodology using XML specifications to encode and guide document structure. The proposed pipeline independently detects textual blocks, tables, and strikethroughs, merging them into the original reading order while filtering out irrelevant content. Evaluated on diverse document formats, this approach yields refined, organized text without extensive manual post-processing. Ultimately, this work enhances engineering document management and provides a foundation for downstream language-model-based information extraction.

Acknowledgment: This research was supported by the Machinery and Equipment Industry Technology Development Program (RS-2025-25449384) funded by the Ministry of Trade Industry & Energy (MOTIE, Korea), by the Industrial Technology Alchemist Project Program (No. RS-2024-00419010) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea), and by the Design Industry Technology Development Program (No. RS-2025-04752997) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea).”

Engineering human in vitro models toward functional and cell-dense tissue architectures

Mian Wang

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Abstract

Bioprinting is an emerging technology for creating functional living tissues, typically employing cell-laden bioinks. However, conventional hydrogel-based methods often suffer from low cell densities, which limit crucial cell-cell interactions and impair overall tissue functionality. In this study, we present an innovative approach that modifies cell membranes with acrylate bonds, allowing living cells at physiological densities to function directly as bioinks. This represents the first demonstration of photoactivated, layer-by-layer bioprinting through digital light processing using purely cellular bioinks. Our CeLl-dense bIoiNK (CLINK) rapidly produces tissue constructs that closely mimic native tissues, characterized by ultrahigh cell densities (~10_ cells mL-_) and robust functionality. The high cellularity and living nature of CLINK enable the creation of advanced biological models, such as functional neural circuits and rhythmically contracting mini-hearts derived entirely from stem cells, effectively capturing essential physiological behaviors. Implants created through this technique demonstrate the capacity of engineered tissues to sense, adapt, and integrate autonomously with surrounding tissues, thereby promoting tissue healing and regeneration. Beyond initial demonstrations, this technology holds significant promise to revolutionize tissue biofabrication, opening new avenues for biomedical applications.

Mechanically Programmable DLP Bioprinting for Scalable Manufacturing of Soft and Perfusable Human Tissues

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Abstract

Digital light processing (DLP) bioprinting enables the fabrication of tissue constructs with high spatial resolution and structural complexity; however, engineering soft tissues remains challenging due to the need to balance bioink printability with biologically appropriate microenvironments. Here, we develop a mechanically programmable bioprinting strategy based on a molecular cleavage approach, in which hyaluronic acid methacrylate (HAMA) is incorporated into gelatin methacryloyl bioinks to support high-fidelity printing and is subsequently selectively degraded by enzymatic digestion. This post-printing modulation yields tissue-matching mechanical properties while preserving architectural complexity and printing accuracy. Using this strategy, we generate bioprinted tissues spanning a wide stiffness range, from muscle-like to brain-like (~1.3 kPa) softness, and demonstrate improved cellular morphology and functional maturation across multiple tissue types. Building on this mechanically tunable platform, we further establish a humanized three-dimensional neurovascular unit (NVU)-on-chip model for ischemic stroke research. Endothelial and neural cells are integrated into biomimetic architectures featuring perfusable, branching vasculature inspired by cerebrovascular geometries reconstructed from stroke patient imaging. This system enables direct vascular-neural interactions and supports long-term perfusion culture. By introducing a localized thrombus into a single vascular branch, we recreate unilateral focal cerebral ischemia in vitro and enable high-throughput evaluation of thrombolytic therapies under physiologically relevant flow conditions. Together, this work demonstrates how mechanically programmable bioprinting of soft, perfusable tissues can bridge advanced biofabrication with human-relevant neurovascular disease modeling, providing a versatile platform for mechanistic studies and therapeutic discovery.

Alignment-Controlled Printing of Anisotropic Materials via Lithography-Based Composite Manufacturing (LCM)

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Abstract

This study presents an integrated lithography-based composite manufacturing (LCM) platform for the aligned printing of anisotropic functional materials, encompassing magnetic composites, spark plasma sintered (SPS) magnets, electron beam post-cured (EBPC) systems, and magnetically aligned carbon fiber composites. The core strategy combines in-situ magnetic field-assisted alignment during vat photopolymerization with tailored post-processing to enhance structural integrity and functional anisotropy. First, highly filled anisotropic NdFeB composites were fabricated using an LCM system equipped with a dual-magnet alignment module, enabling directional particle organization during layer-wise UV curing. Magnetic characterization confirmed enhanced remanence and squareness ratio in field-aligned specimens, while EBPC significantly improved matrix crosslinking, mechanical robustness, and alignment retention in high-solid systems. To further enhance densification and magnetic performance, LCM-printed NdFeB green bodies (84 wt.%) were post-processed via SPS. Optimized moderate-temperature sintering (750 °C) preserved fine-grained microstructures and magnetic anisotropy, whereas excessive thermal exposure induced grain coarsening and ferrite formation, degrading coercivity. The LCM–SPS synergy demonstrates a viable route toward dense, anisotropic additively manufactured permanent magnets. Beyond magnetic systems, the alignment concept was extended to chopped carbon fiber reinforced photopolymers, where magnetic-field-induced orientation enabled anisotropic mechanical reinforcement while maintaining geometric precision in photopolymer-based additive manufacturing. Collectively, this work establishes a unified LCM-based framework for programmable anisotropy in multi-material composites. By integrating field-assisted alignment with advanced post-curing and sintering strategies, the proposed approach enables high-resolution fabrication of structurally and functionally anisotropic components for magnetic devices, lightweight structural parts, and multifunctional composite architectures.

Acknowledgement: This work was supported by a grant of the Basic Research Program funded by the Korea Institute of Machinery and Materials (Grant No. NK263B), and the Technology Innovation Program (Grant No. 20024344) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea).

4D printing of Semi-crystalline Thermoplastic Polyimide

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Abstract

Smart polyimides (PIs) are promising for aerospace and space exploration due to their good shape memory properties, low outgassing, outstanding thermal stability, and good radiation resistance. Compared to conventional shape-memory thermoset polyimides, semi-crystalline thermoplastic polyimides (TPIs) offer several advantages such as melt-processability, better toughness and impact resistance, and more sustainability. More importantly, the TPIs can be processed by additive manufacturing, allowing the formation of complex geometries and flexible designs compared to the rigid structures of the thermoset PIs. However, processing of smart semi-crystalline TPIs has not been explored, especially for 4D printing. In this study, semi-crystalline TPI filaments are developed for 4D printing by using a single-screw extrusion process with TPI powders as feedstocks. The thermal properties, printability, and print quality of the developed TPI filaments are characterized while correlations between thermal treatments, crystallinity, mesostructures, and shape memory performance of the printed TPIs are comprehensively studied. This study suggests the great potential of the smart TPI filaments for 4D printing applications in harsh environments.

AI-driven Process Optimization and Yield Enhancement in Fermentation Manufacturing

Hsin-Hui Huang, Bing-Tsiong Li, Gracy Thomas, Xiao-Ming Wan, Shu-Chuan Lin, Juin-Yi Han

TherapiAI Inc. Panlabs Biologics Inc.

Abstract

In advanced biomanufacturing, fermentation involves highly complex processes with numerous variables. Traditionally, identifying key process parameters that influence fermentation outcomes traditionally requires extensive time and experimental resources. To overcome this bottleneck, this study leverages machine learning (ML) to rapidly identify critical parameters and provide actionable insights for maximizing daily production yields. An XGBoost model was developed using 269 clean records to predict high antibiotic yield increases, validated through 5-fold cross-validation with an 80:20 training-to-testing ratio. The model demonstrated exceptional predictive performance, achieving an accuracy of 0.936 and the area under the receiver operating characteristic curve (AUROC) of 0.985. To ensure transparency, Explainable AI (XAI) via SHAP (SHapley Additive exPlanations) was integrated to illustrate the complex, non-linear relationships between specific parameters and yield. The analysis revealed that metabolic efficiency indicators, such as product yield per glucose, product yield per sodium hydroxide, and sugar consumption rate, act as primary drivers where low values severely penalize production. Conversely, physical culture parameters, including culture viscosity and culture residual nitrogen, exhibited an inverse influence, with lower values positively contributing to yield. By shifting from trial-and-error to AI-driven insights, this study provides a scalable framework for uncovering critical parameters and enabling intelligent industrial manufacturing through data-driven decision support.

Intelligent System for Quality Assessment in EBM Additive Manufacturing using Deep Learning and Large Language Model

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[1]Tohoku University, [2]JAMPT Corporation Ltd.

Abstract

“Electron Beam Melting (EBM) is attracting attention as an efficient additive manufacturing (AM) due to its high energy density and scanning speeds. However, issues including defect formation during the process remain, highlighting the need for quality assurance. This study proposes a new scheme to evaluate overall quality by focusing on the surface (top-surface) images of built parts, specifically looking at flatness and morphology. Furthermore, we attempt to construct a system that can express expected phenomena during manufacturing in natural language and provide the reasoning behind the quality evaluation.

First, a database of 700+ conditions for Ti-6Al-4V and Inconel 718, including process parameters, top-surface images, defect(density), and mechanical properties, was built. Next, the accuracy of three quality indicators was verified: 1) surface roughness, 2) top-surface categories, and 3) density prediction using deep learning (DL). For the first indicator, quality was evaluated as Even, Uneven, or Porous using a combination of parameters such as Sa and Sdr. For the second, top-surface images were classified into 15 categories using non-hierarchical clustering. For the third, a Variational Auto-Encoder was used to compress images into latent vectors, and density was predicted using a Neural Network combined with process conditions. Additionally, a knowledge graph was constructed by describing the features in natural language. Finally, a Large Language Model (LLM) was fine-tuned to comprehensively judge these indicators and provide the reasoning for its decisions.

The results showed while surface roughness was sensitive to deformations caused by over-melting, the image categories corresponded well with physical phenomena and showed a correlation with density. The DL model achieved relatively good performance in predicting density. Finally, the LLM-based comprehensive evaluation demonstrated the ability to make autonomous, logic-based judgments. This suggests the potential for accumulating knowledge on physical phenomena and moving toward the automated discovery of new insights in AM.”sical phenomena and moving toward the automated discovery of new insights in AM.

Advanced Manufacturing of Liquid Crystal Elastomer Artificial Muscles for Soft Robotic Systems

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Abstract

Additive manufacturing is increasingly evolving toward advanced manufacturing strategies capable of producing functional, adaptive systems rather than static components. In this context, 4D printing combines additive manufacturing with stimuli-responsive materials to create structures capable of reversible and programmable shape change. Among these materials, liquid crystal elastomers (LCEs) are particularly attractive due to their ability to generate large, reversible actuation when heated across the nematic–isotropic transition.

This work presents an advanced manufacturing workflow for the fabrication of LCE-based artificial muscles, bridging the gap between printed smart material fibers and fully integrated soft robotic actuators. A thiol–acrylate LCE formulation based on RM82 reactive mesogens was synthesized and processed into printable oligomer inks compatible with Direct Ink Writing (DIW). During extrusion, shear-induced alignment of mesogens enables the fabrication of monodomain LCE filaments capable of anisotropic actuation.

Beyond filament fabrication, the manufacturing strategy leverages Freeform Liquid 3D Printing (FL3DP) to produce architected LCE structures such as yarns and lattice architectures within a Laponite support bath. These printed elements form the basis of hierarchical actuator architectures. To enable functional actuation, electrothermal heating elements were integrated into the printed structures. Conductive threads, including silver-coated nylon, nichrome wire, and stainless-steel yarn, were systematically evaluated to identify suitable heating strategies. Stainless-steel yarn was found to provide the best compromise between electrical stability and mechanical compliance, enabling localized Joule heating without compromising actuator flexibility.

The resulting actuators were integrated into Vertebrate Soft Robots (VSoRo) as artificial tendons and muscle-like bundles, enabling controlled bending and locomotion in demonstrators including a robotic finger, a lizard-inspired robot, and an inchworm platform.

By linking smart material synthesis, advanced additive manufacturing techniques, and electrothermal integration, this work demonstrates a scalable pathway toward manufacturing next-generation soft robotic actuators and artificial muscles.

Bandgap tunability and vibration suppression in a 4D-printed metamaterial

Chenyang Xi[1]; David William Rosen[1,2]

[1]*Institute of High Performance Computing, Agency for Science, Technology and Research, Singapore*
[2]*Singapore Institute of Manufacturing Technology, Agency for Science, Technology and Research, Singapore*

Abstract

Traditional metamaterial designs are typically fixed once fabricated, which limits their engineering adaptability and restricts vibration control to a predefined frequency range. 4D printing, enabled by stimulus-responsive materials, offers a new possibility for adjustable and reconfigurable metamaterial designs. In this work, a thermally driven metamaterial featuring a compliant outer frame and stiff shape memory polymer (SMP)-based core is proposed for broadband vibration attenuation. The structural configuration morphs under different temperature conditions, resulting in shifts of its flexural wave bandgap. Band structures of the unit cell and vibration transmissibility of the finite structure are computed using the finite element method. Numerical results show that temperature-induced morphing shifts the bandgap effectively, enabling vibration reduction across multiple ranges in different working conditions without requiring separate structures. Parametric analyses further confirm the robustness of the proposed design in maintaining effective vibration attenuation performance. This demonstrates the potential of 4D-printed metamaterials for adaptive vibration control in varying operational environments, offering promising applications in engineering systems where broadband and reconfigurable performance is required.

Keywords: 4D printing; adjustable; metamaterial; bandgap; vibration attenuation

Real-Time Monitoring and Closed-Loop Control for Defect Mitigation in Directed Energy Deposition using Optical Emission Spectroscopy

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Abstract

Laser-based directed energy deposition (DED) enables near-net-shape fabrication and repair; however, maintaining process stability during multilayer deposition remains challenging due to continuously evolving melt-pool thermophysical conditions. Conventional in-situ techniques such as high-speed-imaging, infrared-thermography, and pyrometry are widely used for monitoring and control, but mainly provide surface or temperature data, require complex processing, and suffer from emissivity dependence. To overcome these limitations, optical emission spectroscopy (OES) is employed to capture plasma-plume emission that directly reflects melt-pool behaviour, enabling a physics-based indicator suitable for real-time monitoring and control.

Initial investigations were conducted on SS316L to develop a physics-based monitoring and closed-loop control framework. The OES signal was validated through temporal synchronization with high-speed imaging, demonstrating strong co-evolution between emission intensity and plasma plume dynamics. Within the 510-550 nm spectral window, the FeI 520.79 nm line was identified as a stable and isolated spectral feature and established as a proxy metric for plasma plume activity. Using this validated indicator, clads were fabricated by varying laser power from 200-2000 W and scan speed-to-powder feed rate ratios from 0.02-0.12 m/g. An OES-assisted process map was constructed by correlating plasma plume intensity with clad morphology, enabling real-time discrimination of lack-of-fusion, conduction, transition, and keyhole regimes. Intensity variation was mechanistically linked to absorptivity transitions and recoil-pressure-driven instability, with low-intensity deviations indicating lack-of-fusion and elevated intensity anomalies corresponding to spatter and keyhole-induced porosity, enabling defect identification.

The validated intensity metric was embedded into an adaptive closed-loop laser-power control strategy, significantly improving geometric consistency and reducing defect formation. To extend broader applicability to different alloy systems, a normalized plasma plume intensity ratio was formulated to reduce sensitivity to absolute intensity variations during regime identification.

This study establishes plasma plume emission as a compact, physics-linked descriptor for unified regime identification, defect mitigation, and real-time monitoring and control in DED.

Bandgap tunability and vibration suppression in a 4D-printed metamaterial

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[2]*Singapore Institute of Manufacturing Technology, Agency for Science, Technology and Research, Singapore*

Abstract

Traditional metamaterial designs are typically fixed once fabricated, which limits their engineering adaptability and restricts vibration control to a predefined frequency range. 4D printing, enabled by stimulus-responsive materials, offers a new possibility for adjustable and reconfigurable metamaterial designs. In this work, a thermally driven metamaterial featuring a compliant outer frame and stiff shape memory polymer (SMP)-based core is proposed for broadband vibration attenuation. The structural configuration morphs under different temperature conditions, resulting in shifts of its flexural wave bandgap. Band structures of the unit cell and vibration transmissibility of the finite structure are computed using the finite element method. Numerical results show that temperature-induced morphing shifts the bandgap effectively, enabling vibration reduction across multiple ranges in different working conditions without requiring separate structures. Parametric analyses further confirm the robustness of the proposed design in maintaining effective vibration attenuation performance. This demonstrates the potential of 4D-printed metamaterials for adaptive vibration control in varying operational environments, offering promising applications in engineering systems where broadband and reconfigurable performance is required.

Keywords: 4D printing; adjustable; metamaterial; bandgap; vibration attenuation

Ultrafast Photonics for Precision Manufacturing of Semiconductors and Secondary Batteries

Young-Jin KIM, Dongwook Yang, Younggeun Lee, Hyunwoo Kim, Jinwoo Jeon, Hanku Nam

KAIST (Korea Advanced Institute of Science and Technology)

Abstract

This presentation highlights how ultrafast photonics, particularly femtosecond laser–based frequency combs and laser-induced graphene (LIG), enables next-generation precision manufacturing for semiconductors and secondary batteries.

A frequency comb generated by a femtosecond pulse laser provides a stable train of ultrashort pulses in the time domain and millions of evenly spaced optical modes in the frequency domain. These unique properties have transformed precision metrology across multiple length scales. At large scales, nanometer-precision time-of-flight measurements support large engineering systems and space-relevant structures. At the industrial scale, frequency-comb–based metrology enhances stage positioning accuracy and dimensional inspection in semiconductor and display manufacturing, directly improving overlay accuracy and critical dimension control. At the nanoscale, comb-enabled phase-sensitive spectroscopy combined with plasmonic extraordinary optical transmission achieves picometer-level resolution, enabling advanced defect inspection and sub-wavelength structural metrology. Collectively, these capabilities position frequency comb technology as a core platform for ultra-precision process control in advanced semiconductor fabrication.

In parallel, ultrafast lasers provide a scalable and environmentally benign pathway for functional material processing. We have developed a one-step, ambient-condition femtosecond laser process to directly convert diverse carbon-containing precursors—including polymers, fabrics, papers, and biomass—into patterned laser-induced graphene. Structural and electrical characterizations confirm the formation of porous, conductive graphene networks. This LIG exhibits high electrical conductivity and large surface area, making it suitable for energy storage components such as supercapacitors and hybrid capacitor architectures, as well as sensing platforms.

By integrating ultrafast precision metrology with laser-based material transformation, ultrafast photonics offers a unified technological framework for high-accuracy semiconductor manufacturing and sustainable secondary battery production.

Mitigating electrical anisotropy in FDM-printed electronics via laser sintering of copper-flake filaments

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Abstract

The transition of Fused Deposition Modeling (FDM)/ Fused Filament Fabrication (FFF) from structural prototyping to functional electronic fabrication is often hindered by the high resistivity of conductive thermoplastic composites. This limitation stems from the “”polymer barrier””—thin insulating layers of the matrix (e.g., PLA or ABS) that encapsulate conductive fillers, such as copper flakes, preventing efficient electron transport and creating significant electrical anisotropy.

This study demonstrates a hybrid additive manufacturing approach using commercially available FDM filaments and hardware integrated with a localized laser sintering module. By applying laser pulses on the printed parts, the insulating polymer film between adjacent flakes is selectively removed or bypassed, allowing for metallic sintering and the formation of continuous conductive networks. This laser assisted thermal treatment significantly reduces volume resistivity by several orders of magnitude compared to standard FDM prints.

Furthermore, laser-driven sintering at the layer interface enhances copper flake connectivity, effectively bridging the Z-axis conductivity gap. The result is a more “”isotropic”” electrical profile, essential for reliable 3D circuitry. Finally, we explore laser-ablative trimming to sharpen “”as-printed”” traces, moving beyond the physical resolution limits of the 0.4 mm nozzle to achieve more precise print trace. These advancements expand the potential for integrating high-precision laser systems with accessible FDM platforms to fabricate complex 3D electronic features.

Actuating origami-inspired deployable structures through 4D additive manufacturing

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Abstract

Deployable structures are used for space and civil applications for they can be folded to a small volume for transportation and deploy to a functional structure upon reaching their destinations. To actuate the deployment, scientists and engineers usually rely on motors and mechanical latches to move and lock into place, but the hardware adds weight and volume and limits scalability. This work presents a 4D additive manufacturing approach for self-actuating origami-inspired deployable structures, where geometry, material distribution, and actuation are co-designed within a single printed architecture.

Most folding concepts with a large shape transformation can trace their origin to origami because of their advantage in transforming large sheets into compact volumes. In this work, we combine origami-/kirigami-inspired kinematic design with multi-material 3D printing and shape-memory polymers (SMPs) to create deployable structures that are fabricated in a compact state and autonomously morph into target configurations upon thermal stimulation. Our design strategy couples deployable mechanism kinematics with programmable material response, enabling controlled shape transformation while preserving geometric compatibility across connected panels and unit cells. By embedding actuation directly into the printed structure, the need for conventional motors, hinges, or post-assembly integration is reduced, improving manufacturability and system compactness. We will simulate the deployment process based on SMP shape-memory recovery and validate the designs using physical prototypes. The prototypes will demonstrate repeatable deployment behaviour, including both synchronised and sequential global morphing, as well as stable transformed states after deployment.

This work highlights the potential of 4D additive manufacturing for actuator-integrated deployable structures and provides a practical route toward compact, lightweight, and programmable systems for applications in aerospace, soft robotics, and adaptive engineering structures.

Real-Time Interferometric Surface Topography Measurement Using Generalization-Optimized Physics-Informed Deep Learning

Jurim Jeon, Hwan Kim, Hyeokjun Suh, Yangjin Kim

School of Mechanical Engineering, Pusan National University, Republic of Korea

Abstract

Interferometric metrology is a key technique for nanoscale surface topography measurement, offering non-contact operation, high precision, and compatibility with large apertures. In interferometric profilometry, surface height is commonly obtained by estimating and demodulating the phase from captured fringe patterns. Traditional phase recovery frequently employs temporal phase-shifting interferometry (PSI), which is generally more accurate and robust than spatial phase-shifting methods. Nevertheless, temporal PSI requires multiple phase-shifted acquisitions, limiting its applicability to real-time measurements in dynamic scenes or vibration-sensitive environments.
To achieve accurate single-shot phase retrieval, deep-learning-based demodulation methods have recently attracted considerable attention. While these approaches can deliver strong performance under controlled conditions, their generalization often degrades when fringe characteristics, optical setups, or noise statistics differ from those seen during training. In addition, many models behave as black-box regressors, lacking explicit constraints that enforce physical consistency.

In this study, we present a physics-informed deep learning framework designed to preserve high demodulation accuracy while improving robustness and generalization for real-time interferometric surface topography measurement. The network is trained in the spectral domain and is encouraged to internalize the Fourier-transform-based fringe formation model by mimicking essential components of classical frequency-domain processing, such as FFT-based spectral separation and band-limited filtering. Incorporating these physically grounded priors into the learning objective mitigates reliance on spurious correlations and improves tolerance to changes in fringe frequency, contrast, and measurement noise.

We validate the proposed method experimentally through step-height measurements using a interferometric profiler. The results show that the physics-informed model provides accurate phase demodulation and exhibits better generalization than conventional deep-learning baselines, highlighting its potential for real-time, high-precision interferometric profilometry in dynamic measurement conditions.

Advanced Functional 3D Printing for Next-Generation Smart Devices

Prof. Im Doo Jung

UNIST

Abstract

The realization of next-generation smart devices, particularly wearable and extended reality (XR) systems, demands fabrication strategies that integrate functional materials onto unconventional, curved, and miniaturized platforms while remaining scalable. This keynote presents a unified framework of meniscus-engineered functional 3D printing that bridges material patterning, device intelligence, and manufacturability. A meniscus-confined micro-printing strategy enables direct formation of electrochromic patterns for low-power display integration, allowing visual information to be rendered on soft, contact-lens-compatible substrates and demonstrating the feasibility of embedded navigation and augmented interfaces. Meniscus Pixel Printing (MPP) further extends this concept to optoelectronic integration by enabling mask-free patterning of photodetector arrays on planar and curved surfaces; when coupled with artificial intelligence for image reconstruction and eye-gesture recognition, these devices enable intuitive, hands-free interaction and illustrate the potential of contact-lens-based XR platforms. Complementing device-level integration, a dispensing-based volumetric additive manufacturing approach applies meniscus-guided optical control to rapid three-dimensional fabrication, enabling continuous production of complex structures and offering a scalable pathway toward smart device manufacturing. Together, these advances establish meniscus-engineered functional 3D printing as a versatile platform for intelligent, wearable, and manufacturable smart systems.

Thermo responsive 4D printing by PET-RAFT polymerization

Yoshiko Miura, C Jee, Mina Shigeyama, Masanori Nagao

Kyushu University

Abstract

Stimuli-responsive hydrogel materials have emerged as transformative components in the development of smart actuators and soft robotics. In this study, we present a novel fabrication approach for thermo-responsive 4D materials utilizing Photoinduced Electron Transfer - Reversible Addition-Fragmentation Chain Transfer (PET-RAFT) polymerization. This method allows for precise spatiotemporal control over the polymer network architecture under ambient conditions, which is ideal for advanced additive manufacturing.

We developed bilayer-designed hydrogels by integrating monomers with distinct thermal properties: N-isopropylacrylamide (NIPAm) for Lower Critical Solution Temperature (LCST) behavior and 3-[[2-(methacryloyloxy)ethyl]dimethylammonio]propane-1-sulfonate (SBMA) for Upper Critical Solution Temperature (UCST) behavior, alongside acrylamide (AM) as a structural framework. The chemical and mechanical properties of the printed structures were characterized using FT-IR spectroscopy and rheological measurements.

The 4D motion analysis revealed that the bilayer samples exhibited sophisticated curvature and inverse-curvature movements across a broad temperature range (4˚C to 70 ˚C). A key highlight of this research is the integration of computer simulations to predict these complex 4D deformations. By aligning computational modeling with the PET-RAFT printing process, we significantly improved design precision and reduced the iterative experimental timeframe. This study demonstrates that the synergy between oxygen-tolerant PET-RAFT polymerization and predictive simulation offers a robust platform for engineering the next generation of sophisticated, programmable 4D materials.

High-precision freeform DLP bioprinting by thermo-reversible gelation

Daobo Han, Mingshan Zhang, Junfang Xie, Zhaoxuan Dong, Shuang Xia, Yifei Zhan, Yipeng Dong, Yonghe Li, Jin Wang, Zhichao Deng, Jianchun Mei, Jianguo Tian and Qing Ye*

Key Laboratory of Weak-Light Nonlinear Photonics, Ministry of Education, School of Physics and TEDA Applied Physics, Nankai University, Tianjin 300071, China

Abstract

Light-based 3D bioprinting technology can be used to prepare complex hydrogel structures for tissue engineering, but it is limited by reduced precision due to radical diffusion and light scattering, as well as geometric restriction. We propose a reversible gelation suspension stereolithography technique, which combines DLP printing with temperature-controlled reversible gelation, gelling the bioink prior to photocuring. This strategy suppresses diffusion and scattering, achieving 6.8 μm precision, and provides in situ support for suspended structures, overcoming traditional geometric restriction. We demonstrated the feasibility in freeform geometry by printing various structures and demonstrated multi-material printing. Cell-loaded hexagonal hepatic lobule bio-inspired structure and multi-scale branched vessels seeded with HUVEC were then constructed, high survival rates and functional performance demonstrated its superior biocompatibility, thereby providing possibilities for new tissue engineering applications.

Optimization of Process Parameters for Laser Cladding of CoCrFeNiAl-SiC Composite Coatings

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Abstract

To improve the surface hardness and forming quality of 20CrMnTi steel, a CoCrFeNiAl 10%SiC composite coating was prepared on its surface using laser cladding technology. Under the condition of a fixed overlap rate, a three-factor, four-level orthogonal experiment was designed, taking laser power, scanning speed, and powder feeding speed as variables, to investigate their effects on the coating's microhardness and crack rate. Through range and variance analysis, the primary and secondary influences of each process parameter on coating quality were clarified; combined with the grey relational analysis method to handle multi-index coupling problems, the optimal process combination was determined. The results show that under the optimal parameters, the coating's structure is dense and has a good metallurgical bond with the substrate; the SiC particles exert a significant dispersion strengthening effect, greatly increasing the average hardness of the coating compared to the substrate, while effectively suppressing crack initiation and propagation. This study provides a theoretical basis for high-quality surface strengthening of 20CrMnTi parts.

Addressing Warpage in Vat Photopolymerization through an Energy Distribution-Based Exposure Strategy

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Abstract

Distortion caused by warping or curling remains a critical obstacle in vat photopolymerization (VP) based additive manufacturing, as it degrades geometric fidelity and reduces the reliability of mechanical characterization. This problem originates from the inherent curing mechanism of bottom-up systems, where UV light transmitted through previously solidified layers leads to cumulative energy absorption. Accordingly, conversion gradients form along the build direction, inducing differential shrinkage between layers and consequent bending deformation. To mitigate this effect, a modified Beer Lambert based energy control strategy was implemented to regulate layer specific exposure and promote uniform curing throughout the printed structure. Warpage angles were quantitatively evaluated for specimens fabricated under conventional and energy compensated conditions, with systematic variation of layer thickness and overall part thickness. Mechanical consistency was further assessed through three point bending dynamic mechanical analysis (DMA). The compensated specimens exhibited substantially reduced curvature and improved measurement consistency across processing conditions. These findings provide a practical framework for establishing exposure parameters for newly developed photopolymer resins, enabling the fabrication of dimensionally stable specimens suitable for accurate polymer characterization.

Effect of Normalising Temperature on Microstructure and Wear Resistance of Alloy Steel in Arc-Fused Wire Additive Manufacturing

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Abstract

After arc fusion welding using 18CrMnNiMo steel and SMSX900A welding wire, the material underwent normalising heat treatment in a muffle furnace. The effects of different normalising temperatures on microstructure, microhardness, and friction-wear properties were investigated. Specimens under various process conditions were obtained by heating at a rate of 2.5°C/min to different temperatures, holding for 2 hours, and then air cooling. Following specimen preparation, microhardness and friction-wear properties were evaluated, whilst optical metallographic microscopy analysed microstructural transformations under varied normalising conditions. Results indicate that as normalising temperature increases, the material undergoes a progressive evolution from recrystallisation and grain refinement through homogenisation to grain coarsening. Microhardness exhibited an initial increase followed by a decrease with rising normalising temperature. Friction and wear properties were closely correlated with microstructural evolution: specimens with uniformly refined microstructures demonstrated lower friction coefficients and reduced wear rates, indicating enhanced wear resistance. At excessively high temperatures, grain coarsening led to decreased hardness, consequently diminishing friction and wear performance.

Experimental Investigation and Finite Element Modelling of 3D-Printed Recycled Polypropylene with Fused Granulate Fabrication

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Abstract

Fused Granulate Fabrication (FGF) has emerged as a scalable additive manufacturing technology for converting recycled polymers into structural and functional components. As sustainable manufacturing becomes increasingly critical, reliable prediction of mechanical performance in FGF-printed recycled materials remains a key challenge due to complex process–structure–property interactions. Addressing this need requires integrated experimental validation and predictive numerical frameworks capable of capturing structure-dependent behaviour.

This study develops a systematic experimental-statistical-numerical framework to investigate the influence of infill density and printing sequence on the tensile and flexural performance of FGF-printed recycled polypropylene (rPP). Standard mechanical testing combined with statistical analysis demonstrates that infill density is the dominant parameter governing stiffness and strength, whereas printing sequence exhibits comparatively minor and statistically insignificant influence within the investigated range. Mechanical enhancement is primarily attributed to structural densification, improved load-path continuity, and reduced internal porosity, with flexural behaviour showing heightened sensitivity to internal structural architecture.

To overcome the limitations of conventional representative volume element (RVE)-based homogenisation, a multiscale numerical framework incorporating a sophisticated finite element model is developed. The model explicitly represents infill structural architecture and interlayer bonding characteristics, enabling accurate simulation of tensile and flexural responses under varying printing conditions. Strong agreement between numerical predictions and experimental results confirms the capability of the framework to capture density-driven mechanical scaling.

Overall, this integrated methodology provides a robust and transferable approach for performance-oriented optimisation of FGF-printed recycled polymers, reducing reliance on

A study on pressurized sensing channels in LPBF A205 aerospace components for fatigue_driven structural health monitoring

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Abstract

The integration of sub-surface channels in Laser Powder Bed Fusion (LPBF) parts offers a promising pathway toward embedded Structural Health Monitoring (SHM) in safety-critical aerospace structures. This work investigates the manufacturability, surface quality, and fatigue life implications of Ø3 mm channels embedded beneath A205 aluminum alloy components. The SHM concept relies on pressurizing the channels and detecting pressure drops induced by fatigue-driven crack propagation. Achieving effective sensing requires balancing design requirements: channels should be close enough to the surface for early crack detection, yet far enough to avoid acting as fatigue initiators. Within this trade-off, channel surface quality critically affects pressure integrity and local stress concentration, making optimization of the internal surface -particularly downfacing roughness- essential to minimize the fatigue penalty.

A two-stage experimental approach was initially used to improve downfacing channel quality. Optimized LPBF exposure strategies achieved a ~40% reduction in roughness, minimizing mid-channel dross and producing more uniform geometries, confirmed by 2.5D surface topography measurements. Complementary finite-element simulations quantified local stress concentrations and guided the selection of production parameters and coupon design for fatigue testing.
In addition to simple channels, a limited set of lattice-filled microchannels was explored to assess feasibility for improving printability and local stress distribution. While most lattice types introduced undesirable stress peaks, a subset, particularly TPMS-based and single-wall topologies, showed favorable behavior and were selected for evaluation.

A comprehensive four-point bending fatigue campaign was conducted on different specimen groups (baseline, empty channels, optimized downfacing, lattice-enhanced, and two channel-position variants). All specimens were tested under internal pressurization, enabling real-time monitoring of crack initiation and propagation, and providing experimental link between channel design, manufacturability, and SHM functionality. The combined findings from this work define a robust processing window for embedded sensing channels in LPBF A205 and pinpoint design variants best suited for advancing SHM in aerospace applications.

Physics-Guided Learning Framework for Robust In Situ Defect Detection in Laser Powder Bed Fusion

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Abstract

Reliable in situ defect detection is critical for enabling real-time process control and ensuring quality in laser powder bed fusion (LPBF). However, standard top-view sensing provides limited access to subsurface melt pool behavior, making defect detection highly sensitive to process variations. Purely data-driven approaches trained on surface observations often struggle to generalize across operating conditions, while physics-based or hybrid solutions may rely on additional sensing or simulation inputs during deployment, limiting their practical applicability. This work introduces a physics-guided learning framework that incorporates high-fidelity process knowledge during model development while retaining a sensor-minimal configuration at inference. By embedding subsurface physical features into training, the proposed approach enables the model to implicitly capture subsurface process dynamics from top-view thermal observations alone. Importantly, the proposed framework operates during deployment using only standard top-view in situ sensing, without requiring auxiliary inputs. Experimental evaluation across diverse defect regimes demonstrates enhanced detection robustness and reduced sensitivity to process variability. Analysis of learned representations further suggests meaningful alignment between model behavior and underlying melt pool physics. The proposed strategy provides a practical pathway toward reliable and scalable real-time monitoring in LPBF while maintaining compatibility with industrial sensing constraints.

Rheology-guided printing parameter modulation strategies for precise soy-based 3D food printing

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Abstract

Rheological measurements are widely employed to describe food inks, yet their direct translation into process control for 3D printing remains underexplored. This study demonstrates how rheological properties, particularly the shear- and temperature-dependent flow behavior of soy protein matrices, can move beyond characterization to serve as operational parameters for actively modulating printing performance and geometrical accuracy. Two contrasting soy-based matrices were developed: a low-viscosity formulation composed of highly soluble components such as beverage-grade soy protein isolate (SPI), milled soy extrudates, and wheat starch; and a highly viscous formulation dominated by less soluble materials, including microcrystalline cellulose with SPI dedicated for semi-solid meat analogue.

Comprehensive rheological analyses identified the transition range between flow initiation and structural recovery for each formulation across temperatures from 25 to 40 °C, defining optimal processing conditions for extrusion and post-deposition stability. For the highly viscous matrix, controlled temperature modulation during printing transiently reduced viscosity and yield stress, enabling stable extrusion while maintaining rapid structural recovery after deposition. As a result, the processability window of the highly viscous formulation was expanded. Rheology-derived parameters were translated into operational printing conditions in an auger-based 3D printhead, linking applied shear rate or stress to extrusion rate under temperature-modulated flow states.

The predictive framework achieved over 95% shape fidelity at high printing speeds (up to 120 mm s^{-1}). The results demonstrate that temperature-assisted modulation of flow behavior provides an effective strategy to extend the processability of highly viscous soy-based inks, enabling rheology-guided control of extrusion dynamics and advancing data-driven, precision printing of structured, sustainable food products.

Toward autonomous terrain-adaptive additive manufacturing: A legged robotic framework for infrastructure repair

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Abstract

Industrial infrastructure maintenance remains constrained by stationary manufacturing paradigms that require surface preparation, large fixtures, or manual intervention. To address this limitation, this work presents a terrain-adaptive mobile additive manufacturing framework designed for autonomous in-situ repair in unstructured environments.

The system integrates bio-inspired legged mobility, end-effector kinematic coordination and an on-board vision-to-deposition pipeline to enable conformal material deposition across various substrate conditions. Instead of relying on fixed-base positioning, the approach treats the robot body as a dynamically reconfigurable manufacturing platform. By coupling locomotion and manipulation through coordinated multi-leg motion, the framework enables precise nozzle placement while maintaining terrain adaptability.

A modular digital architecture is introduced, incorporating defect sensing, task-space planning, motion retargeting and adaptive deposition control. The system demonstrates stable multi-layer fabrication and surface-conformal repair across varied geometries, highlighting the feasibility of decentralized, material-efficient repair strategies.

This work contributes a new paradigm for mobile additive manufacturing in infrastructure applications, bridging robotics, digital manufacturing and sustainable repair methodologies. The present framework outlines a pathway toward reducing logistical burden and supports circular life-cycle management of built environments.

Cellular dislocation networks in additively manufactured alloys: A double-edged sword for hydrogen embrittlement

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Abstract

Additively manufactured (AM) alloys produced by laser powder bed fusion contain a hierarchical microstructure featuring sub-micron cellular structures decorated with high-density dislocation networks and solute segregation. These cellular dislocation networks fundamentally alter hydrogen transport and deformation behavior, leading to hydrogen embrittlement (HE) mechanisms that differ from those in conventionally processed alloys. This talk presents a mechanistic synthesis of our recent studies on LPBF 316L stainless steel and Inconel 718 to show that such networks play a dual, seemingly contradictory role in governing HE.

On one hand, the cellular structure acts as an effective barrier to hydrogen ingress and diffusion. The high density of dislocations and chemically segregated cell walls introduces abundant trapping sites, reducing the apparent hydrogen diffusivity and local hydrogen accumulation, thereby mitigating hydrogen-induced hardening and delaying damage initiation. On the other hand, hydrogen significantly modifies the stability and mobility of these dislocation networks. Hydrogen-induced elastic shielding and network disentanglement promote planar slip and strain localization, which facilitate hydrogen-enhanced localized plasticity and lead to premature ductility loss despite minimal strength degradation.

In precipitation-strengthened LPBF Inconel 718, post-processing heat treatments further reveal the dual nature of the cellular structure. Retained dislocation networks can homogenize hydrogen distribution and suppress crack localization, whereas their dissolution during high-temperature treatments promotes rapid hydrogen transport along recrystallized grain boundaries, resulting in severe intergranular embrittlement. These results demonstrate that the same microstructural feature can either enhance or degrade HE resistance depending on its stability, spatial distribution, and interaction with deformation.

By establishing the links between cellular dislocation architecture, hydrogen transport, and strain localization across multiple alloys and length scales, this work provides a unified mechanistic framework and outlines microstructure-design strategies for achieving strength–ductility–HE resistance synergy in AM alloys for hydrogen-related applications.

Tolerance-Aware Topology Matching for ID-Free STEP Models

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Abstract

In STEP-based CAD models, persistent topology identifiers are not reliably maintained during modeling operations, making it difficult to associate externally defined feature information with specific geometric entities. This limitation presents a fundamental challenge in automated detailed design workflows, where target edges and faces must be identified consistently without relying on stable IDs. Conventional ID-based mapping approaches are often insufficient in boundary representation environments, particularly when geometric modifications alter the underlying topology. To address this issue, this study formulates the ID-free topology matching problem and proposes a tolerance-aware geometric verification approach for robust identification of topological entities. The method employs reference point sets and geometric proximity evaluation to determine corresponding edges and faces while accommodating potential uncertainty in input coordinates. By incorporating tolerance-based reasoning, the approach enables stable matching even when reference data contains moderate perturbations or minor inconsistencies.

The proposed algorithm is implemented in OpenCASCADE and integrated into an automated feature application pipeline for STEP models. Experimental evaluations on multiple CAD models with varying geometric complexity demonstrate reliable topology identification performance across diverse configurations. Additional robustness analyses under perturbed reference conditions confirm that the proposed approach maintains consistent matching accuracy. These findings indicate that tolerance-based geometric verification provides a practical, robust, and scalable foundation for ID-free topology matching in automated detailed design applications.

Digital Transformation and Content Enhancement for Engineering Documents

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Abstract

Engineering documents contain a wide range of mission-critical information and are typically written in narrative form so that engineers, contractors, and other project participants can readily interpret them. However, because these documents are both large in quantity and weakly structured, locating and collecting relevant content often requires substantial manual effort and time. Although many studies have investigated text extraction from unstructured PDFs, applying general-purpose parsing pipelines to engineering documentation remains challenging. During project execution, revisions are frequently recorded as annotations or strikethrough edits, which can introduce duplicated passages and inconsistent phrasing. In addition, engineering documents often exhibit complex layouts and hierarchical structures; as a result, conventional parsers may misinterpret section organization and produce unreliable alignment between extracted elements.

To overcome these issues, this study presents a text extraction methodology that leverages XML specifications to encode user-defined document structure and uses this structure as guidance for extraction. The proposed pipeline separately detects textual blocks, tables, and strikethrough components, then merges them according to the original reading order and filters out irrelevant content to produce a refined digital text representation. With only a prior structural definition, users can obtain cleaned and organized text without extensive manual post-processing. The method was evaluated on three control narrative documents with different layouts and writing styles, and the results indicate stable performance across heterogeneous document formats. Ultimately, this work supports more efficient engineering document management and serves as a stepping stone for downstream language-model-based information extraction.

Topology Optimization for Multi-axis Hybrid Manufacturing Incorporating Curved Layer Generation

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Abstract

Hybrid additive-subtractive manufacturing (HASM) is a revolutionary technique that fabricates complex-shaped parts in high precision. One setup to finish complicated manufacturing operations ensures high efficiency, and the interlacement of additive-subtractive operations fabricates conventionally difficult-to-process complex geometries. This research is specially focused on design for HASM, to create the suitable mechanical structures for HASM endowed of superior functionality and light-weight over the traditional counterpart.

HASM-oriented topology optimization is specifically focused and the state-of-the-art is reviewed and analyzed. A concurrent optimization model named DGTO (Derivable Geodesics-coupled Topology Optimization) is presented, aiming at simultaneously designing the structure, slices, and sequences for multi-axis HASM. The proposed method involves two variable fields: the density field representing the structure, and the auxiliary variable field for generating geodesic distance-based curved slices for additive manufacturing (AM). A novel heat diffusion equation and Poisson equation-based approach is proposed to generate the curved layers while ensuring all slicing-related information derivable. Additionally, sequence division thresholds are optimized to determine the timings of alternating between AM and subtractive machining (SM) operations. The proposed sequence division method eliminates the initial-guess dependency issue, i.e., the quantity of AM-SM alternations has a reducing trend during optimization and converges to the most compact solution. To realize the synchronous optimization and ensure the successful manufacturing, a coupled and differentiable optimization model is established, including a self-support constraint to eliminate support structure, and a curvature constraint to guarantee the layer thickness uniformity. In addition, a collision-free constraint, coupled with the planned sequences, is introduced to prevent cutting tool collision during SM.
To validate the proposed method, a number of 2D and 3D numerical examples are studied. At the end, the unaddressed technical issues on topology optimization for HASM are summarized to provide guidance for future research.

Multifunctional Additive Manufacturing with Laser_Induced Graphene

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Abstract

The integration of electrical functionality into additively manufactured structures remains a key challenge, largely due to incompatibilities between structural printing processes and conventional electronics fabrication. Laser-induced graphene (LIG) offers a solution by enabling the direct conversion of 3D printed polymer materials into conductive carbon using a digitally controlled laser process, fully compatible with additive manufacturing workflows. We will present our group's work leveraging LIG as a scalable conductive material for hybrid additive manufacturing. We discuss the LIG process, establishing relationships between laser parameters, thermal transport, microstructure evolution, and electrical performance. By analyzing energy delivery, pulse overlap, and scan strategy, we demonstrate how sheet resistance can be systematically minimized while avoiding ablation. To address scalability and parameter-space complexity, we introduce data-driven manufacturing frameworks based on machine learning to predict LIG sheet resistance and identify dominant process variables. This enables reproducible conductors with some of the lowest reported sheet resistance for LIG on both flexible and 3D-printed polymers.

We demonstrate hybrid additive manufacturing strategies, where LIG is patterned directly onto 3D-printed structures. In comparison with commercial conductive 3D printing filaments, LIG provides substantially lower resistance, finer feature control, and seamless integration with structural thermoplastics, without disrupting existing fused-filament fabrication processes. We further extend this approach to embedded microfluidic systems, discussing interface control, encapsulation, and mechanical stabilization. We present a representative variety of functional devices based on LIG, including energy storage, transistors, and sensors

Collectively, this work positions LIG as a digitally tunable, scalable conductor that enables integrated electronic functionality within additive manufacturing.

Smart design of 4D printed actuators based on shape memory polymers

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Abstract

Thermo-responsive shape memory polymers (SMPs) exhibit ubiquitous capabilities to retain programmed temporary shapes when cooled below glass transition temperature and return to their original form upon reheating. With temperature variation, SMPs experience significant change in mechanical properties including stiffness, viscosity and thermal expansion. The thermally induced deformation has inspired diverse applications, such as blood vessel stents and deployable space structures. In this work, we present an efficient constitutive model for characterizing thermomechanical behaviour of SMPs and apply it to design and optimize some 4D-printed SMP actuators.

The constitutive model is based on phase-transition concepts with the stress decomposed into contributions from netpoint and switching domains. The netpoint domain, composed of hard segments, is responsible for permanent shape recovery, whereas the switching domain varies stiffness through temperature-induced crystallization. Explicit expressions are proposed to characterize the evolution of mechanical properties in thermomechanical cycles. With eight essential parameters, the model can capture the shape memory effect with high accuracy against experiment data. We implement the constitutive model in a 3D finite element procedure via an Abaqus User ELement (UEL) subroutine. Several SMP structures under various training loads validate the accuracy and robustness of the computational procedure. The model further enables optimized design of SMP actuators, including bilayer bistable beams and bending hinges. The devices are fabricated via Fused Filament Fabrication material extrusion using thermoplastics such as Polylactic Acid (PLA) and Polyurethane (TPU). The printed actuators show improved restoring force and energy output compared to conventional pure SMP devices, which match the predictions of the simulations. The outcomes will provide new insights into SMP modelling and actuator design.

Uninterrupted Subsurface Temperature Measurement at Multiple Build Heights in PBF-LB Using a Novel Thermocouple Insertion Technique

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Abstract

Understanding the subsurface thermal behaviour in Laser Powder Bed Fusion (PBF LB) is essential for predicting defect formation, microstructural development, and resulting mechanical performance. However, conventional experimental methods have been unable to provide uninterrupted in-situ temperature measurements beneath the build surface, limiting accurate thermal analysis and model validation. This study presents an automated thermocouple insertion mechanism that enables continuous monitoring of subsurface temperatures throughout the entire PBF LB process. Up to four thermocouples are progressively inserted from the build plate into the growing part, allowing temperature measurements at multiple heights within a single build. The subsurface temperature data shows a sharp rise and pronounced fluctuations near the build surface, followed by a shift to a more stable quasi steady regime as distance to the surface increases, together with progressive thermal accumulation as build height increases. Repeated builds confirm strong measurement repeatability, with a maximum standard deviation of 2.4 °C. This technique provides a reliable pathway for acquiring high fidelity subsurface thermal data, supporting improved thermal modelling, process understanding, and optimization of PBF LB.

MagTrack-Soft: A Temperature-Responsive Shape Memory Hydrogel-Based Soft Robot for Adaptive Slope Transition and Magnetically Assisted Inclined Locomotion

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Abstract

In this research, we present MagTrack soft which is designed and development a magnetically embedding soft robotic systems based on a temperature responsible shape memory hydrogel (SMG) for accommodating slope transitions and inclined iron surface locomotion. The hydrogel component is prepared by the N,N-Dimethylacrylamide (DMAAm) as the main monomer, N, N_-Methylenebisacrylamide (MBAA) as a crosslinker agent, thermally stimuli stearyl acrylate (SA) monomer, MG7-1010 as a soft elastic behaviour monomer, and photopolymerization material Diphenyl(2,4,6-trimethyl) phosphine oxide (TPO). The Shape memory hydrogel provides mechanical tunability, activates thermal shape recovery, enhance repeated deformation without permanent structural damage. Additionally, the SMG hydrogel allows the robot to conform to inclined surface geometries and maintain continuous contact.

Conventional rigid tracking robots posses limited slope transition adaptability, struggling with highly varied terrain due to their inflexible and rigid body. Reslove this issue, the Magtrack Soft robot consist of a serially anchoring permanent magnet on the soft hydrogel segment form a continuous locomotion mechanism capable of structural adaptation and provide the externally magnetic adhesion that balancing gravitational forces during inclined climbing. The combined magnetic anchoring and material-driven adaptability improve surface conformity, and traction stability. Magtrack Soft System illustrate how thermal-responsive hydrogel materials enhance robotics adaptability in complex inclined surface. This study contributes to the development of materials programmed in the advancement of adaptive soft robotic mobility systems.

Scalable fabrication of ultra-thin shell lattices via laser powder bed fusion using a single-track scanning strategy

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Abstract

Metallic thin shell lattices are promising for high-end components and devices requiring extreme weight reduction and multifunctionality. However, scalable and defect-free laser additive manufacturing of thin shell lattices is hindered by the conflict between the computational efficiency and geometric resolution inherent in the conventional stereolithography (STL)-based preprocessing pipeline. Here, we propose a single-track scanning strategy that remarkably reduces the slicing computational cost and the as-printed shell thickness. Through direct generation of single-track laser paths from the implicit function geometric models, the proposed strategy not only achieves more than 96% and 80% reductions in memory and time consumptions, respectively, but also reduces the minimum shell thicknesses from 350-500 _m to 170 _m. Through synergistic optimization of laser path and process parameters, serious defects at large overhang and thin-walled regions are eliminated, which enables 48.4%-81.9% improvements in specific stiffness and strength. Based on the proposed strategy, an integrated design and preprocessing software package is developed to generate the laser paths of TPMS lattice infilled structures with user-prescribed boundary shapes. The software enables the design and laser powder bed fusion fabrication of large-scale lattice structures including more than 2000 lattice unit cells, which is difficult to handle using conventional STL based methods. This work enables the high-efficiency and high-quality fabrication of large-scale thin shell lattices for lightweight and multifunctional applications.

Software defined manufacturing and digital twins for the manufacturing of the future

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Abstract

Software-defined manufacturing is changing how processes and products as well as production systems are designed, controlled, and optimized. This presentation focuses on functional digital twins, which go beyond geometry to represent product functions, interactions between components, and system behavior. By linking multiple hardware elements into shared functional models, these twins enable a more holistic view of manufacturing processes and resulting products.

Each hardware component is treated as a software-defined asset with a digital identity, allowing continuous tracking, configuration, and lifecycle monitoring. This supports flexible production, including adaptive lot-size control across manufacturing, assembly, and system operation.
The approach highlights how functional digital twins can improve flexibility, traceability, and responsiveness in future manufacturing environments.

Zero-waste electrospun PLA membranes with biomass-derived carbon dots and hydrochar for sustainable dye removal

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Abstract

The sustainable utilization of biomass waste is a promising route toward green manufacturing and circular-economy–oriented materials. Here, we report an advanced manufacturing approach to water purification by producing an all-bio-based composite adsorbent membrane that co-utilizes two value streams from a single biomass feedstock: biomass-derived carbon dots (CDs) and carbon waste (CW) from apple peels. Here, CW denotes the hydrochar byproduct (carbon waste) from carbonization, which is rarely utilized alongside CDs. CDs and CW were obtained via one-step solvothermal carbonization and integrated into electrospun polylactic acid (PLA) nanofibrous membranes using a scalable single-nozzle electrospinning process followed by ultrasonic-assisted immobilization of CW. This sequential yet modular fabrication enabled a zero-waste design concept in which CW is not treated as a byproduct but as a functional component that complements CDs within the same membrane architecture. Morphological characterization showed that CW loading transformed the nanofibrous mat into a more loosely stacked structure, increasing accessible surface area and pore volume and thereby improving dye diffusion and exposure of adsorption sites. Consequently, the optimized PLA/CDs/CW membrane achieved maximum adsorption capacities of 141.99_mg/g for neutral red, 130.52_mg/g for methylene blue, and 110.83 mg/g for malachite green, outperforming single-component membranes (PLA/CDs or PLA/CW). Adsorption kinetics followed a pseudo-second-order model, and equilibrium data were consistent with Langmuir-type behavior. The enhanced performance is attributed to improved mass transfer enabled by the loosely stacked porous structure and abundant surface functionalities on CDs and CW that promote electrostatic interactions, hydrogen bonding, and π–π interactions with dye molecules. The composite retained >95% removal efficiency after five adsorption–desorption cycles and enabled efficient simultaneous removal of multiple dyes. Overall, this electrospinning-enabled, biomass-waste–derived composite membrane provides a practical strategy for designing high-performance, regenerable adsorbents for sustainable wastewater treatment.

Computational Analysis and Simulation of an Innovative Pellet-Fed Extruder for 3D Printing

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Abstract

As additive manufacturing (AM) transitions toward industrial-scale production, the limitations of filament-based extrusion, specifically high material costs and restricted feedstock options, have driven the development of pellet-based systems. This study focuses on the design optimisation of a novel pellet extruder aimed to enhance the reliability and flow consistency of 3D printing systems. While pellet extrusion offers greater economic and material advantages, it requires precise internal geometry and thermal balance across the extruder to ensure a stable, homogenous melt flow. This study details the design of an innovative pellet extruder through multi-physics numerical Finite Element Analysis (FEA) and Smoothed Particle Hydrodynamics (SPH) performed in Ansys® Academic Research Mechanical, Release 2025 R2 with implicit and LS-DYNA solvers. By integrating rheological data and relevant material models, this simulation approach enables a comprehensive study of the solid-to-melt transition. This allows for analysis of pellet alignment and feeding, heat transfer, and the resultant temperature-dependent viscosity shifts that govern melt pressure buildup and flow stability.

Key results highlight the optimisation of the extruder sub-systems, starting from pellet alignment and feeding, followed by the stabilisation of thermal profile to ensure consistent melt viscosity at the nozzle. By analysing and hence visualising results for these material's phase transitions and rheological shifts, this study provides a precise methodology for refining the extruder components' geometry, while significantly reducing extruder prototyping costs. Ultimately, these coupled thermo-mechanical simulations prove essential for improving the accuracy and scalability of pellet-fed AM. A detailed analysis of the performance benchmarks will be presented during the conference.

AI-enabled inverse design of multifunctional lattice metamaterials

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Abstract

We developed an integrated AI-driven framework for the inverse design of multifunctional lattice metamaterials, addressing the limitations of conventional design methods through four interconnected research phases. First, we constructed a hierarchical plate-TPMS (triply periodic minimal surface) architecture by integrating stretching-dominated plate lattices with TPMS structures, enabling precise mechanical property tuning via implicit function modeling and Gibson-Ashby model optimization. Despite achieving superior stiffness and uniform stress distribution compared to shell-based structures, this parametric approach remained constrained by predefined geometric configurations.

To fully explore the design space, we introduced an ANN (Artificial Neural Network) + NSGA-II (Non-dominated Sorting Genetic Algorithm - II) framework enabling rapid multi-objective optimization of mechanical-acoustic performance with >96% prediction accuracy, revealing Pareto-optimal designs with 50% higher energy absorption than traditional gyroid structures. However, both data-driven methods relied on existing datasets and basic implicit functions, restricting novel topology discovery. This motivated our third phase: a 3D conditional GAN (Generative Adversarial Networks) + CNN (Convolutional Neural Networks) design framework achieving >98% prediction accuracy while autonomously generating architectures with 40-200% enhanced energy absorption and broadband sound absorption (above 0.5 across 1000-5800 Hz), though still limited to single-material system. Recognizing persistent challenges in physical interpretability and material diversity, we developed a PINN (Physics-Informed Neural Networks) + generative model hybrid approach. By embedding physical constraints into the neural architecture, this framework enhances model transparency while enabling inverse design of gradient lattice structures with multi-material composition and multi-geometric configuration. The resulting system demonstrates tailored performance for extreme conditions, including low-temperature impact resistance and high-temperature creep resistance. Collectively, these works form a cohesive design framework: from geometry-constrained parametric optimization, to data-driven performance prediction, to generative topology discovery, and finally to physics-informed multi-material gradient design. This progression establishes a comprehensive AI-enabled design paradigm for next-generation lattice-based metamaterial development, balancing computational efficiency, physical fidelity, and multi-material innovation.

Topology optimization design and deformation behavior control of SMA-actuated bistable structures

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Abstract

Bistable structures, characterized by their ability to maintain two distinct stable configurations without continuous energy input, hold significant promise for applications in space deployable mechanisms and morphing structures. The joule heating–driven actuation of shape memory alloys (SMAs) endows bistable structures with self-actuation capabilities, enabling them to function simultaneously as supporting and driving components. However, the precise design of SMA-actuated bistable structures and effective control over their deformation behavior remain challenging. This paper proposes a topology optimization framework tailored for SMA-actuated bistable structures, aiming to synergistically enhance lightweight design and actuation performance.

First, an isogeometric mechanical model incorporating hyperelastic material constitutive behavior and geometric nonlinearity is established to accurately capture the snap-through behavior under mechanical loading. Second, within the solid isotropic material with penalization (SIMP) framework, a multi_objective topology optimization model is formulated to maximize actuation displacement while minimizing structural compliance. The adjoint method is employed to derive sensitivities, addressing challenges associated with nonlinear convergence. Leveraging this optimization framework, the critical snapping state is treated as a design variable to proactively tailor the snap_through behavior, enabling precise shape–performance control.

Optimization results demonstrate that the resulting bistable configurations allow tailored triggering energy and deformation displacement. By adjusting the weighting factors in the optimization objectives, effective control over the critical snap_through force and deformation amplitude is achieved. These tailored configurations significantly enhance the actuation efficiency of SMAs by lowering the energy barrier for self_actuation. The proposed method validates the feasibility of designing SMA_actuated bistable structures and offers a new approach for active deformation design in 4D_printed smart structures.

Efficient simulation of SMA morphing wings using physics-informed neural networks

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Abstract

Smart morphing wings with shape memory alloy (SMA) components are promising for a wide range of aerospace applications due to their programmability, high energy density, and lightweight nature. However, accurate prediction of their functional behaviour remains challenging because of the complex, thermally dependent phase transformation of SMAs. Classical finite element analysis (FEA) can accurately model the constitutive behaviour of SMAs and the mechanical deformation of smart morphing structures. Nevertheless, its low computational efficiency and reliance on trial-and-error for convergence constitute a major research gap, limiting its applicability to computationally intensive tasks such as system-level design, simulation, and optimization.

This paper presents a physics-informed neural network (PINN)–based framework for the efficient simulation of SMA-driven morphing wings. By embedding governing equations, phase-transformation evolution constraints, and boundary conditions into the training loss, the underlying SMA physics, including the highly nonlinear, temperature-dependent stress-strain hysteresis, is consistently preserved in the PINN model. The proposed framework is further applied to structural topology optimization while avoiding the mesh distortion issues that commonly arise in FEA-based optimization. Moreover, the model is inherently differentiable with respect to the design parameters, greatly simplifying sensitivity computation.

The effectiveness of the proposed method is validated through numerical benchmarks of wing leading and trailing edges under aerodynamic and thermal loading conditions. The results demonstrate that the method maintains both robustness and predictive accuracy even in large-deformation regimes. The PINN-based surrogate model thus offers a promising tool for the structural optimization of SMA-driven morphing wings.

Edge Computing Design Scenario for Direct-ink-writing 3D Printing

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Abstract

Rapid advancement in direct-ink-writing 3D printing needs to ensure high-quality forming and performance fidelity. To address the issues of defect detection delays and high data transmission loads caused by existing monitoring methods, an in-situ intelligent detection method based on edge computing is proposed. Our work builds a two-level detection architecture in series, performing classification from the judgment of defect existence to specific defect types. Based on an improved, lightweight deep learning model and an integrated image acquisition and preprocessing module, the complete intelligent monitoring system is deployed on a designed edge computing platform. Experimental results show that the method achieves a whole-whelming defect-detection accuracy within a single-frame image-detection time limit, and the classification accuracy for local defects across layers is high. This system significantly improves execution efficiency while ensuring detection accuracy, providing an effective technical solution for quality control in direct-ink-writing 3D printing.

Designing against failure in monolithic and graded additively manufactured materials

Allison Beese

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Abstract

To adopt metallic materials made by additive manufacturing (AM), it is critical to understand, and design against fracture, particularly under complex stress states accessed in service, and with the possible presence of internal pores. Additionally, when designing functionally graded materials (FGMs) in which composition is deliberately varied with position within a component to result in spatially tailored properties, it is critical to avoid deleterious phase formation and solidification cracking during fabrication. This talk will describe our approach for studying the combined effects of stress state and internal pores on the fracture behavior of alloys manufactured using laser powder bed fusion AM, providing a pathway for designing against failure under realistic conditions. Additionally, it will describe our framework for considering deleterious phase formation and crack susceptibility when designing compositional pathways for FGMs, and more broadly, compositions amenable to AM in general.

Microwave in Additive Manufacturing - Near-Field Microwave-Plasma Metal Fusion

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Abstract

Microwave-based energy delivery is emerging as a compelling pathway for reducing the power intensity and material limitations of metal additive manufacturing (AM). Conventional laser- and arc-driven systems often require high power densities and face challenges when processing highly reflective metals. Here, we report a Near-Field Microwave-Plasma Metal Fusion (NF-MPMF) approach that leverages confined microwave-induced plasma to deliver localized, efficient heating to metallic powder beds at input powers of 100 W. A coaxial microwave-plasma applicator is designed to concentrate the electromagnetic field and sustain a stable, high-temperature plasma in argon at atmospheric pressure without relying on high-velocity gas jets in typical microwave plasma systems that may disrupt melt-pool stability. A multiphysics model, coupling electromagnetic, plasma, fluid, and thermal fields, was developed to elucidate the plasma ignition mechanism and guide applicator optimization. The model reveals a broad operating window for maximizing energy transfer, with peak power deposition and gas temperatures occurring at stand-off distances of approximately 0.8–1.0 mm. Geometry studies further identify nozzle and applicator configurations to minimize microwave reflections and enhance coupling efficiency. Experimental characterization confirms substrate temperatures exceeding 900 °C at 45W input powers, demonstrating the strong heating capability of the near-field microwave-plasma. Using the NF-MPMF system, we also achieved single-track consolidation with various metals, thus proving the robustness of the method, including for copper, which is difficult to process with a typical laser powder bed fusion system. The combined modelling and experimental results establish NF-MPMF as a promising alternative for metal AM, offering reduced energy demand and improved process stability. This study provides a mechanistic overview and practical design guidelines that advance the integration of microwave-plasma technologies into next-generation metal AM systems.

Aluminium Matrix Composite Powder – Much More Than Just a Simple Powder Mixture: Production, Properties, Applications and Opportunities

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Abstract

Aluminium matrix composites (AMCs), well known in the foundry sector, are increasingly in demand in the AM industry. By adding a hard material (e.g. Silicon Carbide), aluminium, a lightweight construction material, can be used for components subject to wear. The addition of a reinforcing phase also has a positive effect on hardness, stiffness and the thermal properties, respectively. In general, a very wide range of properties can be configured.

When AMCs are used in the AM industry, powder mixtures have generally been used up to now. Such conventional powder mixtures or blends consisting of aluminium alloy powder and a reinforcing phase have a number of disadvantages in terms of processing. In comparison, novel composite powders offer numerous advantages in powder processing and, in addition to that, in the resulting properties of the additively manufactured product.

Instead of mixing two different powders together, AMC bars, cast by CMMC, are atomized crucible-free according to the patented NANOVAL process. In this process, only the tip of the bar will be heated by an induction coil and the melt is carried along by the positively accelerated gas flow and atomized after reaching ultrasonic velocity. This results in extremely fine, spherical particles with a narrow distribution due to a process-related laminar flow and the resulting high momentum exchange. With the NANOVAL process, we achieve a powder quality that is unique worldwide, in which almost every single aluminium matrix particle contains an enclosed SiC particle.

The presentation covers the production of a AMC material (AlSi9Mg + 20 vol.% SiC), the atomisation process, the processing of the powder, for example in coating technologies or 3D metal printing, and the final properties.

Investigating Inorganic Solid-Electrolyte Interphase Compounds for Stabilizing Lithium Metal Anodes

Mun Sek Kim

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Abstract

Lithium-ion batteries (LiBs) have enabled widespread electrification of portable electronics, electric vehicles, and grid-scale energy storage; however, their practical energy density is approaching intrinsic limitations. Lithium metal batteries (LMBs) have consequently attracted renewed attention due to their exceptionally high theoretical energy density, yet their practical implementation remains hindered by limited cycle life and safety concerns associated with unstable lithium metal anodes. These challenges primarily stem from the uncontrolled formation of solid-electrolyte interphase (SEI) and the continued reliance on electrolyte chemistries inherited from LiBs. Recent studies have demonstrated that deliberate manipulation of SEI chemistry through electrolyte design offers an effective route to stabilizing lithium metal interfaces. In particular, inorganic-rich SEIs have emerged as a key factor in suppressing parasitic reactions, mitigating morphological instability, and regulating lithium electrodeposition behaviour. In this work, we investigate the roles of inorganic SEI compounds in stabilizing lithium metal anodes. Mechanistic insights derived from this analysis reveal how inorganic SEI constituents influence interphasial stability and long-term cycling behaviour. These findings establish materials-level design principles for electrolyte and interphase engineering and provide a framework for the rational development of next-generation electrolytes for LMBs. More broadly, this work highlights the central role of interphase chemistry in enabling high-energy-density battery systems beyond conventional LiB technologies.

The Complex Metallurgy Mismatch Emerging from LPBF Supportless Low Angle Printing

M. Brochu, M.A. Shandiz, A. Kumar, M. Park, M. Kesharwani, J. Dhillon and O. Binfahad

McGill University

Abstract

Low angle supportless printing has been researched for several years, and numerous machine OEMs are now beginning to commercialize solutions and advanced protocols to take advantage of reduced printing time, lower material consumption, and decreased post printing machining costs. Supportless printed parts are widely publicized, but the detailed and systematic characterization of the downskin region—and how it differs from the bulk—is rarely reported. Even though the physics of the fusion/solidification process and the resulting heat balance remain similar, local processing conditions must be optimized to permit successful printing, protocol optimisation that will strongly influence the microstructure of this region. In this presentation, several competitive interactions and microstructural/property gradients will be discussed for Ni based, Fe based, Ti based, and Al based alloys. An analysis proposing solutions to eliminate these mismatches will also be presented and rationalized in terms of alloy composition.

Reframing Additive Manufacturing through Textile-Integrated 4D Structures

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Abstract

The integration of additive manufacturing, AM, with 4D textiles establishes a new perspective for both textile engineering and additive production. Conventional 3D printing on fabrics has primarily focused on coating, reinforcement, or surface functionalization. In contrast, this research positions textiles as active structural elements within programmable 4D systems. By combining fabric elasticity with geometrically defined printed architectures, a hybrid manufacturing strategy emerges that expands the functional scope of both technologies.

In this concept, textiles function as mechanical components rather than passive substrates. Structural geometries are deposited onto pre stressed fabrics using fused deposition modeling. When the pre strain is released, stress differentials between textile and polymer trigger controlled three dimensional transformation. The fabric serves as an elastic energy storage medium, while the printed structure defines folding lines, stiffness distribution, and kinematic behavior. Shape change is therefore governed by structural mechanics instead of material phase transitions.

Compared to shape memory polymers and purely polymer based AM structures, the textile integrated approach improves cyclic stability, optimizes flexibility to stiffness ratios, and reduces material usage. The synergy between high tensile textile performance and geometric precision in additive manufacturing enables tunable activation forces and predictable deformation pathways. Mechanical response can be adjusted through crease design, print layout, and process parameters. This textile AM integration introduces a “Flat to Form” manufacturing logic. Components are produced in planar configurations for efficient fabrication and transport, then transform into spatially complex load bearing structures during use. Such systems are relevant for lightweight construction, deployable architectures, mobility concepts, and adaptive protective equipment.

By merging textile mechanics with additive design freedom, this work redefines 3D printing on fabric as a structural engineering methodology. Textile integrated 4D systems demonstrate how additive manufacturing can evolve beyond static fabrication toward intelligent, deployable, and multifunctional material architectures.

Electrically assisted stereolithography 3D printing of graded composites for biomedical applications

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Abstract

Graded composites have broad applications in biomedical fields, including tissue engineering, interventional scaffolds, and implants. However, conventional manufacturing technologies are often inadequate for fabricating multifunctional graded composites. Herein, we demonstrate that a single composite feedstock, combined with electrically assisted stereolithography-based 3D printing, enables the realization of a wide range of material properties and high-resolution three-dimensional graded architectures. Compared with pure resins and uniformly dispersed filler-resin composites, the resulting graded composites better mimic natural biological structures, reproducing the heterogeneity and gradient properties of native tissues. The proposed electrically assisted stereolithography technique, together with the fabricated graded composites, offers a promising strategy to advance biomedical engineering by meeting patients' individualized needs.

Ultrasonic welding process and mechanism of 3D printing continuous carbon fiber reinforced nylon composites

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Abstract

Ultrasonic welding (UW) is a fast, solvent-free solid-state joining method whose local pressure-and-heat action is theoretically well matched to mitigate typical FFF defects at printed interfaces. However, reliable UW of 3D-printed CCFRCs remains challenging: nonuniform energy distribution at the joint, poor understanding of how energy-director (ED) design interacts with printing and welding parameters, and unclear links between process, interface state, and failure mode have impeded development of robust joining protocols.This study adopts a systematic "structure design — parameter optimization — mechanism elucidation" framework to address these gaps. We introduce an integrated, co-formed ED concept that is co-printed with the CF/PA substrate and parametrically couple ED geometry (height, angle) with key printing variables (layer thickness, fiber orientation) to reveal their combined effects on contact mechanics, energy transmission, and melt flow at the weld interface. Core UW parameters (amplitude, welding pressure, weld time, hold time) are then mapped to lap-shear and peel strengths through designed experiments. Fractography by scanning electron microscopy (SEM) and surface chemistry analysis by X-ray photoelectron spectroscopy (XPS) are used to identify dominant failure pathways (interfacial debonding, fiber pull-out, matrix melt fracture) and the interfacial strengthening mechanisms. By correlating mechanical outcomes with microstructural and chemical evidence, we establish quantitative criteria for failure-mode transitions and a process–design window for high-reliability UW of 3D-printed CF/PA structures. The results provide transferable guidelines for designing EDs and welding protocols to meet the demanding reliability requirements of automotive and aerospace structural applications.

Role of Yttria-Stabilized Zirconia Nanoparticles in Enhancing the Strengthening Mechanisms of Laser Powder Bed Fused AlSi10Mg

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Abstract

In this study, AlSi10Mg powder was reinforced with 2.83 vol% yttria-stabilized zirconia (YSZ) nanoparticles and homogenized via ball milling to achieve uniform dispersion of the reinforcement phase. The resulting composite material was fabricated using Laser Powder Bed Fusion (LPBF), an advanced additive manufacturing technique commonly employed for high-performance aluminum alloys. The research examines the effect of YSZ nanoparticle incorporation on the microstructure, grain morphology, and mechanical properties of AlSi10Mg, with a particular focus on the underlying strengthening mechanisms. The results indicate that the addition of YSZ nanoparticles facilitates the development of a refined equiaxed grain structure, leading to enhanced microstructural uniformity. The dominant strengthening mechanism is attributed to dislocation pinning by the nanoparticles, consistent with the Orowan strengthening effect, which effectively impedes dislocation motion and improves material strength. Additionally, the substantial difference in atomic structure between ZrO_ and the aluminum matrix emphasizes the critical role of the reinforcement–matrix interface in governing mechanical performance. This study further assesses the influence of interfacial bonding on load transfer efficiency and its contribution to the overall behavior of the composite. Tensile testing revealed predominantly ductile fracture characteristics; however, premature failure occurred due to lack-of-fusion porosity. These findings highlight the necessity for further optimization of LPBF processing parameters to minimize defects and enhance the mechanical reliability of nanoparticle-reinforced AlSi10Mg composites.

Recent Progress in Ultrafast Laser Micro/Nano Fabrication

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Abstract

Femtosecond laser has become a major tool for micro/nano fabrication. In this talk, applications of femtosecond laser-induced polymerization or two photon polymerization (TPP) for fabrication of several devices and structures are presented. TPP process is studied to identify key variables affecting line width, surface smoothness and 3D structure profiles. Two-scale surface micro/nano structures are manufactured for surface wettability modification and its application in regulating water droplet flow. Metalens arrays are designed and fabricated for achieving diffraction-limited focusing and high-resolution imaging. TPP is employed to produce optofluidic microlenses with sizes below 10 μm, which exhibit tunable focal lengths, numerical apertures, and spot sizes without reliance on external forces and form the essential components of an optofludic system for potential applications in adaptive imaging and variable focal length microscopy. TPP is also studied for producing 3D micro-scaffolds for cell regulation. A method for obtaining Janus membranes with both superhydrophobicity and superhydrophilicity by ethanol and plasma treatment of laser-induced graphene (LIG) is proposed. The asymmetrically superwetting Janus membrane are shown to realize efficient oil–water separation. In addition, the superhydrophobic LIG is used as a coating material with excellent electrothermal properties, which provide the performance of anti-icing and electrothermal de-icing.

Toward Autonomous Additive Manufacturing using AI-driven Monitoring and Adaptive Control

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Abstract

Additive manufacturing (AM) enables precise placement of diverse materials with minimal geometric constraint. Unlike conventional manufacturing, AM functions as a data-rich physical system in which process inputs, material transformations, and structural evolution are digitally prescribed and continuously measurable during fabrication. This tight coupling between process and outcome makes AM uniquely suited for data-driven monitoring, optimization, and automated qualification. As computational costs decline, artificial intelligence (AI) has become central to this landscape by uncovering relationships among process signatures, materials, and final properties that are difficult to model explicitly. These capabilities enable defect prediction, real-time correction, and improved consistency across complex geometries. At the design scale, AI further enables exploration of high-dimensional, nonlinear spaces to identify new geometries and material distributions, particularly in multi-material systems.

Nonetheless, monitoring and AI strategies must be tailored to specific AM modalities. Extrusion-based direct ink writing requires rheological state estimation and flow stability tracking, often using pressure sensing or vision-based filament inspection. Vat photopolymerization depends on optical field characterization and cure-front modeling, where light distribution and polymerization kinetics determine part fidelity. Metal AM demands high-speed thermography and melt pool analysis under extreme thermal gradients. Each modality operates across distinct time scales, signal-to-noise conditions, and causal mechanisms, requiring specialized modeling and control architectures.

A central component of the talk will focus on emerging AI-based optimization and learning strategies which can be used for each technique such as invertible neural networks (INN), evolutionary algorithms (EA), and Bayesian approaches, and how these tools can be easily integrated with monitoring and control to create adaptive, data guided workflows. Rather than offering a purely aspirational view, the talk will emphasize both the strengths and the limitations of these methods, outlining where AI meaningfully advances AM and where current approaches remain fragile or unproven.

Magnetic-assisted laser shock peening of magnesium alloys with real-time monitoring of plasma dynamics and acoustic emission

Yongling Wu, Hongyu Zheng, Hongbiao Hu

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Abstract

To ensure the mechanical properties of magnesium alloy surfaces, laser shock peening (LSP) was adopted as an effective technique for introducing a compressive stress. The effectiveness of this process was largely constrained by the low laser energy absorbed by the surface due to the inherently low plasticity of the material. This study proposes a novel magnetic-assisted LSP (MLSP) strategy that incorporates static magnetic fields and real-time monitoring during the process, including acoustic emission (AE) detection and intensified charge coupled device (ICCD) plasma imaging. Numerical simulations of magnetic field intensity and plasma dynamics were conducted to clarify the MLSP process mechanism. The synergistic effects of plasma intensification and magnetoplastic dislocation unpinning enhanced shock wave intensity and deepened residual stress layer through the coupling of mechanical force and magnetic field applied on the material surface. The results showed that by applying a 0.8 T magnetic field, the plasma expansion distance was reduced to 3.7 mm, being 57.5 % shorter than without the magnetic field, whereby, enhanced the plasma confinement and energy density. Compared with the conventional LSP process, the MLSP process increased yield strength by 8.3 % and tensile strength by 6.5 % while maintaining excellent ductility. At the same time, the compressive residual stress (CRS) achieved a peak value of 194.1 MPa (a 14.0 % increase), extended the CRS-affected layer depth to 776.3 _m (a 10.1 % increase), and raised surface hardness by 23.3 %. In addition, the MLSP induced pronounced microstructural evolution, including surface grain refinement to 34.5 _m, being a 14.4 % reduction compared with LSP samples, increased dislocation entanglement and a higher density of nano-precipitates.

A Self-deployable Parabolic Structure for Statelite Antenna Design Using Multi-Material 4D Additive Manufacturing Approach

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Abstract

As demands increase for lightweight and deployable aerospace structures, 4D additive manufacturing techniques offer significant potential by enabling the creation of adaptive and self-deployable systems. This study investigates a multi-material 4D additive manufacturing approach based on fused filament fabrication (FFF) material extrusion process to fabricate origami-inspired parabolic structures. This study is expected to serve as an early exploration toward future satellite antenna applications. A planar sheet design featuring strategically placed smooth folds and rigid faces is adopted so that the structure is able to transition into a complex 3D configuration when exposed to external thermal stimuli. A sandwich layering strategy is implemented in which polylactic acid (PLA) is used as the outer layers owing to its shape memory properties, thereby providing both shape recovery and structural stability. In contrast, thermoplastic polyurethane (TPU) is incorporated internally to enhance flexibility and to enable controlled folding and deployment. The interface between these two materials is optimized through a mechanically interlocking slicing approach that ensures robust adhesion and functional reliability. In addition, an acrylonitrile butadiene styrene training mold is employed to refine the shape conditioning process, delivering consistent and accurate deployment profiles. Shape training results confirm the feasibility of this integrated multi-material 4D printing methodology for producing transformable parabolic structures. The findings demonstrate that the shape memory characteristics of PLA and the flexibility of TPU enable the fabrication of reliable self-deployable structures with a recovery ratio approaching 100%. This work presents a promising route for the development of advanced aerospace components and demonstrates that the combination of shape memory polymers, carefully structured folding patterns, and targeted interface design can yield efficient and functional deployable systems that are well suited for the aerospace applications.

Development of a Next-Generation Surface-Conformal Cooling System with Enhanced Cooling Performance Using Additive Manufacturing Technique and Rapid Tooling

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Abstract

This study proposes and implements a surface-shaped cooling channel (SSCC) enabled by additive manufacturing (AM)–based rapid tooling technology. Unlike conventional cooling channels that rely on line-contact heat transfer, the proposed SSCC achieves cooling through direct surface contact with the molded product, thereby enhancing heat dissipation efficiency. The complex geometry of the SSCC, which is difficult to realize using traditional subtractive machining, is designed and optimized through numerical simulation and successfully fabricated using an AM-assisted rapid tooling approach. For performance evaluation, rapid tooling inserts incorporating two different cooling channel designs—namely, the proposed SSCC and a conventional conformal cooling channel—are produced and experimentally compared. Cooling performance is assessed using a low-pressure wax injection molding system. A cup-shaped specimen with a mouth diameter of 70 mm, a height of 60 mm, and a wall thickness of 2 mm is selected as the test geometry. Experimental results indicate that the SSCC reduces the cooling time by approximately 265s compared with the conventional conformal cooling channel, corresponding to an improvement in cooling efficiency of about 17.47%. These results demonstrate that the integration of additive manufacturing techniques with rapid tooling provides an effective solution for realizing advanced cooling channel designs and significantly enhancing cooling performance in injection molding applications.

Addressing the Scale-Resolution Dilemma in Vat Photopolymerization Through a Motion-Aided Approach

Yang Xu

The University of Hong Kong

Abstract

3D objects with features spanning scales from the microscale to the macroscale hold immense potential for a wide range of applications, including biomedicine, biomimetic surfaces, and metamaterials. However, fabricating such complex structures remains a significant challenge in projection-based vat photopolymerization (VPP). One major limitation is that the horizontal printing resolution (in the XY direction) decreases as the printing area increases, due to the simultaneous scaling up of the pixel size in the mask image projection. Additionally, light penetration can lead to overcuring of the liquid photopolymer, compromising the Z-axis resolution. These challenges hinder projection-based VPP from producing macroscale objects with intricate microscale features, which are commonly found in both natural and man-made structures. To overcome these limitations, we introduce a novel VPP process that incorporates additional motion axes. First, to resolve the trade-off between resolution and print area in the XY plane, we employ a continuous mask image scanning strategy across the build area. By synchronizing linear scanning projection with galvo mirror rotation, motion blur is effectively eliminated, enabling ultra-fast curing of large-area parts at a projector refresh rate as low as 60 kHz. Furthermore, an auxiliary build platform, controlled by additional motion stages, significantly enhances the Z-axis resolution by mitigating light penetration. This approach allows for the fabrication of microchannels as small as 10 _m. The motion-aided VPP process dramatically expands the capabilities of vat photopolymerization, enabling the creation of macroscale structures with intricate microscale features. These advancements open new possibilities for transformative applications in fields such as microfluidics, biomimetic surfaces, and metamaterials.

Optimization of Laser Powder Bed Fusion Parameters for the Processing of Pure Platinum

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Abstract

Pure platinum presents significant challenges for laser powder bed fusion (LPBF) due to its high reflectivity at near-infrared wavelengths, high thermal conductivity, and elevated melting temperature. These characteristics constrain melt-pool stability and hinder the production of high-density components. With increasing industrial demand for complex platinum-based structures in fields such as catalysis, biomedical devices, jewellery, and high-temperature applications, the need for well-defined LPBF processing parameters for pure platinum and its alloys is becoming increasingly critical.

In this study, the influence of key LPBF process parameters—namely laser power, scan speed, hatch spacing, and layer thickness—on the additive manufacturing of pure platinum parts is investigated. A design-of-experiments (DoE) approach is combined with numerical modelling using FLOW-3D to characterise melt-pool dynamics under varying processing conditions. Experimental builds are evaluated using Archimedes density measurements, optical microscopy, scanning electron microscopy (SEM), and micro-computed tomography (CT) to assess density, defect morphology, and microstructure.

The results aim to establish a robust processing window capable of achieving fully dense specimens by balancing energy input with the rapid thermal dissipation characteristics of platinum. This study contributes to the development of a comprehensive process–microstructure–property relationship for LPBF of pure platinum and provides fundamental insights for advancing the additive manufacturing of high-value platinum components.

Substrate-less bioelectronic fibres fabrication across diverse surfaces

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Department of Engineering, University of Cambridge

Abstract

The biological sensory systems of living structures could be amplified with wearable electronics, enabling applications such as health monitoring, medical treatment, environmental tracking, tactile augmentation, and others. Advances in soft film technologies enable conformal adhesion to human skin, but they largely obstruct the bulk biological functions of the skin when worn for an extended period. Three-dimensional printing or functional ink spraying could produce customised conductive tracks, but the surface texture could compromise print resolution and precision. Challenges remain in designing and creating such electronics that could conform to the various shapes and surface textures of the objects while satisfying the constantly shifting requirements in different situations.

Here, we report a novel fabrication method for producing substrate-less bioelectronic microfibers that can be deposited on various surfaces, including skin, everyday stationery, tools, and smartwatches, as well as unconventional materials such as porous aerogels. The solution-drawn microfibers are directly deposited onto the object surface in a semi-wet state upon synthesising, enabling transfer-free fibre-object integration in a one-step process. The design and format of the microfiber patterns could be tuned on demand to adapt to the shapes and material textures of the target objects and to suit the user-intended applications. Being air-permissive and highly transparent to electromagnetic waves in the gigahertz range, the microfiber functionalization layers would minimally obstruct the original appearance and functions of the objects, while equipping them with sensing, energy conversion, and electronic connection capabilities. On the other hand, as a demonstration, these on-skin bioelectronic fibres are utilised for tactile augmentation to differentiate materials

Generating a Digital Twin of the Laser Powder Bed Fusion Process

Prof. Dermot Brabazon

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Abstract

Metal additive manufacturing, which uses a layer-by-layer approach to fabricate parts, has many potential advantages over conventional techniques, including the ability to produced complex geometries, fast new design part production, personalised production, have lower cost and produce less material waste. While these advantages make AM an attractive option for industry, determining process parameters which result in specific properties, such as the level of porosity and tensile strength, can be a long and costly endeavour. In this review, the state-of-the-art in the control of part properties in AM is examined, including the effect of microstructure on part properties. The simulation of microstructure formation via numerical simulation and machine learning is examined which can provide process quality control and has the potential to aid in rapid process optimization via closed loop control. In-situ monitoring of the AM process couple with modelling and AI technologies, are discussed as a route to enable first time right production in the AM process, along with the hybrid approach of AM fabrication with post-processing. At the end of the presentation, an outlook is presented with a view towards potential avenues for further research required in the field of metal AM.

Sustainable and Functional 3D Printing Platforms for Environmental and Biomedical Applications

nil

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Abstract

Industrial transformation toward sustainable and high-performance manufacturing demands advanced materials and processing strategies that integrate functionality, scalability, and environmental responsibility. This work presents two complementary additive manufacturing (AM) platforms that leverage eco-friendly materials and binder-free processing to enable functional systems for environmental and biomedical applications. First, we demonstrate a scalable, binder-free 3D printing strategy based on brominated poly(2,6-dimethyl-1,4-phenylene oxide) (Br-PPO) for the fabrication of monolithic CO_ adsorbents. By controlling polymer bromination levels and optimizing printed architectures, the resulting structures exhibit enhanced CO_ capture capacity, efficient gas transport, and long-term structural stability without pressure drop, highlighting their potential for compact air purification and gas separation systems in industrial settings. Second, we introduce plant-derived pollen microgels as renewable bio-fillers for hydrogel-based 3D bioprinting, enabling sustainable biofabrication with reduced ink complexity. Incorporation of sunflower and camellia pollen microgels into alginate matrices provides tunable mechanical properties, pH-responsive behavior, and improved cell affinity, offering a bio-inspired route toward functional biomedical scaffolds for tissue engineering and drug delivery. Together, these studies illustrate how material innovation, architectural design, and sustainable AM processes can be combined to develop multifunctional platforms across environmental and biomedical domains. This work underscores the role of advanced manufacturing in driving sustainable, high-value industrial transformation through eco-conscious materials and functional 3D printing systems.

Additive Manufacturing of Elastomer, Ceramic and Metal Multi-functional Structures

Eric MacDonald

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University of Texas at El Paso

Abstract

3D printing has been historically relegated to fabricating conceptual models and prototypes; however, increasingly, research is now focusing on fabricating functional end-use products. As patents for 3D printing expire, new low-cost desktop systems are being adopted more widely and this trend is leading to a diversity of new products, processes and available materials. However, currently the technology is generally confi ned to fabricating single material static structures. For additively manufactured products to be economically meaningful, additional functionalities are required to be incorporated in terms of electronic, electromechanical, electromagnetic, thermodynamic, chemical and optical content. By interrupting the 3D printing and employing complementary manufacturing processes, additional functional content can be included in mass-customized structures. This presentation will review work in multi-process 3D printing for creating structures with consumer-anatomy-specifi c wearable electronics, electromechanical actuation, electromagnetics, energy storage, propulsion, embedded sensors in soft tooling – in polymers, elastomers, metal and ceramic material systems.

Fast laser processing of silicon carbide ceramic materials

Jie Yin*, Xuejian Liu, Zhongming Chen, Zhengren Huang

Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai, China

Abstract

SiC-based Ceramic composites are promising for usages as various large-scale and complex-shaped components. However, the intrinsic brittle nature of SiC ceramics inhibited their wide application. Incorporation of chopped carbon fiber as a reinforcing phase could enhance its reliability. During recent years, efforts have been devoted to fast forming techniques to reduce excess carbon reduction. Additive manufacturing of SiC-based ceramics by adopting various techniques, including digital light processing, direct ink writing, selective laser printing, and et al were emerged. In previous study, our group conducted investigation on direct ink writing of C/SiC ceramic composites. The critical point was the preparation of homogenous C/SiC green bodies. In recent study, we combined selective sintering and liquid silicon infiltration for a higher-efficiency and higher-performance-component fabrication. We prepared complex-structured composites therefrom. The relationship between microstructure tailoring and mechanical performance was investigated.

Low cost in-situ monitoring during wire and arc additive manufacturing: imaging with machine learning

André Ramalho, Anis Assad, Benjamin Bevans, Fernando Deschamps, Telmo G. Santos, Prahalada Rao

Universidade NOVA de Lisboa

Abstract

To address stochastic instabilities in Wire Arc Directed Energy Deposition (WA-DED), this research utilized high-speed meltpool imaging to identify the physical drivers of humping and porosity. By extracting morphological signatures from ER90S-G steel depositions, a process-aware machine learning model was developed for real-time detection. The model achieved 85% accuracy (F1-score), outperforming traditional black-box models (<66%). The findings provide a framework for physically intuitive, real-time quality control in additive manufacturing.

Highly pressure-resistant and high-rate ultrathick micro-Si anodes for 3D microbatteries via direct-ink-writing of directionally continuous porous microstructure

Chi Guo, Zhiyang Lyu*

Jiangsu Key Laboratory for Design and Manufacturing of Precision Medicine Equipment, School of Mechanical Engineering, Southeast University, Nanjing, 211189, China

Abstract

3D microbatteries, featuring customizable and thick electrode designs, are crucial for miniaturized and specialized electronic devices. However, the practical implementation of thick 3D microelectrodes is often challenged by sluggish ion transport and mechanical instability under external and internal stresses. In this report, we developed pressure-resistant ultrathick micro-Si 3D microelectrodes using an in-situ directional freezing-assisted direct-ink-writing 3D printing approach. This approach enables the construction of ultrathick electrodes up to 2.7 mm, achieving an ultrahigh areal capacity of 14.0 mAh cm-2. The 3D-printed thick electrodes demonstrate remarkable pressure-resistant capability due to the formation of directionally continuous porous microstructure, providing a high compression modulus of 3.04 MPa. The directional pore microstructure not only effectively resists external stress and mitigates micro-Si volumetric changes but also significantly enhances ion diffusion, resulting in improved rate capability and cycle stability compared to the non-directional one. This report presents a reliable method for fabricating pressure-resistant ultrathick 3D microelectrodes with high mechanical and electrochemical performances, paving the way for customized 3D microbattery applications.

3D Printing of Customized Li-S Microbatteries

Mengli Li, Zhiyang Lyu*

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Abstract

Microbatteries serve as essential energy supply components in microelectronic, wearable and implantable devices. Despite recent efforts, developing lithium metal microbatteries with high energy densities and mechanical flexibility in structural design is still challenging, because of the poor interfacial stability and poor processability of lithium foil. In this presentation, I will introduce our recent works on lithium-sulfur (Li-S) microbatteries with customized configurations using 3D printing techniques, which consist of a printable Li anode hosted within a graphene aerogel framework and a printable S cathode based on a carbon nanocages framework, featuring abundant porous structures and large specific surface areas. Consequently, the 3D-printed Li anode achieves over 900 hours of cycling with low overpotentials at an ultrahigh current density of 10 mA cm-2, and the 3D-printed S cathode delivers an ultrahigh capacity of 21.9 mAh cm-2 at the high thickness of 2.3 mm. Furthermore, the 3D-printed Li-S cell delivers an ultrahigh areal energy density of 48.4 mWh cm-2 at the high power density of 3.5 mW cm-2. The application potential of the 3D-printed customized Li-S microbatteries with arbitrary form factors is demonstrated by LED lighting and powering wearable sensor integration system, paving the way for their applications in miniaturized devices.

Science-informed materials discovery via computational materials engineering: Multi-scale multi-physics modelling

Honghao Ge, Jang Terry Griffin, Chinnapat Panwisawas*

Queen Mary University of London

Abstract

Additive manufacturing (AM) is a promising, emerging, designable materials processing method used for fabricating complex three-dimensional geometries with multi-material and compositionally/functionally graded structure required for various future engineering applications. Fusion-based AM which melts materials-by-materials and layer-by-layer using prescribed scanning path could offer precise dimensional control and designable microstructure and site-specific property. The challenge lies in process control; melt flow dynamics, materials mixing, and composition change during the multi-material AM process. The composition-process design is vital for predicting laser power-time-temperature processing window and final quality. This talk will focus on computational additive manufacturing enabled materials discovery and the development of a holistic computational AM framework to enable multi-material AM for engineering, especially, discovery of new materials and processing route for biomedical application. A high-fidelity multi-physics multi-scale modelling approach for accurate tracking of surface shape, thermo-capillary dynamics and vaporisation is developed and used to search for new materials with processable conditions to have desired micro/nanostructure and controllable property. The computational materials engineering framework serves as a science-based tool to enable materials discovery with precise processing route using multi-material AM.

From Food Printing and Moving Sushi to Space Dining: A Digital Manufacturing Platform for the STAR-MEALS Project

Hidemitsu Furukawa, Shoko Usui, Toshiyuki Akachi, Kei Toba, Satoshi Kobayashi, Hirofumi Sei, Yuki Kainuma, Mitsuko Doi, Naoyuki Ito, Tomoya Noji, and Ajit Khosla

STAR-MEALS Project, Soft & Wet Matter Engineering Laboratory (SWEL), Graduate School of Science and Engineering, Yamagata University, Japan

Abstract

The STAR-MEALS project aims to establish an advanced manufacturing platform for producing and serving diverse meals in future space and closed environments. Although the space-oriented system is still at an early stage of development, its core concept is supported by terrestrial demonstrations integrating food-material design, three-dimensional food printing, transportation, culinary preparation, and large-scale meal service.

A high-speed food-printing system using three AIRCOOK units in parallel achieved the production of approximately 200 plant-based sea urchin-style portions per hour. In February 2026, a large-scale meal service demonstration was conducted at an official event in Budapest. Sea urchin-style portions were printed on site, while approximately 300 octopus-style portions had been printed in advance in Japan. The octopus-style formulation was primarily plant-based; for this demonstration, a small amount of cryogenically milled hydrated gel powder produced from residual octopus skin was added to provide an authentic aroma and demonstrate the upcycling of food-processing by-products.

These foods were served together with plant-based fish roe-style and tuna-style products designed to reproduce the appearance and flavour of conventional seafood. In total, several hundred portions of multiple menu items were prepared and served during a single event.

We have also developed pneumatically actuated moving sushi, in which air pressure drives motion in the food structure and adds a dynamic, interactive element to the dining experience. While the current prototype relies on external pneumatic actuation, future development will explore 4D food structures that generate programmed motion or shape change through intrinsic material responses.

Based on these demonstrations, STAR-MEALS will integrate food preservation, digital food design, multi-material and 4D printing, texture analysis, robotic handling, and automated serving toward an autonomous space dining system.

Data-Driven Customized Medical AM in low cost: From Implant Imaging to Surgical Planning

Li Weixin; Zhang Yicha

LAMIH, CNRS & INSA Hauts-de-France, Université Polytechnique Hauts-de-France

Abstract

Customized medical additive manufacturing requires the integration of patient-specific imaging, implant design, material selection, and surgical planning. This keynote presents data-driven approaches developed to address several practical challenges in CT-guided implantation. Variations in bone density lead to patient-dependent CT values, while metallic implants generate imaging artifacts and conventional polymer implants such as PEEK provide limited CT visibility. A data-driven method was therefore applied to optimize PEEK–BaSO_ composite formulations for improved CT imaging performance while supporting postoperative observation. In parallel, data-driven image analysis was developed to identify internal anatomical markers and support safe drilling and implant placement. Prototype surgical simulations demonstrated the feasibility of these approaches. Future work will extend toward geometry-driven design methods for customized, cost-effective medical additive manufacturing and digitally supported surgical workflows.

3D printing of cell-laden scaffold

Maling Gou

Sichuan University

Abstract

Light-based additive manufacturing has emerged as a powerful biofabrication technology for the rapid, high-resolution fabrication of cell-laden scaffolds, offering tremendous potential for regenerative medicine and personalized healthcare. However, light propagation is inherently difficult to control and is readily disrupted during the printing process, compromising fabrication fidelity and limiting the range of printable biomaterials.

In this presentation, I will introduce a suite of optical engineering strategies designed to systematically address these challenges. First, we developed an upconversion nanoparticle (UCNP)-mediated near-infrared (NIR) bioprinting platform that enables photopolymerization beneath intact tissue, extending in vivo bioprinting from invasive procedures to non-invasive clinical interventions. Second, we integrated digital light processing (DLP) with two-photon polymerization (2PP) into a hybrid manufacturing platform, enabling cross-scale fabrication from the nanoscale to the macroscale to produce hierarchical scaffolds for advanced cell engineering.

Together, these studies demonstrate that engineering light propagation across biological tissues, biomaterials, and fabrication scales provides a unified framework for next-generation light-based bioprinting, substantially expanding the library of printable biomaterials and unlocking the translational potential of additive manufacturing for biomedical applications.

Contributions to Spatial Variations in Fatigue life in Laser Powder Bed Fusion of Ti6Al4V: A Mechanistic Assessment

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University of Washington

Abstract

Despite the tremendous promise of Laser Powder Bed Fusion (L-PBF) there are outstanding concerns. Spatial variations in microstructure and defects contribute to the fatigue properties of metal printed across the build volume, which reduces the overall reliability of components and reduces the opportunities for safety-critical applications. Here, we describe a round robin program that was performed to: i) characterize variability in the finite life fatigue properties of Grade 5 Ti6Al4V produced by L-PBF, and ii) elucidate the contributing defects through quantitative fractography. Three partners produced twelve builds with identical commercial machines enabling the fatigue response to be defined spatially across the build volume. The metal was subjected to either a stress relief (SR) heat treatment or low-temperature high pressure hot isostatic pressing (HIP), followed by cyclic axial loading to failure according to ASTM E466. Results showed that the root cause of failure in the SR condition was a nearly balanced contribution of lack of fusion (LOF) voids and foreign object debris (FOD). Sgnificant spatial variation in the fatigue life and contributions of LOF were identified, which ranged from approximately 25% to nearly 75% of the origins. While the HIP treatment successfully eliminated LOF as a contributing root cause and reduced the overall degree of variability in the fatigue response, it resulted in failures that originated from a variety of foreign contaminants and debris. We introduce radial root cause diagrams (RRCD)s to support quantitative fractography and a detailed understanding of the contributing defects to fatigue failures. Through the RRCDs we show that there is underlying community of anomalies in L-PBF metal after successful HIP treatment, which may require new approaches to quality control.

Multi-energy Field Assisted Ultra-precision Machining of Difficult-to-Cut Materials

TO Suet

The Hong Kong Polytechnic University

Abstract

Ultra-precision machining technology based on single-point diamond turning (SPDT) and ultra-precision freeform machining have become an indispensable tool for the design and the manufacture of high- technology and high-precision lenses. The process is capable of producing components with micrometer to sub-micrometer form accuracy and surface roughness in the nanometer range. With the fast growing development of machining technology, ultra-precision machining technology is used not only for manufacturing symmetrical spherical and aspheric workpieces, but also to produce some very complex and non-symmetrical microstructures. This presentation mainly introduces Professor To's research team research achievements in the field of ultra-precision machining. These include the study of ultraprecision machining and the combination of physical energy fields such as magnetic fields, ultrasonic, laser, and electric fields on difficult-to-machine and hard and brittle materials, as well as the theory and methods of ultraprecision machining of micro/nano structures.

Extrusion-Based 3D Printing as a Strategy for Sustainable, Customizable Plant-Based Fermented Food Production Using Alternative Grains: An Ancient Sourdough Model

Hatice Saadiye Eryilmaz, Pui Yeu Phoon and Michinao Hashimoto

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Abstract

Extrusion-based three-dimensional (3D) printing enables precise control over the structure and porosity of cereal doughs, albeit with strict requirements for the rheological properties of the dough inks. While the viscoelastic behaviors resulting from a high gluten content (above 10%) in conventional bread dough are essential for overall textural quality, they are unsuitable for 3D printing due to nozzle clogging and inconsistent ink deposition. As an alternative to conventional grains, ancient wheat offers high protein and antioxidant contents amenable to sustainable cultivation; however, its weak gluten network compromises the stability of the ink in extrusion-based printing. To address these inadequate rheological properties, this research aims to develop a printable ink based on the ancient wheat sourdough. The formulated ink harnesses an endogenous population of yeast and lactic acid bacteria (above 7 log CFU/g) as a living fermentation medium, while incorporating a hydrocolloid and a crosslinking enzyme at optimal dosages. The addition of the hydrocolloid increased yield stress, viscosity, and shear recovery, thereby ensuring the structural stability of the printed dough. Concurrently, the enzyme reinforced the arabinoxylan network via oxidative crosslinking during dough fermentation. Large-amplitude oscillatory shear (LAOS) analysis revealed that the enzyme-hydrocolloid formulation produced a more pliable yet resilient structure than the hydrocolloid formulation. The optimized formulation improved bread quality, with a higher specific volume (2.84 cm^3g) and porosity (47.37%) than the native (1.85 cm^3g; 39.32%) and unprinted (2.29 cm^3g; 41.28%) controls, confirming the feasibility of 3D printing. Overall, this study demonstrates that 3D-printed dough, combined with an alternative structural network, realizes a nutrient-dense, sustainable ancient wheat bread comparable to conventional wheat bread.

Study on the Formation Mechanisms and Applications of Electrospray-Printed Microstructures Based on Charged Droplet Deposition Regulation

Li Wang

School of Mechanical Engineering, Xi'an Jiaotong University

Abstract

To meet the growing demand for high-precision, low-cost, and reconfigurable microstructure fabrication in flexible electronics, optical devices, and biosensing, a selective deposition method based on residual-charge-induced electric field control was developed by regulating the transport and deposition behavior of charged microdroplets during electrohydrodynamic atomization. Through the coordinated design of electrode patterns and electric field boundary conditions, the disturbance of residual charges on the trajectories of subsequent droplets was transformed into a programmable driving force for deposition. This enabled maskless fabrication of complex patterned microstructure arrays on silk fibroin surfaces, with a minimum feature width of 20 _m, as well as reversible "erase–rewrite" reconstruction of 5 _ 5 pixel patterns. Building on this approach, shape-memory-based information storage and optical encryption, together with patterned silver electrode fabrication, were further demonstrated, highlighting the potential of electrohydrodynamic atomization for flexible anti-counterfeiting, wearable information carriers, and flexible electronic device manufacturing

Principles of Magnetic Field-Assisted Diamond Cutting and Fabrication of Micro/Nanostructured Functional Surfaces

YIP Wai Sze

The Hong Kong Polytechnic University

Abstract

Magnetic Field-Assisted Ultra-Precision Machining (UPM) is an emerging technique for producing surfaces with high integrity and dimensional accuracy. This talk will introduce the principles of magnetic field-assisted UPM and explain how an external magnetic field can modify the cutting mechanism during diamond machining. The discussion will focus on key effects such as vibration suppression, reduced elastic recovery, eddy-current-induced damping, and regulation of the thermal field in the cutting zone. In addition, the talk will discuss the fabrication of microstructures and nanotextures through layer-by-layer machining strategies, enabling controllable surface functionalization for applications such as hydrophobic surfaces. Overall, magnetic field-assisted diamond machining provides a promising route for understanding and controlling the material removal mechanism, as well as fabricating high-precision functional surfaces.

3D Symmetry-Engineered Carbon Scaffold for Room Temperature Sodium-Sulfur Batteries

Hui Yang Yang

NUS

Abstract

We have designed interface-first sodium–sulfur (RT Na_S) batteries offer high theoretical energy density (1274 Wh kg_1) and low-cost, abundant materials, making them suitable for large-scale energy storage. In our work, an oxygen-doped carbon fiber (OCF) framework is designed and employed as a bifunctional host within a symmetric all-carbon-fiber cell architecture to simultaneously address these issues. The 3D porous OCF framework chemically anchors polysulfides, catalyzes their redox reactions, and guides uniform sodium nucleation/deposition. This synergy suppresses polysulfide shuttling and dendrite growth. Performance tests demonstrate an extremely low Na nucleation overpotential (27 mV at 1 mA cm_2) and stable, dendrite-free cycling exceeding 3600 h. In full Na_S cells, this design delivers a specific capacity of 753 mAh g_1 after 200 cycles at 0.2 C, retains ≈85% capacity after 2000 cycles at 0.5 C, and exhibits excellent rate performance (5 C). Our work presents a generalizable, interface-first design paradigm for safe, long-lasting, low-cost Na_S batteries free from shuttling and dendrites.

Simulation and Experimental Investigation of Residual Stress Redistribution Induced by Interlayer End and Side Milling in L-DED Hybrid Manufacturing

Xu Lai, Tong Zhengren, Shen Hongyao

College of Mechanical Engineering, Zhejiang University

Abstract

Additive–subtractive hybrid manufacturing combines the geometric flexibility of laser directed energy deposition (L-DED) with the dimensional accuracy of milling, but the alternating thermal and mechanical loads lead to complex residual-stress redistribution that is difficult to predict. This study proposes a five-axis toolpath-driven thermo-mechanical simulation framework for hybrid manufacturing and experimentally investigates the effect of interlayer milling on residual-stress evolution in 316L stainless-steel thin walls. Additive and subtractive toolpaths are discretized using tool-tip positions and tool-axis vectors, while deposition and milling swept volumes are constructed to determine element activation and deactivation. A dynamically transformed moving heat-source model is used for arbitrary five-axis deposition paths, and equivalent milling loads are introduced during material removal. Four experimental routes were designed: continuous L-DED, L-DED with matched interlayer cooling delays, interlayer end milling, and interlayer end milling combined with side milling. Near-surface residual stresses were measured at four build heights using the hole-drilling strain-gage method. Comparison between simulation and experiments shows that the framework captures the qualitative stress redistribution induced by interlayer milling. Experimentally, interlayer cooling altered the thermal history but did not produce a monotonic reduction in residual stress. End milling interrupted stress accumulation, yet subsequent deposition rebuilt tensile stress near hybrid interfaces. Side milling introduced a clear compressive bias in directly machined regions, whereas insufficient repeated cutting height left remelted and redeposited interface regions in a tensile state. These findings provide a basis for process-aware residual-stress prediction and optimization of milling intervention strategies in five-axis hybrid manufacturing.

Construction 3D Printing – Safety, Digitalisation and Sustainability

Daniel Tay, Lim Sean Gip, Lee Junghyun, Suvash Paul, Tan Ming Jen

NTU, Singapore

Abstract

Digitalisation has not been adopted by the Construction industry to an extent that it has revolutionized it, compared to most other 21st Century industries, viz. Manufacturing, Biomedical and even the Agricultural industries. In fact, traditional construction methods has hardly progressed for hundreds of years, even as buildings have become more complicated and with complex requirements. With digitalisation comes the opportunity to reduce errors, make the workplace safer, enable continuous round-the-clock progress etc.

This presentation also looks at Sustainability in Construction Industry. Aside from Construction being the most polluting industry, accounting for up to 40% of the total CO2 outputs, if including operations, the relentless urbanisation and migration of agricultural workers (supplanted by mechanisation) to the cities exacerbates this problem, and will continue for the coming decades. This cannot continue, if not our existence will be endangered, evidenced by the dire climate change catastrophes that has already affected many regions of the world in recent years.

Construction 3D Printing presents a technology whose time has cometh ! This presentation will cover various aspects of this technology which can reduce the consequences of climate change, and some of the work done at the Singapore Centre of 3D Printing/NTU, Singapore to address this urgency.

Training Humanoid Robots for Factory Work — From Data to Deployment

Mingyu Wu; Xueyan Oh; Jonathan Her

Singapore University of Technology and Design

Abstract

With the increasing manpower costs and need for flexible automation, there has been an increasing interest in using humanoids to replace humans on the manufacturing floor. Realizing this will require both data and training, which is not the typical expertise of current automation engineers working in the factory. In this talk, I will talk about the possible pipeline on humanoid learning for industrial applications. We will begin with data collection strategies, covering approaches such as teleoperation, human demonstration capture, and on-robot data gathering. We then discuss real-to-real transfer for training of policy. Next, we turn to sim-to-real transfer, where policies trained in simulation are adapted to perform reliably on physical hardware despite the inevitable gap between simulated and real-world dynamics. Finally, we present the increasing demand for synthetic data generation from simulation, highlighting how simulated environments can be used to generate large-scale, diverse training data through techniques such as domain randomization, reducing reliance on expensive real-world data collection. Together, these approaches enable humanoid learning for deployment on the factory floor.

With the increasing demand for flexible automation, there has been an increasing interest in using humanoids to replace humans. Realizing this will require both data and training and in this session, we will talk about the possible pipeline on humanoid learning. Data collection strategies such as human demonstration will be covered. Topics like real-to-real as well as sim-to-real transfer will also be introduced. Synthetic data generation from simulation to reduce the reliance on expensive real-world data will also be introduced.

Hierarchical Biofabrication of Physiological Structures

Qi Gu

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Abstract

The fabrication of physiologically relevant tissues and organs requires the precise reconstruction of biological structures across multiple length scales, from cellular organization and extracellular microenvironments to complex tissue architectures and functional systems. In this talk, I will present a hierarchical fabrication strategy for engineering physiological structures by integrating biofabrication, bioassembly, adaptive biomaterials, and spatiotemporally controlled bioprinting. Beyond conventional approaches that primarily focus on spatial patterning, this strategy introduces dynamic and instructive microenvironments to regulate cellular organization, self-assembly, maturation, and functional development. By enabling coordinated fabrication across cellular, microtissue, and organ-relevant scales, complex tissue architectures with vascular, neural, and other functional components can be assembled to better recapitulate native physiological structures. I will further discuss how engineered microenvironments and multiscale fabrication processes influence emergent tissue properties and structure–function relationships. These advances provide new opportunities for creating predictive human tissue models, advancing regenerative medicine, and developing next-generation organ manufacturing platforms. Ultimately, hierarchical fabrication approaches may offer a powerful framework for bridging engineering design with biological self-organization toward the construction of functional living systems.

High-resolution 3D printed integrated photonic devices.

Gao Hongwei, George Chen

Singapore University of Technology and Design

Abstract

3D printing using two-photon polymerization enables three-dimensional structures with sub-micron feature sizes to be fabricated. Importantly, photonic integrated circuits which have traditionally relied on planar structures defined through subtract processes may now be achieved with greater design freedom.

In this talk, we report recent advancements in the realization of high-resolution integrated photonic devices using two-photon polymerization. Three-dimensional couplers, resonators and waveguide devices are demonstrated. Nested photonic waveguides provide an avenue for spatial division multiplexing. High-speed measurements using intensity modulated direct detection data through the 3D printed integrated photonic devices reveal low bit error rates, demonstrating their suitability for data transmission. Lastly, we demonstrate 3D printing for implementing continuous deformation in the optical path of an integrated microresonator for polarization control of the optical field. Two-photon polymerization-based 3D printing is an important paradigm for the realization of complex structures not limited by planar lithography.

3D Printing of Ceramics and Composites for Orthopaedic and Dental Applications

Susmita Bose

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Abstract

Three-dimensional printing (3DP) or additive manufacturing (AM) technology is used for on-demand manufacturing of both patient-matched and generic implants. Establishing structure-process-property relationships for different AM techniques is vital to successfully implementing these manufacturing practices in biomedical devices and other applications. We have used digital light processing (DLP), binder jet methods to fabricate high-strength ceramic structures, and Directed Energy Deposition (DED) to make metal-ceramic composites, and direct ink writing (DIW) or extrusion-based 3DP techniques to fabricate polymer-ceramic composites with improved mechanical strength. The objective is to establish relationships between processing conditions, porosity, and composition with resulting mechanical and application-dependent properties using different AM methods.

Calcium phosphate (CaP) ceramics, compositionally similar to the inorganic part of bone, are used in orthopaedic and dental devices; AM of ceramics poses a different set of challenges to make multifunctional patient-specific bone grafts in specific clinical scenarios, which is also a focus of our current research. Natural medicinal compounds (NMCs) loaded on these 3DP CaP scaffolds and composites show improved biological properties. These systems show promise for their use in orthopaedic and dental applications while improving their current lifetime. The presentation will discuss the design, processing issues, and characterization of ceramic and composite structures, with reliability to meet current needs for AM'ed structures. Related characterization of next-generation ceramic and composite implants with reliability and tailored to meet clinical needs in orthopaedic and dental applications will also be discussed.

Investigation of Volumetric Additive Manufacturing Technologies for Functional Devices

SHUAI PENG

School of Mechanical Engineering, Jiangnan University

Abstract

Volumetric additive manufacturing, particularly tomographic volumetric 3D printing, enables three-dimensional energy reconstruction inside resin through multi-angle light-field projection. This approach can overcome key limitations of conventional layer-by-layer printing, including printing speed, support dependence, staircase effects, and material compatibility. This report focuses on the fundamental principles, process optimization, and functional device fabrication of volumetric 3D printing, with emphasis on optical dose calculation, hardware optical system design, online/offline feedback, and material photorheological matching. In terms of applications, this technology has demonstrated significant potential in optical components, flexible electronics, biological tissues, 4D responsive structures, and multimaterial overprinting, enabling high transparency, high surface quality, assembly-free fabrication, and integrated structural-functional manufacturing. Overall, volumetric additive manufacturing is evolving from rapid prototyping toward cross-scale, high-precision, multimaterial, and functionally integrated manufacturing, providing a new technical route for the design and fabrication of advanced functional devices.

3D-Printable Composite Filaments with Controlled Water Resistance for Sacrificial Molding of Biomimetic Vasculatures

Joseph Zhi Wei Lee, Shu-Yung Chang, Yanisa Keeratimongkollert, Brandon Tay Kaiheng, Muhammad Dinie Bin Zaini, Michinao Hashimoto

Singapore University of Technology and Design

Abstract

Sacrificial molding is a biofabrication technique in which sacrificial templates embedded in cell-laden extracellular matrix (ECM) hydrogels are dissolved to form perfusable vascular networks for tissue engineering. 3D printing is often used to shape the sacrificial structures. However, printed sacrificial structures struggle to retain their printed shape in the aqueous hydrogel environment before dissolving. To address this challenge, we fabricated a water-resistant, 3D-printable composite filament for building biomimetic vasculatures. This material outperformed commercial sacrificial filaments in water resistance while remaining compatible with fused deposition modeling (FDM) printing. Using this material, we created microchannels with complex geometries, extending vascular fabrication in hydrogels unattainable by conventional methods. Overall, our method opens an avenue for fabricating vascularized cell-laden hydrogels, advancing the capabilities of tissue engineering.

AI-driven Process Optimization and Yield Enhancement in Fermentation Manufacturing

Hsin-Hui Huang, Bing-Tsiong Li, Gracy Thomas, Xiao-Ming Wan, Chun-Chieh Chen, Shu-Chuan Lin, Juin-Yi Han

TherapiAI Inc. Panlabs Biologics Inc.

Abstract

In advanced biomanufacturing, fermentation involves highly complex processes with numerous variables. Traditionally, identifying key process parameters that influence fermentation outcomes traditionally requires extensive time and experimental resources. To overcome this bottleneck, this study leverages machine learning (ML) to rapidly identify critical parameters and provide actionable insights for maximizing daily production yields. An XGBoost model was developed using 269 clean records to predict high antibiotic yield increases, validated through 5-fold cross-validation with an 80:20 training-to-testing ratio.

The model demonstrated exceptional predictive performance, achieving an accuracy of 0.936 and the area under the receiver operating characteristic curve (AUROC) of 0.985. To ensure transparency, Explainable AI (XAI) via SHAP (SHapley Additive exPlanations) was integrated to illustrate the complex, non-linear relationships between specific parameters and yield. The analysis revealed that metabolic efficiency indicators, such as product yield per glucose, product yield per sodium hydroxide, and sugar consumption rate, act as primary drivers where low values severely penalize production. Conversely, physical culture parameters, including culture viscosity and culture residual nitrogen, exhibited an inverse influence, with lower values positively contributing to yield. By shifting from trial-and-error to AI-driven insights, this study provides a scalable framework for uncovering critical parameters and enabling intelligent industrial manufacturing through data-driven decision support.

In-Situ Radiant Auxiliary Heating in Fused Filament Fabrication (FFF)

Eleonora Ferraris, Jie Zhang

KU Leuven, Department of Mechanical Engineering, Faculty of Engineering Technology, Advanced Manufacturing Laboratory (AML)

Abstract

Fused Filament Fabrication (FFF), also known as Fused Deposition Modeling (FDM), is a material-extrusion additive manufacturing process widely adopted due to its low cost and operational simplicity. Research in this field remains highly active, with recent developments including the processing of metallic, ceramic, and composite materials, non-planar deposition strategies, large-scale additive manufacturing, and robotic printing systems. Despite these advances, process efficiency and reliability remain limiting factors. Furthermore, the adoption of FFF for load-bearing and fluid-tight applications is constrained by weak interlayer bonding and relatively high porosity.

Effective thermal management during printing is essential to improve part quality and mechanical performance. Several modelling and simulation approaches have been proposed to predict and control the thermal history of printed parts. In this presentation, recent advances in temperature-control strategies for FFF are reviewed and critically discussed, together with their applications and future perspectives.

Particular attention is devoted to the work developed at the Advanced Manufacturing Laboratory (AML) of KU Leuven on thermal management through in-situ radiant auxiliary heating. This approach addresses insufficient interlayer diffusion by locally heating the deposited material before and after extrusion. Infrared thermography and numerical simulations demonstrate that radiant heating effectively maintains elevated temperatures in the vicinity of the nozzle, significantly reducing cooling rates. Tensile specimens produced with auxiliary heating exhibited quasi-ductile failure behaviour under loading perpendicular to the bonding plane, in contrast to the brittle delamination typically observed in conventional FFF parts. Moreover, the proposed solution accommodates complex nozzle trajectories, requires minimal energy input (approximately 1.3 W at 200 °C), and can be readily integrated into most filament- and pellet-based 3D printers. The approach offers a promising route towards structurally reliable additively manufactured polymer components for load-bearing applications.

Structurally Instructive Biofabrication: High-Fidelity Light-Based 3D Printing of Architected Scaffolds for Tissue Engineering

Xiaoxiao Han

Hunan University

Abstract

Engineered human living tissues offer powerful platforms for disease modeling, drug screening, and regenerative medicine. However, their fabrication remains limited by the challenges of high-density cell printing, microscale structural fidelity, and scalable manufacturing. In this talk, I will present our recent advances in cell printing technologies for frontier biomanufacturing. By integrating bioink design, optical regulation, and bioprinting equipment, we developed high-resolution and high-efficiency platforms for constructing cell-laden tissue models. The system enables microscale printing precision below 5 _m, volumetric printing with approximately 30-fold higher speed than conventional layer-by-layer methods, and high-density cell printing with over 90% cell viability after 24 hours. These technologies have been applied to human-relevant tissue models for cancer drug screening and spinal cord injury repair, providing new tools for precision medicine and regenerative medicine.

Acoustic and Multimodal Defect Detection for Wire Arc Additive Manufacturing

Soh Gim Song

Singapore University of Technology and Design

Abstract

Wire arc additive manufacturing (WAAM) is a direct energy deposition manufacturing process that builds near-net shape parts layer by layer on a substrate using a motion system. Its high deposition rate makes it commercially viable for medium- to large-scale parts, but the process's sensitivity to variation makes in situ defect detection essential for qualification and certification. This paper presents our work on acoustic-based defect detection, SVM-derived process maps, and their ongoing extension into multimodal, LLM-driven monitoring for WAAM. First, we discussed a machine learning framework that identifies geometrically defective bead segments, caused by incomplete fusion between non-uniform overlapping beads, using acoustic features combined with torch speed and wire feed rate. Five models (KNN, SVM, RF, NN, CNN) achieved F1 scores of 80-87% on Inconel 718, generalizing from single-bead to multi-bead prints. Next, we described an SVM-based process map that predicts bead geometric uniformity across Bronze, Stainless Steel, and Inconel materials, which correlated well with manual quantification and offered a systematic alternative to hand-labeled maps. Finally, we presented our ongoing work extending this foundation into a multimodal, LLM-based defect detection and correction system, developed following a closed-loop architecture we built for a separate speech-driven 3D printing platform. The system logs acoustic signatures, vision, and process parameters in a structured schema, retrieves similar past defect cases, and uses an LLM to reason across modalities and propose in-situ corrections, turning each print into a labeled case that sharpens future detection.

3D Food Printing Research at the SUTD Digital Gastronomy Lab

Chee Kai Chua, U-Xuan Tan

SUTD

Abstract

The Digital Gastronomy Lab explores the integration of artificial intelligence (AI), advanced food printing technologies, and sustainable materials to redefine the design and manufacture of personalized foods. The lab's research focuses on AI-driven food design, where computational approaches are used to generate novel food geometries and architectures. Sustainability is a central research theme, with particular emphasis on valorising food waste as printable materials, supporting circular food systems and reducing environmental impact. The lab also develops advanced 3D printing processes, including high-throughput food printing for scalable production, multi-material food printing, 4D printing for stimuli-responsive food structures, cryogenic bio/food printing, and post-processing techniques. Together, these technologies enable the development of innovative food products with improved functionality and manufacturing efficiency. By combining digital design, sustainable materials, and advanced additive manufacturing, the Digital Gastronomy Lab aims to advance the future of personalized, sustainable, and functional food production.

Control and AI-Driven Robotics for Human-Centered Smart Automation

Masami Iwase

Tokyo Denki University

Abstract

Recent advances in control, artificial intelligence, and robotics are opening new possibilities for assisting humans and automating complex tasks in real-world environments. Unlike well-structured factory automation, many practical systems must operate under uncertainty, physical constraints, limited sensing, and close interaction with human operators. This talk introduces our research activities in smart automation based on the integration of control theory, AI-based perception, and robotic system design.

Several representative case studies will be presented, including remote operation and safety control of forestry machinery, human-assist control of bicycles with riders, and the introduction of robotic technologies into electrical facility construction and maintenance tasks. These examples share a common design philosophy: automation should not simply replace human workers, but should extend human capability, improve safety, and enable work in difficult, hazardous, or labor-intensive environments. An important objective is to develop technologies that are useful for skilled workers while also making such fields more accessible and attractive to beginners and new entrants.

In this context, the talk emphasizes the role of control systems in connecting AI-based environmental perception with the physical behavior of robotic systems. For physical AI to coexist with and support humans, control design must ensure safety, robustness, and appropriate human-machine interaction. Topics such as shared autonomy, safety-critical control, control barrier functions, and human-centered interfaces will be discussed through practical examples.

The talk also introduces educational and research activities such as AI-Formula, which aim to cultivate the next generation of engineers by integrating robotics, control, and AI in project-based learning. Through these discussions, the presentation considers how control and AI-driven robotics can contribute to smart, safe, and human-centered automation in future industrial and field systems.

Machine learning-assisted thickness prediction and 3D surface reconstruction for multi-material powder beds in micronozzle-controlled laser powder bed fusion

Xiyuan Dong, Qimin Shi, Shoufeng Yang

Harbin Engineering University; Chongqing Institute of Green and Intelligent Technology; Chinese Academy of Sciences

Abstract

Micronozzle-controlled laser powder bed fusion (LPBF) innovates fabrication of multi-material structures, but also introduces a unique powder bed spreading mechanism and requires a technique for real-time in-situ monitoring of powder bed topography during process control. Existing thickness monitoring methods, such as those employing laser displacement sensors and high-resolution balances, are limited by lengthy measurement cycles and high instrumentation costs. This work develops a new pathway based on 4K imaging and supervised machine learning for powder bed thickness prediction and 3D topography reconstruction, which can be flexibly integrated onto a multi-material LPBF system. The results highlight the high accuracy of the powder bed thickness prediction using the developed multi-feature support vector regression (SVR) fitting. The prediction error remains within approximately 3.31 μm, with an average error of 1-2 μm (maximum absolute percentage error is 9.2%). The reconstructed topography exhibits excellent agreement with the measurements obtained by the laser displacement sensor. In the reconstruction of defected powder beds, the SVR-predicted errors in defect location and width are less than 1 μm. The defect depth errors are below 5 μm, typically remaining around 1 μm. Compared with traditional laser sensor approaches, the developed method is a rapid and cost-effective tool for in-line characterisation of powder bed thickness, reducing data acquisition time to 2 seconds. Importantly, the pathway can be further integrated into various additive manufacturing systems, and benefits the development of high-resolution closed-loop strategies for improving powder bed uniformity.

Additive Manufacturing of Functional Magnetic Materials for Electrification and Energy Technologies

Varun Chaudhary, Mukesh Murali

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Abstract

Magnetic materials are central to electrification technologies, from electric motors and transformers to energy conversion and sensing systems, where performance is governed by the interplay of composition, microstructure, and anisotropy. Additive manufacturing (AM) provides a unique pathway to process magnetic materials that are difficult to fabricate conventionally, while enabling direct control over solidification, texture, and functionality. This talk will focus on recent advances in the additive manufacturing of high-silicon soft magnetic steels, particularly Fe–6.5 wt.% Si, a material of significant interest for high-frequency electromagnetic applications but difficult to process through conventional routes due to its intrinsic brittleness. Particular emphasis will be placed on laser path rotation as a strategy to systematically tailor melt pool evolution, grain morphology, and crystallographic texture within a single build. By controlling laser path rotation, coercivity was reduced to as low as 81 A/m in the as-printed state and further to ~35 A/m after annealing, while electrical resistivity was tuned up to 228 μΩ·cm, demonstrating simultaneous optimization of magnetic softness and eddy-current suppression. These results highlight how process-path design can serve as a powerful tool for microstructural programming and property optimization in next-generation energy-efficient magnetic materials.

From Nanopores to Microfibres: Micro- and Nano-Architected Bioactive Materials for Bone Repair

Chun Xu, Chang Lei, Yuan Chen, Chengzhong Yu

The University of Sydney; The University of Queensland

Abstract

Bone repair requires biomaterials that can guide healing across multiple length scales, from nanoscale biochemical interactions to microscale tissue organisation. In this presentation, I will introduce a multiscale materials strategy that combines bioactive porous nanoparticles with FLIGHT-printed gelatin microfibres to create next-generation materials for bone regeneration.

At the nanoscale, we developed inorganic porous nanoparticles with tunable calcium and aluminium incorporation, high surface area and large accessible pores. These nanoparticles are designed not only to release bioactive ions, but also to interact with endogenous proteins and regulate the local healing microenvironment. Their unique porous architecture enables activation of latent TGF-β1, enhancement of osteogenic signalling, recruitment of bone-forming cells and rapid haemostatic activity. This transforms the nanoparticles from passive fillers into programmable nano–bio interfaces that actively direct early bone repair.

At the microscale, we use FLIGHT printing to fabricate gelatin-based microfibres that mimic key features of the natural extracellular matrix. By controlling fibre formation, alignment and organisation, this platform provides structural and biological guidance cues for cell attachment, migration and tissue formation.

Together, these studies demonstrate how micro- and nano-engineering can be integrated with advanced additive manufacturing to control material–cell interactions and promote bone regeneration. This work highlights a promising direction for developing bioactive, customisable and clinically relevant materials for future bone repair.

AM Qualification and Certification in the Age of AI

Alex Liu

ASTM International

Abstract

Additive manufacturing (AM) has matured from a prototyping tool into a production technology for aerospace, medical, defense, and energy applications, yet qualification and certification (Q&C) remain the most persistent barriers to industrial adoption. Traditional Q&C pathways, built on extensive empirical testing, statistically-based allowables, and fixed process windows, are costly, slow, and poorly suited to AM's inherent variability across machines, materials, and geometries. The emergence of artificial intelligence and machine learning presents both an opportunity and a challenge for rethinking these frameworks.

This presentation examines how AI is reshaping the AM Q&C landscape across three fronts. First, AI-enabled in-situ monitoring and real-time defect detection are shifting quality assurance from post-build inspection toward layer-wise process assurance, opening the door to "born-qualified" parts. Second, machine learning models trained on process-structure-property relationships are compressing the design-allowables generation cycle, reducing the coupon-testing burden that dominates qualification cost and schedule. Third, AI-driven digital twins and predictive models are enabling qualification by similarity and rapid requalification across machines and sites—critical for distributed and point-of-need manufacturing.

However, these advances raise fundamental questions for standards development organizations, regulators, and certifying bodies: How do we validate the validators? What constitutes sufficient training data, model transparency, and uncertainty quantification for certification decisions? How should standards address model drift, cybersecurity, and data provenance in AI-augmented quality systems?

Translating Nature's Blueprints: Additive Manufacturing of Bio-Inspired and Fracture-Tolerant Architectures

Jonathan Tran

RMIT University

Abstract

In the pursuit of developing stronger and lighter materials, nature's fracture-tolerant designs offer invaluable inspiration for modern protective structures subjected to extreme loadings. Biological materials such as nacre (mother-of-pearl) and porcupine quills exhibit highly optimized, hierarchical laminar microstructures spanning multiple length scales. However, replicating these intricate, multi-scale geometries has traditionally posed a significant manufacturing challenge. This talk explores how advanced additive manufacturing techniques serve as the enabling vehicle to realize these complex biological architectures. By utilising non-destructive micro-computed tomography, we examine the internal microstructure of the porcupine quill to extract its underlying design principles. These insights are then translated into bio-inspired sandwich panels fabricated via high-resolution 3D printing, successfully mimicking the hierarchical organization observed in nature. This synergy between biomimicry and additive manufacturing demonstrates how advanced fabrication can unlock the full potential of nature-inspired designs, paving the way for next-generation synthetic materials with unprecedented mechanical properties, resilience, and fracture tolerance.

Microstructure and Mechanical Properties of IN718-based Dissimilar Alloys Fabricated by Oscillating Laser Directed Energy Deposition

Gang Xu, Hongmei Zhang, Kaiyu Luo, Jinzhong Lu

Jiangsu University of Science and Technology, JiangSu University, Yangzhou University

Abstract

To address the challenge of improving interfacial bonding strength and overall mechanical properties in dissimilar alloys, which arises from differences in alloying elements and thermophysical properties. Oscillating laser directed energy deposition (OLDED) is proposed for fabricating Ni-based dissimilar alloys. By employing oscillating laser, the interfacial microstructure and elemental distribution of the dissimilar joint can be effectively tailored, thereby enhancing the interfacial strength and improving the overall mechanical properties. In this study, the effects of oscillating laser on elemental diffusion, phase precipitation, and grain refinement at the interface are systematically clarified, and the underlying enhancement mechanism of interfacial bonding strength via oscillating laser deposition is revealed. The experimental results indicate that laser oscillation significantly promotes elemental diffusion across the interface, forming a microzone compositional gradient transition layer in the heterogeneous bonding zone. Consequently, the strength of the Ni/steel dissimilar alloy is increased from approximately 451 MPa to 645 MPa, while the elongation is improved from 4.13% to 17.92%.

Enhanced Internal Cooling of Ceramic-Matrix Turbine Blades through Coupled Thermal-Conduction-Axis Orientation Design and Additive Manufacturing

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Abstract

Under high-temperature gas environments, ceramic-matrix composite (CMC) turbine blades are prone to localized hot spots on their surfaces. Excessive wall temperatures and non-uniform temperature distributions can significantly compromise the thermal protection capability and service reliability of the blades. Conventional internal cooling strategies primarily enhance coolant-side convective heat transfer through turbulators and complex flow passages; however, the solid blade is generally treated as a homogeneous heat-conducting medium, with limited active control over internal heat-transfer pathways. To address this limitation, this study proposes a directional heat-guiding approach that couples branched internal cooling ribs with three-dimensionally printed fiber-reinforced CMC turbine blades. By actively controlling the spatial orientation of reinforcing fibers through 3D printing, preferential heat-conduction pathways are constructed between high-heat-flux regions on the blade surface and the internal cooling channels, enabling heat to be preferentially transferred toward the cooling side along prescribed directions. Meanwhile, the branched rib structures increase the heat-transfer area, intensify near-wall flow disturbance, and promote heat absorption by the coolant, thereby achieving synergistic enhancement of oriented heat-conduction pathways within the solid and convective heat transfer on the fluid side. This study systematically compares the heat-transfer and cooling performances of conventional two-dimensional laminated prepreg-infiltrated structures and 3D-printed oriented-fiber structures. Furthermore, the effects of the principal heat-conduction direction, branched-rib geometric parameters, and coolant flow rate on the maximum blade surface temperature, surface temperature uniformity, cooling efficiency, and channel pressure drop are investigated. This work is expected to overcome the limitations of conventional internal cooling designs that rely solely on fluid-side convective enhancement, providing a new thermal-management strategy for surface temperature control, complex internal cooling design, and additive manufacturing of high-temperature CMC turbine blades.

Patient-Specific Additive Manufacturing of Cervical Orthoses for Dropped Head Syndrome: Design, Implementation and Clinical Evaluation

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Abstract

Dropped Head Syndrome (DHS) is a debilitating neurological condition characterised by severe weakness and atrophy of the cervical extensor muscles, resulting in an inability to maintain a horizontal gaze and often causing significant neck pain and functional limitations. Conventional off-the-shelf cervical orthoses frequently provide inadequate support due to poor fit and limited customisation.

This feasibility study developed and implemented a feedback-driven workflow for the design and manufacture of personalised 3D-printed cervical orthotic devices using Powder Bed Fusion technology. Six patients with DHS of varying aetiologies were fitted with bespoke collars designed to address their individual anatomical and clinical requirements. Clinical effectiveness was evaluated before and after intervention using validated outcome measures, including patient support questionnaires, the Neck Disability Index (NDI), Visual Analogue Scale (VAS) for neck pain, Global Cervical Angle (GCA), and Vertical Chin–Brow Angle (VCBA). Quantitative and qualitative data were collected over a 6-month follow-up period.

The personalised collars demonstrated clinically meaningful improvements in cervical posture and symptom management. Patients showed increased GCA and reduced VCBA while wearing the bespoke orthoses, indicating improved head and neck alignment compared with their unsupported condition. Neck pain scores, measured using the VAS, progressively decreased throughout the 6-month follow-up period. Patient feedback highlighted improved comfort, support, and ability to perform daily activities. The iterative design workflow enabled refinement of orthotic fit and function to meet individual patient needs.

Personalised 3D-printed cervical orthoses produced through a feedback-integrated design workflow provided effective postural support and pain reduction in patients with DHS. The bespoke devices improved functional outcomes and quality of life, demonstrating the potential of patient-specific additive manufacturing approaches in rehabilitative and supportive healthcare. These findings support further evaluation in larger prospective studies to establish clinical efficacy and long-term benefits.

Real-Time Prediction of Porosity Levels in Welds

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KU Leuven

Abstract

Metal manufacturing processes such as arc welding can produce internal voids (porosity) that reduce mechanical strength and fatigue resistance. Detecting these defects early is essential, as identifying them only during final inspection wastes material, energy, and production time. Our previous research showed that acoustic emission signals recorded during welding contain sufficient information to distinguish porous from sound welds. Using these signals, the Sparse Wavelet Network (SWaN), a hybrid wavelet-scattering and deep-learning model, performs real-time porosity detection. However, its current binary output does not indicate defect severity.

This work extends SWaN to classify porosity according to the three quality levels defined in the ISO 10042 standard while maintaining real-time performance. The primary focus is aluminium welding, where porosity is particularly common. X-ray computed tomography was used to quantify pore characteristics and assign ISO quality classes, supported by a newly developed labeling algorithm and a modular experimental pipeline with automated hyperparameter optimization. The approach was also evaluated on CMT-WAAM samples, whose acoustic characteristics differ significantly from conventional pulsed MIG welding.

The model achieved strong performance in both welding processes, indicating that it learns features associated with pore formation rather than process-specific signatures. Reducing the acoustic sampling rate both improved classification accuracy and reduced inference time below the real-time threshold. The lower sampling rate provides longer temporal context per analysis window, enhancing model performance despite lower data resolution.

A consistent temporal offset was observed between predictions and ground-truth labels, causing predictions to lag slightly behind actual defect locations. Because this offset is stable, it can be corrected with a fixed adjustment when precise defect localization is required.

Effects of Annealing Conditions and Minor Alloying Additions on the Microstructure and Properties of Rolled Low Thermal Expansion FeNi Alloys

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Department of Materials and Optoelectronic Science National Sun Yat-sen University, China Steel Corporation

Abstract

With the rapid development of advanced technologies such as Fan-Out Panel Level Packaging (FOPLP), FeNi alloys have become the key materials due to low coefficients of thermal expansion and excellent dimensional stability. Low thermal expansion FeNi alloys were usually fabricated through a rolling process; however, the severe plastic deformation introduced a significant amount of residual stress into the material, which can lead to deformation and affect the yield of FOPLP. Therefore, the effects of annealing temperature and holding time on residual stress relief, recrystallization behavior, microstructure evolution, and mechanical property response need to be systematically investigated. Furthermore, increasing the strength of FeNi alloys helps resist deformation induced by thermal stress during the FOPLP process. To enhance the strength while maintaining the low thermal expansion characteristics, minor alloying elements (Ti, V, and Ce) were added, and the effects of alloy design on grain refinement, precipitate formation and distribution, phase stability, and strengthening mechanisms (including grain refinement strengthening, solid solution strengthening, and precipitation strengthening) were evaluated. Through microstructural characterization, residual stress measurements, thermal expansion analysis, and mechanical property evaluation, the relationships among rolling process parameters, annealing conditions, microstructural evolution, and material properties were established. Hence, the optimal annealing conditions and alloying element additions for achieving both superior mechanical properties and dimensional stability were determined.

Biofabrication of Vascularized Heterogeneous Tissue

Yang Wu

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Abstract

3D bioprinting has the capability to fabricate artificial tissues with precise control over the distribution of cells and extracellular matrix in different regions. In a series of studies, using platforms such as multi-material digital light processing printing, extrusion-based printing, aspiration-assisted bioprinting, electrohydrodynamic jet printing, and suspension bioprinting, we have focused on shape and property control during the printing process. Key scientific challenges addressed include the preparation and regulation of high-cell-density bioinks, the synergistic control mechanisms of construct and function in biomanufacturing, functional induction mechanisms for printed tissues, and multiscale biomimetic fabrication of soft tissue structures. These efforts explore the application potential of biofabrication in constructing layered artificial cartilage with high cell density, controllable fabrication of porous tissues, development of fibrous, high-strength, and tough artificial tendons, and freeform fabrication of complex biomimetic constructs. Creatively leveraging biofabrication technologies, we aim to develop tissue substitutes suitable for repairing human cartilage and tendons, achieving integrated structural and functional biomimetic tissue manufacturing.

Process-Aware Adaptive Exposure for First-Time-Right Metal 3D Printing

Guglielmo Vastola, Kitty Wang

SynaCore Pte. Ltd.

Abstract

Recent innovations in software ecosystem for scan pattern generation, specifically, the introduction of the Open Vector Format (OVF) framework, open new possibilities to leverage scientific computing to predict and control printing quality. Starting from our additive manufacturing digital twin platform, we demonstrate generation of machine scan pattern which is informed by process, where the capability to predict temperature at part scale enables generation of adaptive toolpath which eliminates overheating in difficult regions, such as overhangs. By developing adaptive scan pattern fully at build job preparation stage, we envision first-time-right metal 3D printing free of overheating, irrespective of part design.

Quantum-Inspired Information Modeling for Tool Condition Monitoring in Smart Manufacturing

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Abstract

Tool condition monitoring (TCM) is essential for ensuring machining accuracy, process stability, and intelligent decision-making in advanced manufacturing systems. As the primary component directly interacting with the workpiece, the cutting tool undergoes progressive wear during machining, which is commonly reflected in macroscopic monitoring signals. However, most existing feature extraction methods rely on empirical indicators or purely data-driven strategies, and the extracted features often show limited physical consistency with the underlying wear evolution. This limitation restricts the robustness and predictive performance of TCM models under varying machining conditions. To address this issue, this paper proposes a quantum-inspired information modeling approach for tool wear prediction in smart manufacturing. The proposed method establishes a unified state–evolution representation framework to characterize wear-related information from multivariate cutting force signals. Specifically, the force signals are formulated as quantum-inspired state representations, where complex wavefunctions evolve in imaginary time under a potential field constrained by machining parameters. The resulting ground-state representations are used to extract structured quantum-inspired features that capture stable wear-sensitive information from macroscopic monitoring signals. Based on the extracted features, a machine learning model is developed for tool wear prediction. Experimental validation under multiple machining conditions demonstrates that the proposed approach achieves accurate and robust prediction performance and outperforms representative baseline methods. The results demonstrate the effectiveness of the proposed quantum-inspired information modeling framework for intelligent TCM and its potential for supporting reliable decision-making in smart and advanced manufacturing.

Chat with the manufacturing process: Knowledge-guided cross-modal LLM for machining condition predictive maintenance

Jun Li, Xin Lin, Guochao Li, Qingguo Wang, Kunpeng Zhu

Wuhan University of Science and Technology

Abstract

Predictive maintenance has become essential for ensuring the reliability of modern manufacturing systems. This work proposes a knowledge-guided cross-modal large language model that enables conversational interaction with the machining process, allowing users to chat with manufacturing equipment for condition diagnosis and decision support. The framework integrates multi-source sensor data with structured domain knowledge to build an interactive perception–decision loop. A knowledge-guided graph fusion method is first introduced to unify heterogeneous information streams. A lightweight cross-modal alignment module then projects time-series sensor imaging features into the language space, empowering the model to generate interpretable diagnostic reports. To overcome the knowledge fragmentation and hallucination issues of general-purpose large language models in industrial contexts, a dedicated domain knowledge graph is constructed, covering tool wear mechanisms and machining parameter effects. This structured knowledge is injected through a parameter-efficient fine-tuning strategy, grounding the model's reasoning in physical principles. The system engages users in natural language dialogues, delivering dynamic maintenance recommendations and transparent condition assessments. Experimental results demonstrate that the framework substantially outperforms traditional deep learning models in tool condition prediction, while providing interpretable and interactive reasoning. This work lays a theoretical and practical foundation for human–machine collaborative machining systems and promotes the evolution of online monitoring toward interpretable, conversational paradigms.

Physics-Informed AI for Data-Efficient Inverse Design of Programmable, Manufacturable Architected Materials

Seunghwa Ryu

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Abstract

Additive manufacturing has unlocked an enormous design space of architected materials whose mechanical function arises from geometry rather than composition. Realizing this potential, however, hinges on solving the inverse problem: finding the geometry that yields a prescribed, often highly nonlinear, mechanical response. Conventional data-driven approaches demand large labeled datasets from costly simulations and frequently fail to generalize. In this keynote, I present a physics-informed AI paradigm that embeds governing mechanics directly into the learning objective, enabling data-efficient and interpretable inverse design across three classes of programmable architected materials. First, I introduce a data-free physics-informed neural network (PINN) that programs the full energy landscapes of conical Kresling origami, controlling stable states and energy barriers from minimal specifications and orchestrating sequential, layer-by-layer deployment in multilayer assemblies. Second, I extend this principle to bistable kirigami: by embedding equilibrium and geometric compatibility into the loss, the framework inversely programs barrier hierarchies that drive sequential actuation, validated on 3D-printed prototypes. Third, for continuous microstructures, I present a dual-constrained diffusion model that jointly generates design and solution fields under physical and conditional constraints, allowing a thousand candidates to be screened by direct evaluation in under a second, without surrogate models or repeated finite element analysis. Across origami, kirigami, and hyperelastic microstructures, embedding physics as a prior removes the dependence on labeled data, suppresses non-physical artifacts, and yields fabrication-aware designs confirmed by finite element analysis and experiment. I conclude by discussing how this physics-first strategy reframes inverse design as energy-landscape and field programming, and its implications for closing the design-to-fabrication loop in next-generation additive manufacturing.

Trustworthy Situational Awareness for Industrial IoT

David Yau

SUTD

Abstract

Automated advanced manufacturing in smart factories and processing pipelines relies increasingly on ITC technologies spanning sensing, actuation, communications, and robotics. In the face of noises, uncertainties, dynamics, and even possible malicious attacks in real-world deployments, how to ensure the reliability and trustworthiness of operations becomes a critical problem. In this talk, I will discuss how AI and deep learning can be applied to improve the robustness and resilience of system operations, where label-efficient, low-shot, and zero-shot learning techniques can help improve the practicality of solutions by significantly reducing the efforts of data labeling and model training.

AI-Driven 3D Food Printing for Personalized Nutrition and Special Medical Applications

Yi Zhang

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Abstract

3D food printing, as a novel additive manufacturing technology, can produce foods with tailored nutrition and textures, yet traditional formula development relies heavily on empirical trials and hinders its medical application. This work adopts direct ink writing (DIW) technology and develops diverse printable food inks using dairy proteins, plant proteins, dietary fibers, mushroom powders and hydrocolloids. We systematically characterized their rheological properties, printability, structural stability and texture performance, and established an AI-assisted framework combined with machine learning and image analysis to predict printing quality and optimize formulations efficiently. The optimized inks present favorable extrudability and shape fidelity. On this basis, we successfully fabricated two types of special medical foods: low-glycemic 3D printed foods for diabetic patients with complications, and serine/glycine-restricted semi-solid foods for cancer nutrition therapy. Both products feature patient-friendly textures and standard nutritional compositions. This study verifies that the integration of 3D printing and artificial intelligence can greatly accelerate the R&D of personalized and medical-specific foods, offering a viable technical route for digital food manufacturing and precision nutrition in clinical practice.

Hybrid multimodal artificial intelligence, vision sensory, and robotic cyber-physical systems for plastic inspection and sorting in digital circular remanufacturing

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Abstract

Plastic inspection has emerged as an important component of industrial manufacturing processes, quality control, and recycling, driven by a growing emphasis on sustainable, circular, and efficient modes of production. This systematic narrative review focuses on three key areas: (i) a review on the imaging techniques used in the plastic industry for creating training datasets for artificial intelligence (AI) models; (ii) an evaluation of various AI approaches, including support vector machines (SVMs), deep reinforcement learning (DRL), convolutional neural networks (CNNs), and hybrid/multimodal techniques; and (iii) the integration of these techniques within robotic cyber-physical systems (CPS) for the automation of plastic defect identification, material classification, and sorting for recycling/remanufacturing, supplemented by circular business aspects. CNNs demonstrate exceptional performance in feature extraction and in detecting surface defects, such as scratches, cracks, and inconsistencies in plastic materials. SVMs, with their robustness to small, noisy datasets, provide accurate classification and quality control, making them a valuable complement to CNNs. Hybrid approaches that combine CNNs and SVMs leverage the strengths of both methods for complex tasks, thereby maximizing the advantages of each. DRL enhances the inspection and sorting capabilities of robotic CPS when integrated together. Despite these advancements, challenges remain, including high resource costs, data-intensive requirements, and constraints on real-time implementation. Potential solutions include adopting efficient architectures and lightweight frameworks. A pilot application of these AI strategies within a robotic CPS demonstrates their transformative potential to automate large-scale remanufacturing and recycling systems efficiently, accurately, and in an eco-friendly manner, supporting circular economy principles and sustainability.

Achieving enhanced structural and functional properties with laser additive manufacturing

Hongze Wang

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Abstract

Laser additive manufacturing technology provides the possibility for rapid manufacturing of lightweight and high-strength aluminum alloy structures. Facing the urgent demand for batch manufacturing of high-performance aluminum alloy components in aviation, robotics and other fields, a series of work has been carried out around aluminum alloy powder, additive manufacturing process and structure. Through composition design, a series of in-situ mixed TiB2 particle-reinforced aluminum alloy powders were invented, which successfully transformed highly crack-sensitive materials into printable materials, and optimization of equipment and process for gas atomization powder production has been achieved based on in-situ monitoring and continuous-discrete coupling simulation ; through in-situ monitoring of the additive manufacturing process through synchrotron radiation imaging and multi-physics field coupling modeling, the laser additive manufacturing process was optimized, and the defects of the laser additive manufacturing process were significantly reduced; At the same time, a 2000W blue laser powder deposition additive manufacturing, repair and welding equipment has been developed, which has significantly improved the efficiency and precision of aluminum alloy laser manufacturing. This report proposes a technical route for mass-scale additive manufacturing of high-performance aluminum alloy components, and provides ideas for the large-scale application of aluminum alloy additive manufacturing technology.

Laser Powder Bed Fusion of Ultra-High-Strength Maraging Steel: Towards High Performance and Excellent Surface Quality

Yuchao Bai, Bing Li, Cuiling Zhao, Zihong Zheng

Harbin Institute of Technlology, Shenzhen

Abstract

Maraging steel is a precipitation-hardened, ultra-high-strength steel characterized by exceptional toughness, a low work-hardening exponent, excellent formability, and a straightforward heat treatment process that induces minimal dimensional deformation during aging. Capable of achieving an ultimate tensile strength exceeding 2000 MPa, it is widely utilized in aerospace, national defense, military, and precision molding applications. Laser powder bed fusion (LPBF) is a prominent additive manufacturing technology that utilizes a laser heat source to melt a powder bed. Renowned for producing high-density components with superior geometric resolution, LPBF is uniquely suited for the high-performance, rapid manufacturing of metallic parts with complex geometries. To advance the application of additively manufactured maraging steel in high-end component production, a systematic investigation into the LPBF process of 18Ni300 maraging steel was conducted. This study comprehensively addresses defect formation mechanisms, process optimization, microstructure evolution regulation, performance enhancement, and precision post-processing. By optimizing key process parameters—including laser power, scanning speed, hatch spacing, and powder layer thickness—the formation of surface and internal defects was successfully suppressed. This optimization reduced surface roughness to under 10 _m and increased the relative density to over 99%. Additionally, the heat treatment process was tailored to precipitate a high density of nanoscale strengthening phases, successfully elevating the tensile strength beyond 2100 MPa. Furthermore, to enhance post-manufacture surface quality, an efficient machining process leveraging mechanochemical effects is proposed. This approach reduces the cutting force of LPBF-fabricated maraging steel by more than 50% while improving surface quality by over 80%. Ultimately, these research outcomes establish a robust theoretical foundation and technical framework for the precision manufacturing of high-performance, complex components utilizing ultra-high-strength maraging steel.

Microstructure regulation and biocompatibility enhancement of biomedical Titanium alloys for implant applications

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Abstract

Titanium and its alloys have become the mainstream metallic biomaterials for orthopedic implantation due to their low density, excellent corrosion resistance and mechanical reliability. However, traditional pure titanium and Ti-6Al-4V alloy still suffer from obvious drawbacks: their elastic modulus is far higher than human cortical bone, triggering stress shielding effect and long-term implant loosening; meanwhile, toxic aluminum and vanadium ions released by corrosion will cause inflammation and cytotoxicity in vivo.

In this work, novel low-modulus biomedical titanium alloys with non-toxic alloying elements were fabricated via advanced additive manufacturing and post-heat treatment. Metallographic observation, tensile mechanical tests and electrochemical corrosion characterizations were carried out to analyze the alloy microstructure, elastic modulus and anti-corrosion performance. In vitro cell culture experiments using osteoblasts were further conducted to evaluate cell adhesion, proliferation and osteogenic differentiation capacity.

The results show that the optimized titanium alloy achieves an elastic modulus close to human bone, effectively relieving stress shielding. The alloy exhibits superior corrosion resistance, and no toxic ion precipitation is detected. Osteoblasts display favorable spreading and robust osteogenic activity on the alloy surface.

This study provides a feasible preparation strategy for high-performance biomedical titanium alloys, which can greatly promote the application of advanced manufacturing technology in orthopedic implant manufacturing.

Thermal-Driven Microstructure Evolution, Defect Formation and Property Control in Metal Additive Manufacturing

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Abstract

Powder bed fusion (PBF) has emerged as a versatile manufacturing platform for producing complex metallic components with unprecedented geometric freedom. Beyond fabrication, however, PBF offers unique opportunities for microstructure engineering through its highly localized melting, rapid solidification, and repeated thermal cycling. These process-induced thermal histories fundamentally govern phase evolution, defect formation, and ultimately the performance of additively manufactured components. In this talk, I will present a unified perspective on thermal-driven microstructure evolution, defect formation, and property control in both electron beam powder bed fusion (PBF-EB) and laser powder bed fusion (PBF-LB). By comparing the distinct thermal characteristics of these two technologies, I will demonstrate how process-specific thermal histories influence phase selection, grain structure development, microstructural heterogeneity, cracking behavior, and lack-of-fusion defects across a wide range of advanced alloys, including titanium alloys, nickel-based superalloys, shape memory alloys, intermetallics, high-entropy alloys, and refractory metals. The insights presented position metal additive manufacturing not merely as a fabrication technology, but as a thermal-driven microstructure and defect engineering platform. Such an approach provides new opportunities for integrated materials and process design, enabling the development of next-generation structural materials for aerospace, biomedical, energy, and advanced manufacturing applications.

Next-Generation Fatigue Design of Laser Powder Bed Fusion Manufactured Inconel 718 through Realistic Loading Characterization and Constitutive Modelling

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Abstract

Fatigue life prediction in realistic service environments is essential to ensure the structural integrity of additive manufacturing (AM) components for next-generation engineering components in aerospace, energy, and transportation sectors. Unlike conventionally manufactured materials, AM metals exhibit unique microstructural features, residual stresses, anisotropy, and process-induced defects that significantly influence their deformation and fatigue behaviour. Consequently, advanced constitutive models capable of accurately capturing these complex material responses are essential for the reliable design, analysis, and life prediction of additively manufactured components. In this work, LPBF Inconel 718 alloy was developed and designed for fatigue under both constant and variable-amplitude loading conditions. Strain-controlled fatigue loading was applied to the developed alloy to investigate its fatigue behaviour. A fighter-aircraft spectrum load sequence was applied to replicate realistic service loading and determine fatigue life under spectrum conditions. Fatigue life is estimated using rainflow counting and a linear damage accumulation model. LPBF Inconel 718 alloy exhibits rapid cyclic hardening in the initial cycles, followed by cyclic softening. A cyclic elasto-plastic constitutive model based on combined kinematic and isotropic hardening was developed to capture the complex cyclic hardening and softening of LPBF Inconel 718. The modified isotropic hardening predicted the cyclic stress response suitably well. The resulting framework improves the design of AM Inconel 718 fatigue behaviour under realistic service spectra and provides a physics-based foundation for fatigue life assessment and structural integrity evaluation of AM components.

Prediction of defect size in friction stir additive manufacturing using machine learning algorithms

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Abstract

Friction stir additive manufacturing (FSAM) is a sheet-lamination type of AM in which the material is processed in the solid state. Particularly with non-age hardenable aluminium alloys, FSAM has the capability of producing good mechanical strength structures. However, defects such as tunnels in the stir zone remain a significant problem that affects build quality and structural integrity. The conventional experimental and statistical approaches for evaluating and predicting defect sizes is time-consuming and cannot accurately capture the complex thermomechanical nature of the FSAM process. Machine learning (ML) algorithms, on the other hand, can map multiple FSAM process variables and are anticipated to accurately predict defect size. The ML models are also fundamental to enabling an intelligent FSAM process by ensuring reliable defect prediction, which can later be minimized by adjusting process variables in real time. The present work is, therefore, motivated by the aforementioned advantages of ML techniques and hence four of the ML methods, namely, Support Vector Regression (SVR), Gaussian Process Regression (GPR), Ensemble Learning (ENS), and Multi-Layer Perceptron (MLP) are utilized for prediction of tunnel defect cross-sectional area in FSAM of aluminium alloy 5083-O sheets of thickness 3 mm each, for a total of five sheets. The work is novel because it integrates not only the FSAM process parameters but also process characteristics to obtain reliable ML models for predicting defect size in the build. Using three different combinations of tool rotational speeds, travel speeds, and pin geometries, and building five layers (or joining four interfaces), a total of 108 experimental data points were collected. The defect size was quantified using image analysis software, and pre-processing and feature extraction were then performed on the dataset. Among the ML algorithms, the MLP model performed best, with the lowest root mean square error (RMSE) of 0.476.

Imperceptible augmentation of living systems with organic bioelectronic fibres

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Abstract

The functional and sensory augmentation of living structures, such as human skin and plant epidermis, with electronics can be used to create platforms for health management and environmental monitoring. Ideally, such bioelectronic interfaces should not obstruct the inherent sensations and physiological changes of their hosts. The full life cycle of the interfaces should also be designed to minimize their environmental footprint. Here we report imperceptible augmentation of living systems through in situ tethering of organic bioelectronic fibres. Using an orbital spinning technique, substrate-free and open fibre networks—which are based on poly (3,4-ethylenedioxythiophene):polystyrene sulfonate—can be tethered to biological surfaces, including fingertips, chick embryos and plants. We use customizable fibre networks to create on-skin electrodes that can record electrocardiogram and electromyography signals, skin-gated organic electrochemical transistors and augmented touch and plant interfaces. We also show that the fibres can be used to couple prefabricated microelectronics and electronic textiles, and that the fibres can be repaired, upgraded and recycled.

3D-Printed Support for a Huygens Source Antenna: Design and Near-Field Impact

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Abstract

Electrically small antennas (ESAs) are key to battery-free IoT sensors powered by ambient RF energy harvesting. Because an ESA is far smaller than the wavelength, it confines large reactive energy in its near field and exhibits a very high quality factor, rendering its resonance acutely sensitive to nearby dielectrics and small geometric variations. Any support holding the radiator therefore becomes an electromagnetically active element rather than a passive fixture. This work presents the additively manufactured design of a three-dimensional Huygens source antenna and quantifies how 3D-printed structures govern its performance.

The antenna stacks a magnetic dipole, an electric dipole, and a driven dipole, whose centimeter-scale vertical separations must be controlled to millimeter precision to set its resonance, radiation pattern, and impedance match. Lateral misalignment or distortion of these layers detunes the antenna and degrades the cardioid pattern, demanding precision beyond conventional desktop 3D printers. The support frame was produced by high precision stereolithography (Formlabs Clear Resin V5) at the SUTD NAMIC, the material chosen for both its dimensional precision and its dielectric properties, since the resin enters the antenna's reactive near field.

In simulation, removing the support shifted the reflection minimum from −11.8 dB at 921.8 MHz to −2.32 dB at 941.6 MHz, predicting significant detuning. Measurement contradicted this: with printed support and with only a foam substitute ($\varepsilon_r \approx 1$), the antenna operated near 1055 MHz in both cases, showing the support is nearly transparent and that simulation overestimates its influence.

We conclude that simulation alone is unreliable for such high-Q ESAs. Both the substrate and 3D-printed support materials must be experimentally characterized rather than assumed, and a series of prototypes spanning several frequency points should be fabricated to bracket tolerances and enable rapid iteration toward the target band.