

1st International Conference on Future of AM 2025

AM Powered by AI

5 - 7 August • Sands Expo and Convention Centre • Singapore

Sponsor and Exhibitor List

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Sliver Exhibitors:

Digital Gastronomy Lab
From 3D Food Printing to Personalized Nutrition



Standard Exhibitors:



Singapore Centre for 3D Printing



Centre for
Additive Manufacturing



Innovation Showcase:

BRD Lab
Art & Science of Design



WELCOME MESSAGE

Dear FutureAM attendees,

It is my great pleasure to welcome you to the 1st International Conference on Future of Additive Manufacturing (FutureAM) 2025 and to Singapore!

The theme of this conference is additive manufacturing (AM) powered by artificial intelligence (AI).

AI has emerged as a disruptive technology that is changing the way we live, work and study. At the same time, AM had become a critical technology and cornerstone of advanced manufacturing.

Powered by AI, AM is now experiencing a new boost in growth that unlocks new frontiers from materials, design, process and to advanced applications. The combination of AI and AM is anticipated to have an unprecedented impact in the advancement of manufacturing.

In this inaugural edition of FutureAM, close to 300 speakers from more than 20 countries will share their latest research in AM. The conference is organised into several key areas that are highly relevant to the industry. It also has special symposia on topics ranging from metal additive manufacturing to 3D printing for biomedical and extreme performance applications.

In addition, FutureAM 2025 serves as a unique platform to showcase innovations, demonstrating the full spectrum of technological potentials of AM in research and commercialisation. We are pleased to have more than 15 exhibitors, showcasing their technology advancements in various 3D printing and AI sectors.

Finally, and most importantly, we hope that this conference will be a starting point of a community with new friendships forged and new knowledge hubs created.

We look forward to creating the future of AM with you.



Prof Yeong Wai Yee
General Chair

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

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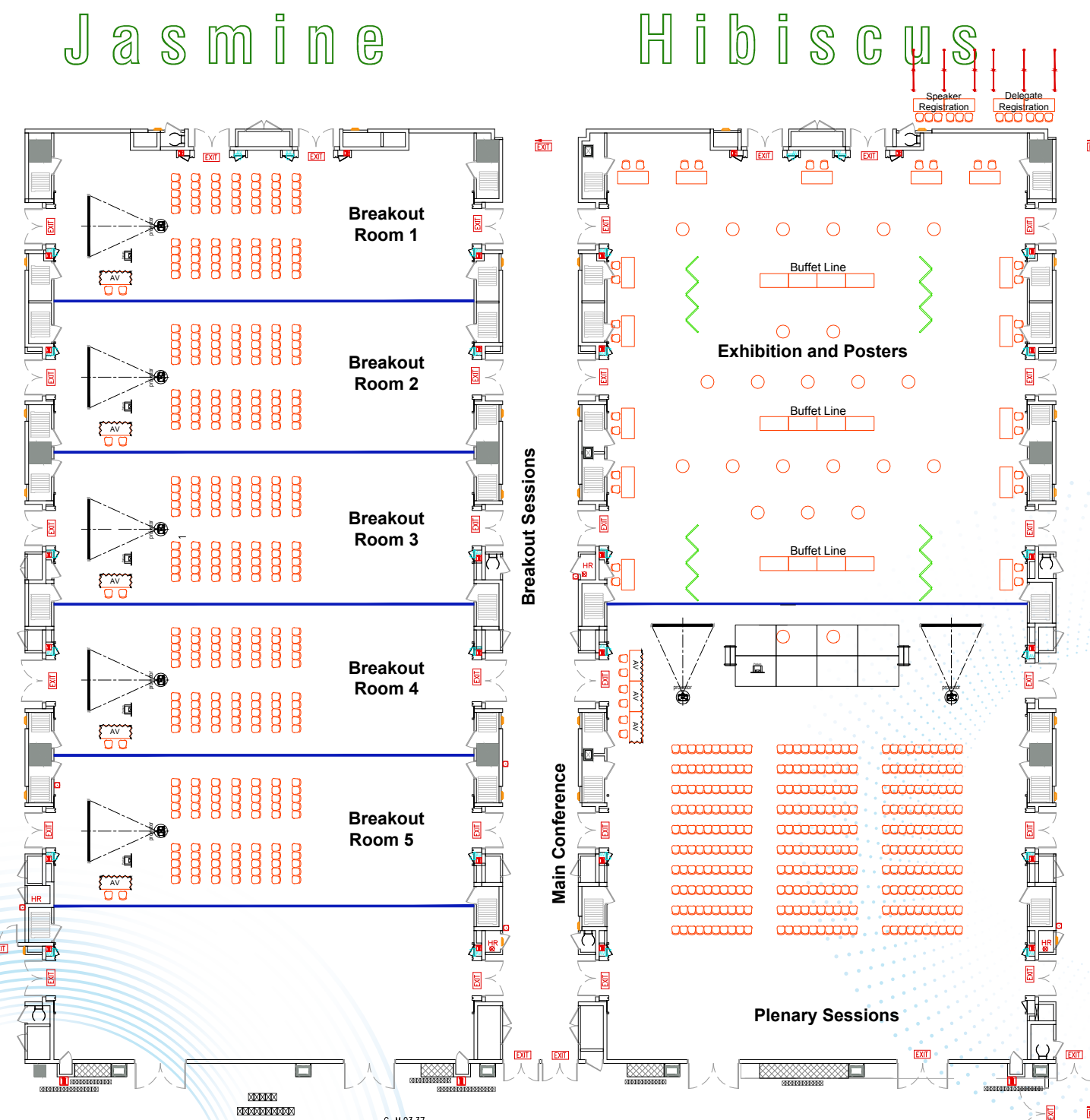
CONFERENCE VENUE

Marina Bay Sands: Singapore's Iconic Destination
Marina Bay Sands is a world-renowned integrated resort and architectural marvel in the heart of Singapore. Known for its iconic SkyPark and rooftop infinity pool, it offers stunning views of the city skyline. The resort features over 2,500 luxury rooms, celebrity chef restaurants, designer shopping, and world-class entertainment. Visitors can explore the lotus-shaped ArtScience Museum or enjoy performances at the Sands Theatre. Combining elegance, innovation, and excitement, Marina Bay Sands is a must-visit landmark that redefines luxury travel and showcases the best of Singapore's hospitality, culture, and modern spirit.



CONFERENCE FLOORPLANS

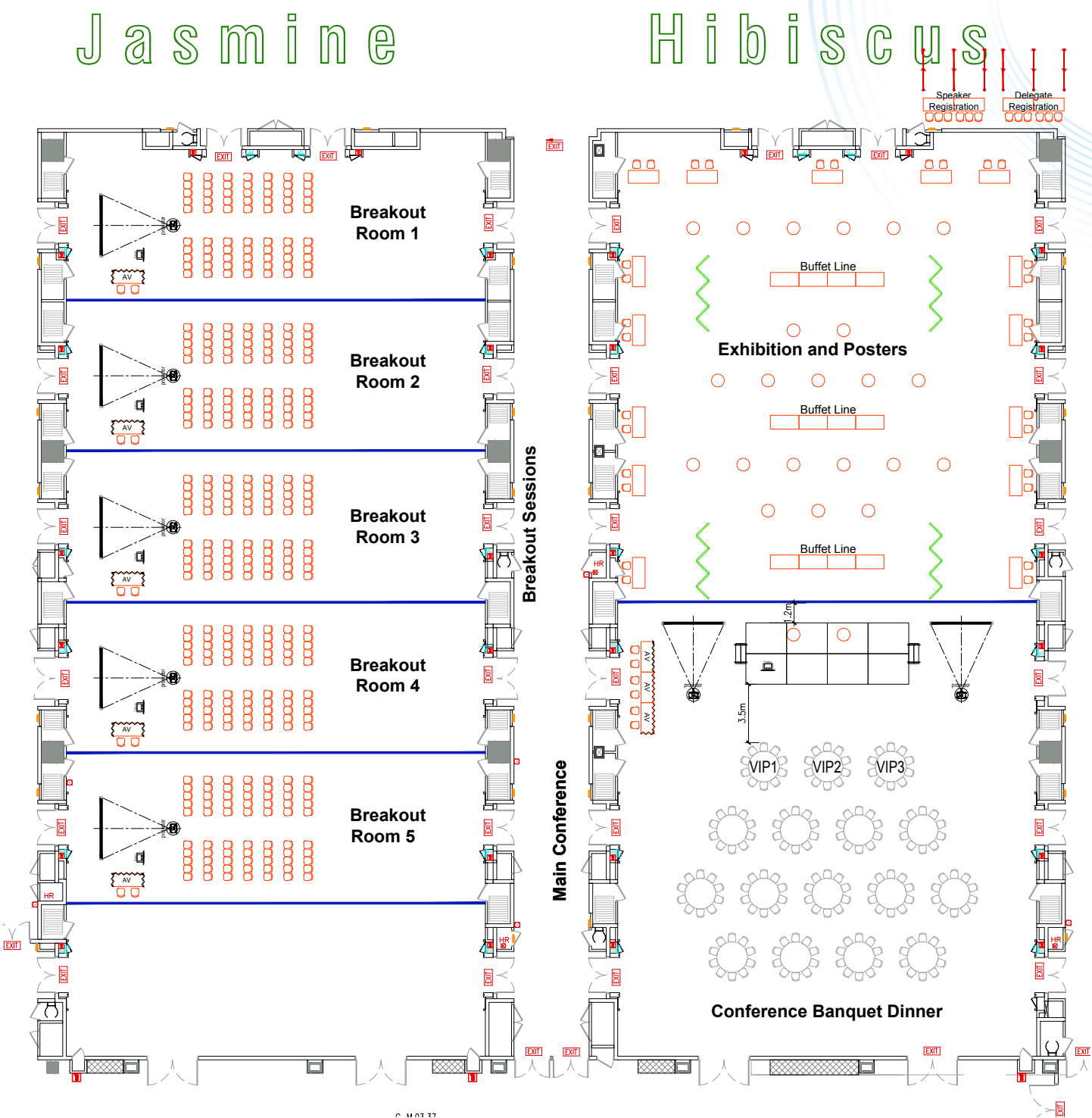
Day 1 – 05 August 2025



CONFERENCE FLOORPLANS

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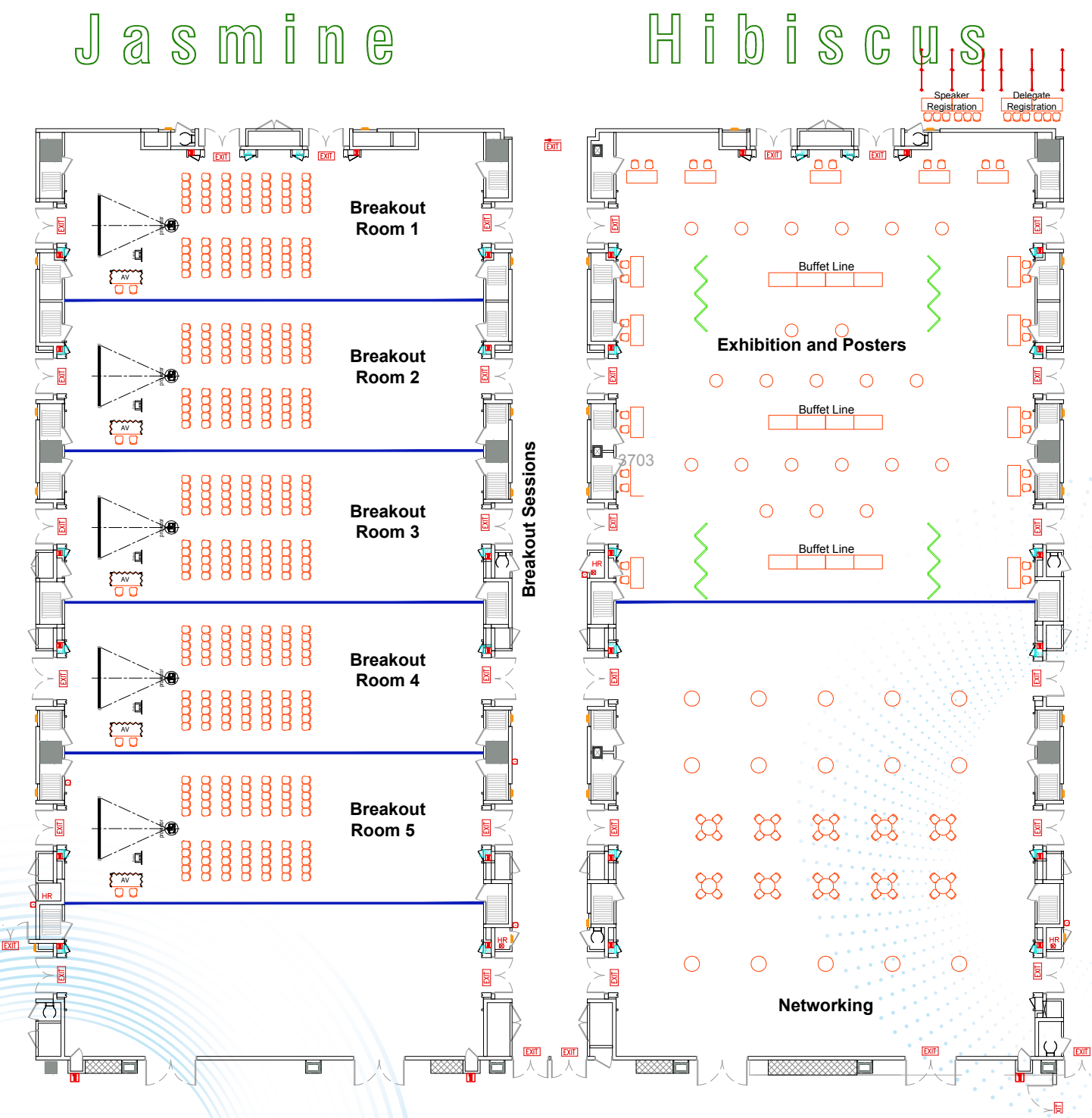
Day 2 – 06 August 2025



CONFERENCE FLOORPLANS

MBS LEVEL 3

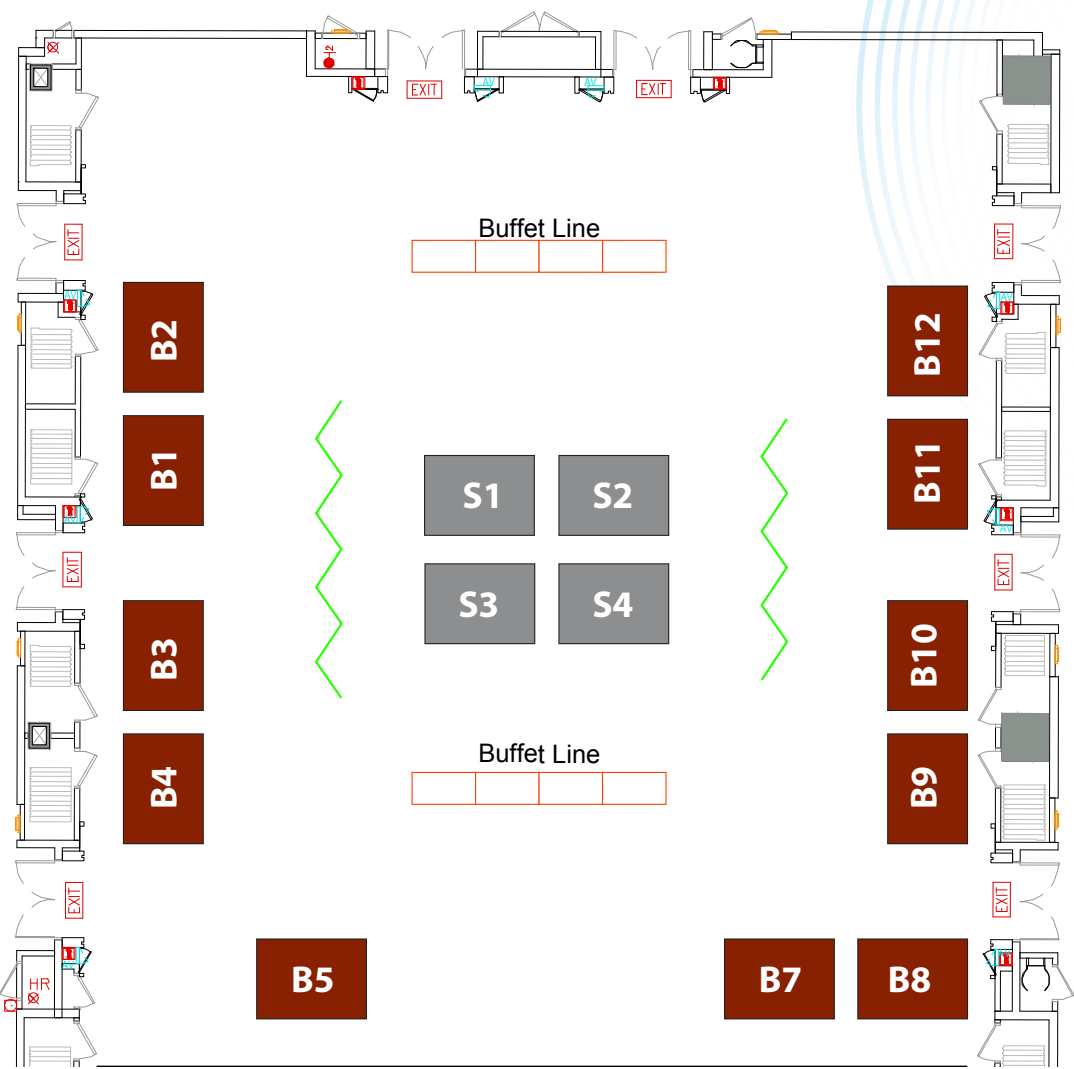
Day 3 – 07 August 2025



FLOOR PLAN

Exhibition

Hibiscus



Silver Booth

S1	NAMIC
S2	Fastform 美光速造
S3	Digital Gastronomy Programme
S4	ACCSscience Publishing

Standard Booth

B1	Dash - BMF Precision Tech Inc
B2	Gaia Science and CELLINK
B3	SUTD Robotics Innovation Laboratory
B4	Zrapid
B5	PolyMate
B7	Bambulab
B8	Concord
B9	Singapore Centre of 3D Printing (SC3DP)
B10	Castomize
B11	BRD Lab
B12	NUS Centre for Additive Manufacturing

PROGRAMME

Day 1 – 05 August 2025

TIME	PROGRAMME
07:30	Registration
09:00	Opening and Welcome Address by Conference General Chair Professor Wai Yee YEONG School of Mechanical and Aerospace Engineering, NTU
09:15	Plenary Speaker 1 The Future of Additive Manufacturing Dr Chaw Sing HO Chief Executive Officer, National Additive Manufacturing Innovation Cluster
09:45	Plenary Speaker 2 Design for 4D Additive Manufacturing Prof David W. ROSEN Principal Scientist, Institute of High Performance Computing and Singapore Institute of Manufacturing Technology, A*STAR
10:15	Tea Break (Exhibition & Poster viewing)
10:45	Plenary Speaker 3 Converging Frontiers: AI, Additive Manufacturing, and the Future of Standardization Dr Mohsen SEIFI Vice President, Global Advanced Manufacturing Programs, ASTM International
11:15	Plenary Speaker 4 Mechanical Behaviors of 3D-Printed Polymer Materials and Structures Prof Kun ZHOU Associate Chair (Research), School of Mechanical and Aerospace Engineering, NTU
11:45	Plenary Speaker 5 Multi-materials Powder Bed Based Additive Manufacturing: The Powder Bed and Interface Challenge Prof Shoufeng YANG Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences

BREAKOUT TRACKS

	Track 1	Track 1	Track 3	Track 4	Track 5
	Chairperson/s: Prof. Maling Gou	Chairperson/s: Prof. Hae-Jin Choi	Chairperson/s: Prof. Wonjoon Choi	Chairperson/s: Prof. Wang Di, Prof. Han Changjun	Chairperson/s: Yaoyao Fiona Zhao, Prof. Xin Lin
13:30 – 15:30	Special Symposium – 3D Printing and Personalized Medicine	Special Symposium – KSME Smart Additive Manufacturing	Special Symposium – Mechanics in Additive Manufacturing	Special Symposium – Metallic Additive Manufacturing	Special Symposium – Artificial Intelligence for Multifunctional Metal Additive Manufacturing

15:30	Tea Break (Exhibition & Poster viewing)				
16:00 – 17:00	Special Symposium – 3D Printing and Personalized Medicine	Special Symposium – KSME Smart Additive Manufacturing	Special Symposium – Additive Manufacturing for Extreme Performance	Special Symposium – Metallic Additive Manufacturing	Special Symposium – Multifunctional Metal Additive Manufacturing
17:00	End of Day 1 Programme				

DETAILED PROGRAMME - BREAKOUT SESSIONS

Track 1 – 05 August 2025 (13:30 – 17:00) Special Symposium – 3D Printing and Personalized Medicine Chairs: Prof. Maling Gou	
13:30 – 13:50	Construction of dynamic tumor microenvironment through bioprinting Tiankun Liu , Institute of Zoology, Chinese Academy of Sciences
13:50 – 14:10	Advancing Bioartificial Liver Transplantation: 3D Bioprinting for Functional Liver Grafts (Invited) Mingchang Pang , Peking Union Medical College Hospital
14:10 – 14:30	Durable Immunomodulatory Hierarchical Patch for Rotator Cuff Repairing (Invited) Liren Wang , Shanghai Sixth People’s Hospital
14:30 – 14:50	Large-scale AI models optimize bone microstructure and enhance additive manufacturing artificial bone design Jun Zou , The First Affiliated Hospital of Soochow University
14:50 – 15:10	Dual metabolic reprogramming of cancer cells and macrophages via a 3D-printed CuMn platform potentiates systemic anti-tumor immunity Jingke Fu , Shanghai Ninth People’s Hospital
15:10 – 15:30	3D Printing and Personalized Medicine (Invited) Shasha Liu , Shanghai Ninth People’s Hospital
15:30 – 16:00	Tea break
16:00 – 16:20	Platelet-rich Plasma-exosomes Therapy Overcoming Pro-inflamminatory and Catabolic Effects for Temporomandibular Joint Osteoarthritis Shasha Liu , Shanghai Ninth People’s Hospital
16:20 – 16:40	3D bioprinting of high-performance hydrogel for cell therapy (Invited) Jie Tao , Army Medical University
16:40 – 17:00	Three-dimensional Bioprinting Utilizing Sacrificial Material Support and Longitudinal Printability Evaluation (Invited) Shanshan Yang , Hangzhou Dianzi University

Track 2 – 05 August 2025 (13:30 – 17:00) Special Symposium – KSME Smart Additive Manufacturing Chairs: Prof. Hae-Jin Choi	
13:30 – 13:50	Advances in 3D Printing of Magnetic Materials: Current Status, Challenges, and Future Directions (Invited) Joon Phil Choi , Korea Institute of Machinery & Materials
13:50 – 14:10	AI Powered Metal Additive Manufacturing (Invited) Im Doo Jung , Ulsan National Institute of Science and Technology
14:10 – 14:30	Optimizing Process Parameters Using Machine Learning and Finite Element Analysis to Enhance Dimensional Accuracy in Robot-Based Large Object Additive Manufacturing (Invited) Namhun Kim , Ulsan National Institute of Science and Technology
14:30 – 14:50	Accelerating Process Optimization and Design for Additive Manufacturing with Machine Learning (Invited) Howon Lee , Seoul National University
14:50 – 15:10	Autonomous process planning and monitoring in additive manufacturing using AI techniques (Invited) Suk-Hee Park , Pusan National University
15:10 – 15:30	TBD
15:30 – 16:00	Tea break
16:00 – 16:20	Advancing Osteoarthritis Therapy via Stem Cell-laden 3D Bioprinting: From Bioink Innovations to Anti-inflammatory Functionalization and Clinical Applications (Invited) Sang-in Park , Incheon National University
16:20 – 16:40	Direct Laser Writing of Laser-Induced Graphene Electronics for Advanced Healthcare Applications (Invited) Young-Jin Kim , Korea Advanced Institute of Science and Technology
16:40 – 17:00	TBD

Track 3 – 05 August 2025 (13:30 – 17:00) Special Symposium – Additive Manufacturing for Extreme Performance Chairs: Prof. Wonjoon Choi	
13:30 – 13:50	Advanced materials through structure and material design in 3D printing (Invited) Wei Zhai , National University of Singapore
13:50 – 14:05	Accelerating the design of novel alloys for hydrogen applications: an AI-driven Additive Manufacturing approach Matteo Vanazzi , f3nice Srl
14:05 – 14:20	Laser Powder Bed Fusion of Pure Copper Using Green Laser Bikram K. Khandai , Indian Institute of Technology Hyderabad
14:20 – 14:35	Reinforcement Learning Framework for Optimizing Random Voronoi Lattice Structures Jinghao Li , Aarhus University
14:35 – 14:50	Computational Investigation of Powder-Induced Porosity in Laser-Based DED Shuhao Wang , Wuhan University of Science and Technology

14:50 – 15:05	High-temperature high-entropy alloys: Targeted composition and microstructural design for synergistic multi-property enhancement (Invited) Shiwei Wu , Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences
15:05 – 15:20	Assessing and Predicting the Mechanical Performance, Durability Attributes and Degradability Trait of 3D-Printed Specimens in Tropical Climatic Conditions Raviduth Ramful , University of Mauritius
15:20 – 16:00	Tea break
16:00 – 16:15	Model-Based Additive Manufacturing Verification and Validation for the Maritime Industry Wenjin Wu , ABS
16:15 – 16:35	Direct Ink Writing 3D Printing for Fabricating Microfluidic Devices (Invited) Michinao Hashimoto , Singapore University of Technology and Design
16:35 – 16:55	Polymer Powder Bed Fusion: Challenges and Opportunities (Invited) Hesheng Xia , Sichuan University

Track 4 - 05 August 2025 (13:30 – 17:00) Special Symposium – Metallic Additive Manufacturing Chairs: Prof. Wang Di, Prof. Han Changjun	
13:30 – 13:50	Unraveling crack formation and elimination in AA7075 alloy during laser remelting: insights from in-situ high speed X-ray imaging (Invited) Wenhui Yu , Shandong University of Technology
13:50 – 14:10	Laser powder directed energy deposition of FeCoNiCrMox high entropy alloys for high performance protective coatings (Invited) Yongling Wu , Shandong University of Technology
14:10 – 14:30	Additive manufacturing of biodegradable zinc alloys: materials, structures, and applications (Invited) Changjun Han , South China University of Technology
14:30 – 14:50	Machine learning driven additive manufacturing technology in metallic materials (Invited) Fulin Jiang , Hunan University
14:50 – 15:10	Effect mechanism of electroshock treatment on mechanical properties of laser melting deposited Ti55531 alloy (Invited) Lechun Xie , Wuhan University of Technology
15:10 – 15:30	The innovative laser sources applications in metal 3D printing (Invited) Shuai Li , FastForm
15:30 – 16:00	Tea break
16:00 – 16:15	Microstructure refinement and strength enhancement of Ti-45Al-5Nb alloy via electromagnetic shock Hongxin Sun , Wuhan University of Technology
16:15 – 16:30	Arc Additive Manufacturing of High-Strength Aluminum Alloy with Lamellar Heterogeneous Structure for Enhanced Strength-Toughness Yinghui Zhou , Xi'an University of Technology

16:30 – 16:45	Cavity-induced bubbles and pore formation of laser direct energy deposited titanium alloy: influence of powder melting degree Mingyuan Chen , Beihang University
16:45 – 17:00	Dynamic mechanical properties and its mechanisms of fcc-type medium entropy alloys Ao Fu , Central South University

Track 5 - 05 August 2025 (13:30 – 17:00) Special Symposium – Multifunctional Metal Additive Manufacturing Chairs: Prof. Yaoyao Fiona Zhao, Prof. Xin Lin	
13:30 – 13:50	iTwin: Intelligent Twin for In Situ Monitoring and Real-Time Adaptive Quality Assurance in Metal Additive Manufacturing (Invited) Mehdi Jafary Zadeh , Institute of High Performance Computing
13:50 – 14:10	Leveraging Additive Manufacturing for Lightweight, Thermally Efficient Battery Casings in Electric Vehicles (Invited) Ali Ghasemi , National University of Singapore
14:10 – 14:25	Synergistic enhancement of strength and ductility of laser-based powder bed fusion of metals (PBF-LB/M) AISi10Mg alloy by in-situ magnetic field assistant and post-heat treatment Dafan Du , Shanghai Jiao Tong University
14:25 – 14:40	Machine Learning-based Thermal Deformation Prediction for Laser Powder Bed Fusion Haoyu Li , Nanyang Technological University
14:40 – 14:55	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
14:55 – 15:15	Data driven part quality prediction in additive manufacturing (Invited) Seung Ki Moon , Nanyang Technological University
15:15 – 15:35	Enhancing L-PBF processing efficiency for Ti-6Al-4V printing using a combination of machine learning and a decision support system (Invited) Denis Dowling , University College Dublin
15:35 – 16:00	Tea break
16:00 – 16:20	Recent Developments in Laser Processing for Enhancing Metallic Surfaces (Invited) Ying Chun Guan , Beihang University
16:20 – 16:40	Improved Strength and Ductility in Novel Metamaterials Additively Manufactured using Laser Sheet Fusion (Invited) Changquan Lai , Nanyang Technological University
16:40 – 17:00	Real-time defect detection in Wire Arc Additive Manufacturing (WAAM) using microphone and emission spectroscopy (Invited) Tegoeh Tjahjowidodo , KU Leuven
17:00 – 17:20	Alveolar bone repair of rhesus monkey by using BMP-2 gene and MSCs loaded three-dimensional printed bioglass scaffold (Invited) Weikang Xu , Guangdong Academy of Sciences

PROGRAMME

Day 2 – 06 August 2025

BREAKOUT TRACKS					
	Track 1	Track 1	Track 3	Track 4	Track 5
	Chairperson/s: Prof. Hae-Jin Choi	Chairperson/s: Prof. Yiting Lei	Chairperson/s: Prof. Zhili Dong	Chairperson/s: Prof. Teck Neng Wong	Chairperson/s: Dr. Pan Wang
08:30	Special Symposium – KSME Smart Additive Manufacturing	Special Symposium – Bioprinting in Regenerative Medicine	Metal Additive Manufacturing	Functional 3D Printing	Simulations and Modeling for Additive Manufacturing
10:30	Tea Break (Exhibition & Poster viewing)				
11:00	Panel Discussion Panellists: Xuanze Wang, CEO, Deep Material Kun Zhang, CEO, Growlib Rui Liu, CEO, Anisoprint Hao Bai, CEO, Concord AM	Special Symposium – Bioprinting in Regenerative Medicine	Metal Additive Manufacturing	Functional 3D Printing	Simulations and Modeling for Additive Manufacturing
12:20	Lunch (Poster Presentations Session) Meet the Editor – Prof Wai Yee Yeong (IJAMD)				
	Chairperson/s: Dr. Yunlong Tang	Chairperson/s: Dr. Jia An	Chairperson/s: Dr. Swee Leong Sing	Chairperson/s: Dr. Ri Han	Chairperson/s: Prof. Hao Wang
13:30	Industrial Additive Manufacturing	3D Printing for Biomedical Applications	Metal Additive Manufacturing	Functional 3D Printing	Novel Techniques in Additive Manufacturing
15:30	Tea Break (Exhibition & Poster viewing)				
16:00	Industrial Additive Manufacturing	3D Printing for Biomedical Applications	Metal Additive Manufacturing	Functional 3D Printing	Novel Techniques in Additive Manufacturing
17:00	Free Time				
19:00	Conference Banquet Dinner				
22:00	End of Day 2 Programme				

DETAILED PROGRAMME - BREAKOUT SESSIONS

Track 1 – 06 August 2025 (0900 – 1020) Special Symposium – KSME Smart Additive Manufacturing II Chairs: Prof. Hae-Jin Choi	
09:00 – 09:20	Data-Driven Design of Architected Materials: Enhancing Specific Stiffness through Multi-Objective Optimization (Invited) Seunghwa Ryu , Korea Advanced Institute of Science and Technology
09:20 – 09:40	Multiscale Architected Structures with Tailored Thermal, Mechanical, and Electromagnetic Functions via Additive Manufacturing (Invited) Wonjoon Choi , Korea University
09:40 – 10:00	Nanoscale Additive Manufacturing for Photonic Anti-counterfeiting Labels (Invited) Ji Tae Kim , Korea Advanced Institute of Science and Technology
10:00 – 10:20	Design of High-Strength Dual Cure Resin for Digital Light Processing (Invited) Hae-Jin Choi , Chung-Ang University
10:20 – 11:00	Tea break
Track 1 – 06 August 2025 (1100 – 1230) Special Symposium – Breakthroughs in Additive Manufacturing Mass Production	
Panel Discussions	Panellists: Xuanze Wang, CEO, Deep Material Kun Zhang, CEO, Growlib Rui Liu, CEO, Anisoprint Hao Bai, CEO, Concord AM
Track 2 – 06 August 2025 (0900 – 1230) Special Symposium – Bioprinting in Regenerative Medicine Chairs: Prof. Yiting Lei	
09:00 – 09:20	3D printing for cell delivery using dynamic hydrogel (Invited) Maling Gou , West China Hospital
09:20 – 09:40	Current status of radiation induced injuries models and future developments Xiangkun Yuan , Cangzhou Hospital of Integrated Traditional Chinese Medicine and Western Medicine
09:40 – 10:00	Advanced Additive Manufacturing of Immunomodulatory Patches for Rotator Cuff Repair Liren Wang , Shanghai Sixth People’s Hospital
10:00 – 10:20	Wafer-scale integration of metal oxide-based gas sensors via direct lithographic patterning (Invited) Guanghai Fei , Zhongda Hospital, Southeast University
10:20 – 11:00	Tea break
11:00 – 11:20	Integrating coaxial electrospinning and 3D printing technologies for the development of biphasic porous scaffolds enabling spatiotemporal control in tumor ablation and osteochondral regeneration (Invited) Yong Xu , Shanghai Pulmonary Hospital

11:20 – 11:40	The Transformative Role of Additive Manufacturing: Validated Framework for Biomechanically Optimized Patient-Specific Mandibular Reconstruction Plate (Invited) Shenping Zhong , Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences
11:40 – 12:00	3D Bioprinted scaffolds for joints regeneration (Invited) Tao Li , Xin Hua Hospital Affiliated to Shanghai Jiao Tong University
12:00 – 12:20	3D Printing of Ceramic Bone Scaffolds (Invited) Lisheng Sun , Southeast University

Track 3 - 06 August 2025 (0900 – 1230) Metal Additive Manufacturing Chairs: Prof. Zhili Dong	
09:00 – 09:20	Ultrastrong nanotwinned titanium alloys through additive manufacturing (Invited) Yuman Zhu , Monash University
09:20 – 09:40	Enhanced hydrogen embrittlement resistance through microstructure tailoring by metal additive manufacturing (Invited) Zhili Dong , Nanyang Technological University
09:40 – 10:00	Modelling the failure in lattices with fracture locus of additive manufactured metals (Invited) Peifeng Li , University of Glasgow
10:00 – 10:20	Laser powder bed fusion of overhang structures using donut-shaped laser beam Quanquan Han , Shandong University
10:20 – 11:00	Tea break
11:00 – 11:15	In-Situ Alloying Modulation in Laser Powder Bed Fusion of Titanium-Tantalum Alloy: From Melt Pool Modelling to Process Development Yanting Liu , National University of Singapore
11:15 – 11:30	Addressing the Present and Future Research Gaps in Build Orientation Effects on Fatigue Properties of PBF-LB/M Components Aloysius Tay , National University of Singapore
11:30 – 11:45	Optimising Mechanical Performance in laser powder bed fusion of Ti-6Al-4V: Interplay of Powder Packing, Surface Orientation, and Predictive Modelling Joe Elambasseril , RMIT University
11:45 – 12:00	Development of High-Silicon (6.5 wt.% Si) Fe-Based Soft Magnetic Cores via Dual-Nozzle Material Extrusion and Spark Plasma Sintering Taehyeob Im , Hanyang University
12:00 – 12:20	Effect of Topological Characteristics on the Manufacturability and Mechanical Performance of Multiscale Graded Structures Fabricated by Laser Powder Bed Fusion (Invited) Ruiqi Wang , Nanjing University of Aeronautics and Astronautics

Track 4 - 06 August 2025 (0900 – 1230) Functional 3D Printing Chairs: Prof. Teck Neng Wong	
09:00 – 09:20	Computational Fluid Dynamics Simulation of the Effects of Flow Conditions in 3D Concrete Printing (Invited) Teck Neng Wong , Nanyang Technological University
09:20 – 09:40	Effect of Printing Parameters and Material Rheology on the Filament Quality in 3D Concrete Printing (Invited) Mingyang Li , Nanyang Technological University
09:40 – 10:00	Binder Jet 3D Printing of Ceramic-Based Composites: Enabling Functional Materials for Advanced Applications (Invited) Yanhan Liew , Singapore Institute of Manufacturing Technology
10:00 – 10:20	Experimental and machine learning analysis of warping behaviour in LPBF-fabricated stainless steel cantilever beams (Invited) Wang Chen , Singapore Institute of Manufacturing Technology
10:20 – 11:00	Tea break
11:00 – 11:20	Design and Fabrication of Sensor-Integrated 3D-Printed Toys for Early Childhood Cognitive Intervention: A Review and Case Study (Invited) Guo Liang Goh , Nanyang Technological University
11:20 – 11:40	Design for Additive Manufacturing of Continuous Fiber-Reinforced Composites (Invited) Yi Xiong , Southern University of Science and Technology
11:40 – 12:00	Desktop 4D printing of hybrid materials (Invited) Mika Salmi , Aalto University
12:00 – 12:15	Viability of vegetable waste as a 3D printable ink Phoebe Xin Ni Leam , Singapore University of Technology and Design
12:15 – 12:30	Polyurethane Nanocoating for Improving the Mechanical Performance and Comfort of 3D-Printed Elastomeric Materials Xinshou Li , Jiangsu Normal University

Track 5 - 06 August 2025 (0900 – 1230) Simulations and Modeling for Additive Manufacturing Chairs: Dr. Pan Wang	
09:00 – 09:15	Multiscale Phase-Field Modeling of Dendritic Growth and Dislocation Dynamics in Laser Additive Manufactured NiTi Alloys Haodong Chen , Wuhan University of Science and Technology
09:15 – 09:30	Melt pool dynamics and grain growth behavior during directed energy deposition additive manufacturing of high-entropy Cantor alloy by integrating in-situ and ex-situ monitoring Shuya Zhang , Shanghai Jiao Tong University
09:30 – 09:50	Simulating Microstructure Evolution in Sintering and Additive Manufacturing Using Phase-Field Micromechanics: Model Development and Experimental Validation (Invited) Qingcheng Yang , Shanghai University
09:50 – 10:10	Model-based qualification of metal 3D printed components (Invited) Guglielmo Vastola , Institute of High Performance Computing

10:10 – 10:30	Machine Learning-Based Defect Detection and Prediction in Laser Powder Bed Fusion via in situ Monitoring (Invited) Pan Wang , Singapore Institute of Manufacturing Technology
10:30 – 11:00	Tea break
11:00 – 11:15	Machine learning-guided 3D printing optimization and heat treatment for high-density and enhanced performance refractory high entropy alloys Deyu Jiang , Shanghai Jiao Tong University
11:15 – 11:30	Multi-Scale Analysis of Material Uncertainty and Its Impact on Mechanical Property Distribution in L-PBF Parts Umesh Kizhakkinan , Singapore University of Design and Technology
11:30 – 11:45	Artificial intelligence-aided defect detection and healing in laser-based powder bed fusion Jan Akmal , Aalto University
11:45 – 12:00	Biomimetic Design of Animal Skeletal Structures via Topology Optimization and Rapid Prototyping-based Physical Simulation Minda Wang , Nanyang Technological University
12:00 – 12:15	Machine Learning-based Process Parameter Optimization for Tailoring Mechanical Properties of Material Extrusion-fabricated Recycled Carbon Fiber Reinforced Plastic Sangjun Jeon , Kongju National University
12:15 – 12:30	Coupling Physics-Informed Neural Networks with CFD for Multi-Physics Modelling of Metallic Glass Formation in Laser Powder Bed Fusion Xuyang Chen , Institute of Engineering Thermophysics, Chinese Academy of Science

Track 1 – 06 August 2025 (1330 – 1700) Industrial Additive Manufacturing Chairs: Dr. Yunlong Tang	
13:30 – 13:20	Machine Learning-Enabled Additive Manufacturing: Advancing Process Optimization, Intelligent Design, and Knowledge-Driven Engineering (Invited) Yaoyao Fiona Zhao , McGill University
13:20 – 13:40	Purely-dissolutive wetting behaviours in metallic systems: a combined experimental and numerical approach (Invited) Youqing Sun , Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences
13:40 – 14:00	Bridge Design and Manufacturing for Additive Manufacturing: An AI-Driven Approach (Invited) Yunlong Tang , Monash University
14:00 – 14:20	The Future of Construction 3D Printing (Invited) Ming Jen Tan , Nanyang Technological University
14:20 – 14:40	Strategies For Fatigue Design, Testing and Qualification of Parts Printed by Metal Additive Manufacturing (Invited) John Hock Lye Pang , Nanyang Technological University
14:40 – 14:55	Unraveling the Creep Behavior of Inconel 718 Lattice Metamaterials: A High-Throughput Approach Xi He , Southern University of Science and Technology
14:55 – 15:15	Evolution of standards in additive manufacturing with emphasis on ASTM standards (Invited) Andy Lu , ASTM International

15:15 – 15:30	Intelligent Wire Arc Additive Manufacturing System: Process Optimization, Multi-Sensor Fusion, Machine Learning Decision-Making, and Aero-Engine Maintenance Applications Runsheng Li , Hong Kong Polytechnic University
15:30 – 16:00	Tea break
16:00 – 16:15	Impact of Scan Strategy and Beam Diameter on the Porosity of ASTM A131 EH36 Fabricated via Laser Powder Bed Fusion Aw Beng Loon , Singapore Institute of Manufacturing Technology
16:15 – 16:30	3D printed Knot-Based Resonators Structures Jin An Chu , Singapore University of Technology and Design
16:30 – 16:45	Design of peristaltic-based extrusion printer for high-throughput food printing Qing Yang Tan , Singapore University of Technology and Design
16:45 – 17:00	Effect of Deposition Sequence on Interface Evolution and Tensile Behaviour in WAAM-Fabricated Bimetallic Structures Ozan Can Ozaner , KU Leuven

Track 2 – 06 August 2025 (1330 – 1700) 3D Printing for Biomedical Applications Chairs: Dr. Jia An	
13:30 – 13:50	Laser-Based High-Definition 3D Printing and Bioprinting– upscaling and addressing industrial applications (Invited) Aleksandr Ovsianikov , Technische Universität Wien
13:50 – 14:10	Extrusion bioprinting via multi-nozzle syringe (Invited) Jia An , Singapore University of Technology and Design
14:10 – 14:30	Reverse Engineering of Meat Structures Using 3D Printing of Plant Based Materials (Invited) Lay Poh Tan , Nanyang Technological University
14:30 – 14:50	Design and Preparation of Body-Temperature Responsive Biodegradable Polymer Materials for Laser-based 4D Printing (Invited) Wei Zhu , Hunan University
14:50 – 15:10	Rapid Bioprinting of Biomimetic Tissues in Multi-Well Plates for High-Throughput Drug Screening and Complex Disease Modeling Kar Perng Low , Cellink
15:10 – 15:25	Enhancing degradation behavior, osteogenic capacity and angiogenic performance of additively manufactured porous Zn-Mg scaffold via a neobavaisoflavone-doped GelMA composite hydrogel coating Cheng Chen , South China University of Technology
10:20 – 11:00	Tea break
16:00 – 16:15	Computational investigation of a 3D-printed osteochondral interface scaffold with comprehensive interfacial mechanical properties Kaicheng Yu , Harbin Institute of Technology
16:15 – 16:30	Tuning the adsorption of metal ions in 3D printed organogels via pKa modification Samuel Lee , Nanyang Technological University
16:30– 16:45	A Review on 3D Biofabrication of Organ-scale Cardiac Models for Tissue Engineering Shi Hui Cheng , Nanyang Technological University

16:45 – 17:05	3D-printed Intelligent magnetic soft millirobots for biomedical application (Invited) Yi Zhang , University of Electronic Science and Technology of China
17:05 – 17:25	Development of Neural Cells in Engineered Brain-like Constructs and its application for Transplantation (Invited) Yu Song , Tsinghua University
17:25 – 17:45	Alveolar bone repair of rhesus by using BMP-2 gene and MSCs loaded three-dimensional printed bioglass scaffold (Invited) Weikang Xu , Guangdong Academy of Sciences
17:45 – 18:05	Moving Bioprinting Towards Clinical Application (Invited) Laurence Meagher , Monash University

Track 3 – 06 August 2025 (1330 – 1700) Metal Additive Manufacturing Chairs: Dr. Swee Leong Sing	
13:30 – 13:45	Enhanced Laser Powder Bed Fusion for Lattice Structures: Integration of Wobble Scanning and Variable Laser Power Modulation Chung-Wei Cheng , National Yang Ming Chiao Tung University
13:45 – 14:00	Characterisation of Hidden Dimensional Structure using Non-destructive X-ray Computed Tomography Yuchen Lu , National Metrology Centre
14:00 – 14:15	Investigation of the Effects of Additive Manufacturing Parameters on Porosity Using X-ray Computed Tomography Shihua Wang , National Metrology Centre
14:15 – 14:30	Unraveling microstructure and mechanical response of an additively manufactured refractory TiVHfNbMo high-entropy alloy Dingcong Cui , Northwestern Polytechnical University
14:30 – 14:45	Additively manufactured Ta-based medical devices: Innovative study and exploration in industrial application Qiu Hao , Guangzhou Academy of Sciences
14:45 – 15:00	Using AI and Machine Learning to Correlate Microstructure with Printing Parameters in LPBF Aluminum Alloys Yi Chao , National Sun Yat-Sen University
10:20 – 11:00	Using AI and Machine Learning to Correlate Microstructure with Printing Parameters in LPBF Aluminum Alloys Yi Chao , National Sun Yat-Sen University
15:00 – 15:15	Recent Advances in the Fatigue Behavior of Direct Energy Deposition–Fabricated Metals and Alloys Ran An , Nanyang Technological University
15:15 – 15:30	A Hamiltonian toolpath planning approach for processing of multi-void geometries in the Directed Energy Deposition Process A S Vishnu , Indian Institute of Technology Hyderabad
15:30 – 16:00	Tea break
16:00 – 16:20	Design of shape memory alloy and maraging steel for additive manufacturing via in-situ alloying (Invited) Zhiyuan Liu , Shenzhen University

16:20 – 16:40	Additively manufactured biodegradable metal implants for repairing bone defects (Invited) Peng Wen , Tsinghua University
16:40 – 17:00	Additive Printing for the Fast Prototyping of Portable Magnetic Resonance Imaging (MRI) (Invited) Shaoying Huang , Singapore University of Technology and Design

Track 4 – 06 August 2025 (1330 – 1700) Functional 3D Printing Chairs: Dr. Ri Han	
13:30 – 13:50	High-performance or functional UV-curing 3D printing materials derived from plant oils and natural phenols (Invited) Chengguo Liu , Nanjing Forestry University
13:50 – 14:10	4D Printing of Versatile Shape Memory Polymers with Digital Light Processing (Invited) Pei-Chen Su , Nanyang Technological University
14:10 – 14:30	Novel Texture Creation in Food Printing: A Review and Case Study on Nozzle Geometry and Robotic Arm Integration (Invited) Guo Dong Goh , Nanyang Technological University
14:30 – 14:45	Multi-Axis Additive Manufacturing: Challenges and Opportunities Guoxin Fang , The Chinese University of Hong Kong
14:45 – 15:00	Additive Manufacturing of Two-Stage Flexible Piezoresistive Sensors with Liquid Rope Coiling for Health Monitoring and Human–Computer Interaction Shahid Hussain , Hefei University of Technology
15:00 – 15:15	Miniaturized Mechanical Testing of Fused Filament Fabricated Alumina: Effects of Sintering Temperature and Anisotropy Mayank Mishra , Indian Institute of Technology Madras
15:15 – 15:30	Direct-Ink-Write 3D Printing of Hierarchically Structured Composite Materials Quyang Liu , National University of Singapore
15:30 – 16:00	Tea break
16:00 – 16:15	3D-printed tempeh for spatially controlled texture Jian Da Tan , Singapore University of Technology and Design
16:15 – 16:30	Control of Droplet Formation in Inkjet 3D Printing Using Deep Reinforcement Learning Yi Cai , The Hong Kong University of Science and Technology (Guangzhou)
16:30 – 16:45	Ultrafast dynamic evolution of materials processed by femtosecond laser Guodong Lyu , Shandong University of Technology
16:45 – 17:00	Formulation of a starch-based protein fortified three-dimensional construct utilizing different post-processing methods Aakanksha Pant , Singapore University of Technology and Design
17:00 – 17:20	AI Gastronomic Design: 3D Food Printing for Aesthetic Experience (Invited) Immanuel Koh , Singapore University of Technology and Design
17:20– 17:40	Additively Manufactured Architected Materials with Unprecedented Mechanical Performance and Functional Integration (Invited) Zhendong Li , Central South University

Track 5 - 06 August 2025 (1330 – 1700) Novel Techniques in Additive Manufacturing Chairs: Prof. Hao Wang	
13:30 – 13:50	Design of cellular-structured heat sink for additive manufacturing based on Voronoi tessellation and machine learning (Invited) Asuka Suzuki , Nagoya University
13:50 – 14:10	Novel Post Processing with Augmented Machining (Machining+) for Metal Additive Manufacturing (Invited) Hao Wang , National University of Singapore
14:10 – 14:30	Two-Photon Polymerization Lithography: Enabling 3D Printing in Photonics (Invited) Hongtao Wang , Singapore University of Technology and Design
14:30 – 14:50	Sustainable 3D Printing Based on A Multifunctional Photoinitiator (Invited) Jieping Wang , Hangzhou Institute for Advanced Study
14:50 – 15:10	Machine learning accelerated design of lattice metamaterials (Invited) Miao Zhao , University of Electronic Science and Technology of China
15:10 – 15:30	Nanosecond-femtosecond laser-materials processes and the functional structures preparation of thin film (Invited) Dongfeng Qi , Shandong University
15:30 – 16:00	Tea break
16:00 – 16:15	Möbius Ring Resonators Fabricated by Two-Photon Polymerization Hongwei Gao , Singapore University of Technology and Design
16:15 – 16:30	Reducing Solidification Cracks and Enhancing Mechanical Performance in Additively Manufactured Cu-Ti Alloys via Chemical Fluctuation Manipulation Qi Liu , The Hong Kong Polytechnic University
16:30 – 16:50	Upscaling of 3D Printing (Invited) U-Xuan Tan , =and Design
16:50 – 17:10	High-resolution integrated photonic devices realized using additive processes (Invited) Dawn Tan , Singapore University of Technology and Design

PROGRAMME

Day 3 – 07 August 2025

BREAKOUT TRACKS					
	Track 1	Track 1	Track 3	Track 4	Track 5
	Chairperson/s: Dr. Swee Leong Sing	Chairperson/s: Prof. Changjin Huang	Chairperson/s: Prof. Gopu Sriram	Chairperson/s: Dr. Sharon Nai	Chairperson/s: Dr. Jia Min Lee
08:30	Metal Additive Manufacturing	Functional 3D Printing	3D Printing for Biomedical Applications	Industrial Additive Manufacturing	Novel Techniques in Additive Manufacturing
10:30	Tea Break (Exhibition & Poster viewing) Meet the Editor – Jia An (IJB)				
11:00	Metal Additive Manufacturing	Functional 3D Printing	3D Printing for Biomedical Applications	Industrial Additive Manufacturing	Novel Techniques in Additive Manufacturing
12:20	Lunch Meet the Editor – Swee Leong Sing (ESAM)				
	Chairperson/s: Prof. Soh Gim Song	Chairperson/s: Prof. Xiaolong Wang	Chairperson/s: Dr. Ri Han	Chairperson/s: Dr. Ali Ghasemi	Chairperson/s: Dr. Ali Ghasemi
13:30	Metal Additive Manufacturing	Functional 3D Printing	3D Printing for Biomedical Applications	Industrial Additive Manufacturing	Novel Techniques in Additive Manufacturing
15:30	Tea Break (Exhibition & Poster viewing) Meet the Editor – Swee Leong Sing (MSAM)				
16:00	Metal Additive Manufacturing	Functional 3D Printing	3D Printing for Biomedical Applications	Industrial Additive Manufacturing	Novel Techniques in Additive Manufacturing
17:00	End of Day 3 Programme				

DETAILED PROGRAMME - BREAKOUT SESSIONS

Track 1 - 07 August 2025 (0900 - 1230) Metal Additive Manufacturing Chairs: Prof. John Pang	
09:00 - 09:20	Interpretable machine learning approach for exploring process-structure-property relationships in metal additive manufacturing (Invited) Xiaopeng Li, The University of New South Wales (UNSW Sydney)
09:20 - 09:40	In-Situ Additive Manufacturing of Graphene-Reinforced Metal Matrix Composites (Invited) Kaihao Zhang, The Hong Kong University of Science and Technology (Guangzhou)
09:40 - 10:00	Microstructure and enhanced wear and oxidation resistance of tungsten carbide reinforced Inconel 625 matrix coating using high-speed laser metal deposition (Invited) Jingjing Wang, Nanyang Technological University
10:00 - 10:20	Tungsten-inert gas welding performance of 304L stainless steel manufactured by laser powder bed fusion with wrought ones Hongbo Li, Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences
10:20 - 11:00	Tea break
11:00 - 11:15	Application of Hybrid Additive Manufacturing to Produce a Novel Adaptive Fixture for Railway Track Emergency Maintenance Yi Zhou, Nanyang Technological University
11:15 - 11:30	Challenges in Large-Scale Part Fabrication via Multi-Laser Powder Bed Fusion Di Wang, South China University of Technology
11:30 - 11:45	Effect of tantalum content on microstructure, mechanical properties and biocompatibility of titanium-tantalum alloy fabricated by laser powder bed fusion Gaoling Hu, South China University of Technology
11:45 - 12:00	Additive Manufacturing for Repairing and Remanufacturing of Metal Components Qiang Yang, Xi'an Jiaotong University
12:00 - 12:15	Research Progress on Additive Manufacturing of Magnesium Alloys Qingchen Deng, Shanghai Jiao Tong University
12:15 - 12:30	Experimental study on Magnetohydrodynamic driven liquid metal aluminum Drop-on-demand 3D printing Sheng-Wei Tian, Beihang University

Track 2 - 07 August 2025 (0900 - 1230) Functional 3D Printing Chairs: Prof. Changjin Huang	
09:00 - 09:20	Adaptive 3D Printing for Soft Electronics and Shape-Morphing Structures (Invited) Changjin Huang, Nanyang Technological University
09:20 - 09:40	In-flight jet experimental study of Aerosol Jet® Printing by means of Phase Doppler Anemometry (Invited) Eleonora Ferraris, KU Leuven
09:40 - 10:00	3D printed strain sensors with organohydrogel-based structural (Invited) Hui Ying Yang, Singapore University of Technology and Design

10:00 - 10:15	Tensile testing of thermoplastic composites printed by Fused Filament Fabrication - challenges, results, finite element modelling Jaroslav Majko, University of Žilina
10:15 - 10:30	Exceptional strength and ductility in heterogeneous multi-gradient TiAl alloys through additive manufacturing Xingdong Dan, The Hong Kong Polytechnic University
10:30 - 11:00	Tea break
11:00 - 11:20	Electro-Mechanical Textile via Digital Knitting (Invited) Hong Yee Low, Singapore University of Technology and Design
11:20 - 11:35	Solvent-Free Additive Manufacturing of Electrochromic Patterns via Aerodynamically Focused Nanoparticle (AFN) System Minseok Kim, Hanyang University
11:35 - 11:50	Biofabricated Multiorgan-on-a-Chip for Disease Modeling and Therapeutic Screening Jungbin Yoon, Pohang University of Science and Technology
11:50 - 12:10	Energy Absorption and Mechanics of Origami Metamaterials (Invited) Guoxing Lu, Zhejiang University
12:10 - 12:30	Selective Laser Melting Ultra-High Strength Maraging Steel: Process Optimization, Performance Enhancement and Precision Post-processing (Invited) Yuchao Bai, Harbin Institute of Technology

Track 3 - 07 August 2025 (0900 - 1220) 3D Printing for Biomedical Applications Chairs: Prof. Gopu Sriram	
09:00 - 09:20	3D Bioprinting, Artificial Intelligence & Microfluidic Strategies for Gum Health & Disease (Invited) Gopu Sriram, National University of Singapore
09:20 - 09:40	3D Bioprinting of Colorectal Organoid Models within Chemically Defined Peptide-Based Matrices for Therapeutic Applications and Disease Modeling (Invited) Charlotte A. E. Hauser, Graz University of Technology
09:40 - 10:00	Multiscale Composite Materials in Bone and Joint Diseases (Invited) Yiting Lei, The Chinese University of Hong Kong
10:00 - 10:20	Advanced Bioprinting Strategies for the Fabrication of Biomimetic Tissues and Organs (Invited) Wei Long Ng, Nanyang Technological University
10:20 - 11:00	Tea break
11:15 - 11:30	Engineered Hierarchical Porous Structures in SLS-Fabricated PLA/HA Scaffolds for Enhancing Capillary Force-Driven Hydrogel Infiltration in Bone Regeneration Xun Yuan, Hunan University
11:30 - 11:45	Design and High-Precision 3D Printing of Capillary-Confined Microfluidic Chips Xiaojiang Liu, Southeast University
11:45 - 12:00	TBD

12:00 – 12:15	3D Printed Self-folding Multi-Lumen Nerve Conduits for Neural Regeneration Renzhi Hu , Nanyang Technological University
12:15 – 12:35	3D printing applications in craniomaxillofacial surgery (Invited) Raymond Wong Chung Wen , National University of Singapore

Track 4 - 07 August 2025 (0900 – 1240) Industrial Additive Manufacturing Chairs: Dr. Sharon Nai	
09:00 – 09:20	Advancing Additive Manufacturing: A*STAR’s Innovation for Industry (Invited) Sharon Nai , Singapore Institute of Manufacturing Technology
09:20 – 09:40	Thermomechanical Behavior of Additively Manufactured Alloys Under Static and Impact Loads (Invited) Clodualdo Aranas Jr. , University of New Brunswick
09:40 – 10:00	Generative Construction of Toolpaths for Additive Manufacturing Driven by Principal Stress Lines (Invited) Yicha Zhang , Université Polytechnique Hauts-de-France
10:00 – 10:15	Implementation of TPMS-Structured Multi-Airflow Channels in High-Performance Brake Discs Shuai Zhang , Jiangsu Normal University
10:15 – 10:30	Additive manufacturing of lattice metamaterials with both load-bearing and vibration isolation Lei Yang , Huazhong University of Science and Technology
10:30 – 11:00	Tea break
11:00 – 11:15	Real-time quality control and intelligent decision making for additive manufacturing Can Zhou , Wuhan University of Science and Technology
11:15 – 11:30	Advanced Characterization of Additive Manufacturing Materials Using X-ray Nanodiffraction at the Taiwan Photon Source Ching-Yu Chiang , National Synchrotron Radiation
11:30 – 11:45	The role of oxygen in additively manufactured titanium alloys Zibin Chen , The Hong Kong Polytechnic University
11:45 – 12:00	Polyurethane Nanocoating for Improving the Mechanical Performance and Comfort of 3D-Printed Elastomeric Materials Xinshuo Li , Jiangsu Normal University
12:00 – 12:20	Nanoscale TiC reinforced titanium matrix composites fabricated via gas-liquid reaction additive manufacturing (Invited) Wenhou Wei , Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences

Track 5 - 07 August 2025 (0900 – 1230) Novel Techniques in Additive Manufacturing Chairs: Dr. Jia Min Lee	
09:00 – 09:15	Process, microstructure and properties of zinc fabricated by laser powder bed fusion additive manufacturing Zhi Dong , South China University of Technology
09:15 – 09:30	Electrochemical Additive Manufacturing of Metals: Advances, Challenges, and Applications Daniel Jee Seng Goh , Nanyang Technological University

09:30 – 09:45	Surface-Aware Robotic 3D Printing via real-time RGB-D Mapping and Semantic Segmentation Naresh Kumar Thanigaivel , Singapore University of Technology and Design
09:45 – 10:05	No More Guesswork: Predictive Control for Silicone Printing via Vision and Machine Learning (Invited) Pablo Valdivia y Alvarado , Singapore University of Technology and Design
10:05 – 10:20	Precise and Rapid Design and Manufacture of Low-Frequency Acoustic Absorption Metamaterials with Enhanced Coupling Characteristic Qingxuan Liang , Xi’an Jiaotong University
10:20 – 10:35	Self-Support Topology Optimization for Multi-axis Additive Manufacturing Incorporated with Curved Layer Slicing Jikai Liu , Shandong University
10:35 – 11:00	Tea break
11:00 – 11:15	Ultrafast Laser-Integrated Hybrid Additive Manufacturing of high-performance aluminum alloys: Achieving Superior Surface Integrity and Tailored Microstructure via In-situ Subtractive Processing Han Zhang , Nanjing University of Aeronautics and Astronautics
11:15 – 11:30	Investigating the Influence of Laser Remelting Strategy in Laser-Based Additive Manufacturing via In Situ Pyrometer Data and Machine Learning Rajesh Kumar Balaraman , Singapore University of Technology and Design
11:30 – 11:50	Pseudoelastic Response Prediction of NiTi TPMS Lattice Structures Using Deep Learning (Invited) Dermot Brabazon , Dublin City University
11:50 – 12:05	A material-agnostic and trustworthy meltpool states recognition based on in-situ acoustic emission monitoring in laser powder bed fusion Jiafeng Tang , Xi’an Jiaotong University
12:05 – 12:20	Improving Copper-Steel Interfacial Quality in Multi-material Laser Powder Bed Fusion via Process Parameter Optimization Xue Cao , University of Nottingham

Track 1 - 07 August 2025 (1330 – 1700) Metal Additive Manufacturing Chairs: Prof. Soh Gim Song	
13:30 – 13:50	WAAM Certification of a Non-Production Inconel 718 Spacer Sleeve (Invited) Soh Gim Song , Singapore University of Technology and Design
13:50 – 14:10	Metal Additive Manufacturing Process Monitoring and Defect Detection Based on Physics-Constrained Dictionary Learning (Invited) Yanglong Lu , The Hong Kong University of Science and Technology
14:10 – 14:30	Laser powder bed fusion of oxide dispersion strengthened copper for sub-100micron component fabrication (Invited) Xu Song , The Chinese University of Hong Kong
14:30 – 14:45	Post-Deposition Forging and Effect to Mechanical Properties of Wire Arc Additive Manufactured High Speed Low Carbon Alloy (HSLA) Ahmad Baharuddin Abdullah , Universiti Sains Malaysia
14:45 – 15:00	Heterostructured AlCoCrFeNi2.1 high entropy alloy with simultaneously improved strength and ductility via laser powder bed fusion Yuang Dong , Huazhong University of Science and Technology

15:00 – 15:15	Enhanced manufacturing quality and mechanical performance of laser additive manufactured TiC/AZ91D magnesium matrix composites Lixia Xi , Nanjing University of Aeronautics and Astronautics
15:15 – 15:30	Evaluation of machine learning methodology for predicting fatigue model data for metal additive manufacturing materials Jason Jiaping Ng , Nanyang Technological University
15:30 – 16:00	Tea break
16:00 – 16:20	Laser-arc hybrid additive manufacturing of lightweight alloys (Invited) Danlei Zhao , Dalian University of Technology
16:20 – 16:40	Defect prediction with multi-sensor monitoring in laser-directed energy deposition (Invited) Haiying Wei , Hunan University
16:40 – 17:00	Evolution and cracking inhibition of liquid film in laser cladding of non-weldable nickel-based superalloy (Invited) Zhenlin Zhang , Southwest Jiaotong University

Track 2 - 07 August 2025 (1330 – 1700) Functional 3D Printing Chairs: Prof. Xiaolong Wang	
13:30 – 13:50	Two-photon polymerization-fabricated scaffolds: precise tools for regulating cell morphology and differentiation (Invited) Hongyu Zheng , Shandong University of Technology
13:50 – 14:10	3D printed scaffolds with hierarchical biomimetic structure for bone defect repair (Invited) Wei Zhang , Chinese Academy of Sciences
14:10 – 14:30	Vat Photopolymerization 3D Printing of Self-Lubricating Polymer Composites (Invited) Xiaolong Wang , Chinese Academy of Sciences
14:30 – 14:45	Strategies for High-Quality 3d-Printed Elastomers Xiang Lin , University of Science and Technology Beijing
14:45 – 15:00	3D Printing Fungus-like Adhesive Materials Stylianios Dritsas , Singapore University of Technology and Design
15:00 – 15:20	Personalized AI-Driven Design and Precision Manufacturing of 3D Bio-Implants (Invited) Feng Chen , Hunan University
15:20 – 16:00	Tea break
16:00 – 16:15	The Influence of Rice Husk Biochar Particle Size on Printability, Performance and Sustainability of 3D Concrete Printing Jihye Jhun , Nanyang Technological University
16:15 – 16:30	Fabrication and Characterization of Microelectrode Arrays via Aerosol Jet Printed Gold Micro-Pillars Zibin Nian , Nanyang Technological University
16:30 – 16:45	Effect of Simultaneous CO2 & Steam Curing on the Buildability of 3D Concrete Printed Structures Sean Gip Lim , Nanyang Technological University
16:45 – 17:00	3D printed dual network cross linked hydrogel electrolyte for wearable strain sensors and supercapacitors Chen Lei , Shandong University of Technology

Track 3 - 07 August 2025 (1330 – 1700) 3D Printing for Biomedical Applications Chairs: Dr. Ri Han	
13:30 – 13:50	The Human Bone 3D Printer and Printing Technology (Invited) Eric Luis , Beijing Tsinghua Changgung Hospital
13:50 – 14:10	Nature-Inspired Diatom Biosilica for 3D Printed Bioresorbable Scaffolds via Improving Mechanical Stability and Enabling Drug Delivery for Bone Tissue Engineering (Invited) Ri Han , National University of Singapore
14:10 – 14:25	Acoustic levitation for omnidirectional and multi-material in situ printing Hongyi Chen , University College London
14:25 – 14:40	3D Printing of Bioelectronic Components for Tissue Engineering Xinchao Gao , Nanyang Technological University
14:40 – 14:55	3D-printable poly(vinyl alcohol) for sacrificial molding in biomimetic matrices Joseph Zhi Wei Lee , Singapore University of Technology and Design
14:55 – 15:10	Predictive Finite Element Analysis of TPMS PCL Scaffolds for Biomedical Applications Yuehua Li , National University of Singapore
15:10 – 15:25	Combinatory Aerosol Jet and Digital Light Processing Printing for Advanced Bioelectronic Applications Ernest Cheah , Nanyang Technological University
15:25 – 16:00	Tea break
16:00 – 16:15	Isogeometric Topology Optimization for Nonlinearities in 4D Printing Design Xinqing Li , South China University of Technology
16:15 – 16:30	Deep learning for self-calibrated bioprinting Xi Huang , Nanyang Technological University

Track 4 - 07 August 2025 (1330 – 1800) Industrial Additive Manufacturing Chairs: Dr. Ali Ghasemi	
13:30 – 13:45	Development of a 3D-Printable Compact Static Mixer for In-Situ Silicone 3D Printing and Validation via Mechanical Testing Thileepan Stalin , Singapore University of Technology and Design
13:45 – 14:00	Generative Deep Learning Framework for Tailored NiTi TPMS Lattice Architectures Mehran Bahramyan , Dublin City University
14:00 – 14:15	3D concrete printing with coarse aggregate: a study of mechanical properties and CO2 uptake Suvash Ghandra Paul , Nanyang Technological University
14:15 – 14:30	Machine learning-driven simultaneous optimisation of support structures and process parameters in additive manufacturing Yang Mo , National University of Singapore
14:30 – 14:45	Laser additive manufacturing of a novel NiTi thin-walled metamaterial for improving manufacturability and mechanical protection Jianfeng Sun , Nanjing University of Aeronautics and Astronautics

14:45 – 15:00	Crack Control in Laser Powder Bed Fusion of Nickel-Based Superalloy Hastelloy X: Optimization of Scanning Strategies and Nano-Modification Jingjia Sun , Nanjing University of Aeronautics and Astronautics
15:00 – 15:15	Acoustic levitation for omnidirectional and multi-material in situ printing Hongyi Chen , University College London
15:15 – 15:30	An innovative liquid-induced healing process for defect elimination and performance enhancement in additively manufactured nickel-based superalloy Zhifang Shi , Southern University of Science and Technology
15:30 – 16:00	Tea break
16:00 – 16:15	Influence of in-situ rolling strategies of Ti-6Al-4V in directed energy deposition Xinni Tian , Monash University
16:15 – 16:35	Electrospinning Mass Production of Functional Flexible Nanofibrous Membrane Shufan Li , Xiamen University of Technology
16:30 – 16:45	TBD
16:45 – 17:00	TBD

Track 5 - 07 August 2025 (1330 – 1700) Novel Techniques in Additive Manufacturing Chairs: Dr. Swee Leong Sing	
13:30 – 13:50	TBD
13:50 – 14:10	Engineering Conductive PEDOT:PSS Inks for Bioelectronics (Invited) Jia Min Lee , Nanyang Technological University
14:10 – 14:25	Toughening mechanisms of bioinspired dual-phase mechanical metamaterials by additive manufacturing Sha Yin , Beihang University
14:25 – 14:40	Acoustic-based dripping anomaly detection in wire laser-directed energy deposition Yuxian Xie , National University of Singapore
14:40 – 14:55	A Generic Calibration Method for Volumetric Heat Source Models in Additive Manufacturing Xiaofeng Hu , Monash University
14:55 – 15:10	A hybrid machine learning model for predicting residual stress and optimising process parameters in directed energy deposition Joachim Eng , Monash University
15:10 – 15:25	Interaction of surface roughness and subsurface defects in laser powder bed fusion parts for fatigue life prediction Ninian Sing Kok Ho , Nanyang Technological University
15:25 – 16:00	Tea break
16:00 – 16:15	Embedding Lifecycle Intelligence in Additive Manufacturing: Multidisciplinary Optimization for Sustainable Design-to-Manufacturing Iñigo Flores Ituarte , Tampere University

16:15 – 16:30	TBD
16:30 – 16:45	TBD
16:45 – 17:00	TBD

PLENARY SPEAKERS



Dr Ho Chaw Sing

National Additive Manufacturing Innovation Cluster (NAMIC)

Chaw Sing is the CEO of NAMIC, a Singapore government platform he co-founded that focuses on translational research to develop and scale industrial adoption of digital additive manufacturing technologies.

Before joining the public sector, he spent 16 years in the private sector. He was Head of Innovation and Strategic Partnerships at HP Singapore, Printing and Personal Systems Group and the Global Head for Consumer Inkjet Supplies Business Operations, overseeing manufacturing supply chain operations and product innovation. He began his career in the semiconductor foundry industry with Chartered Semiconductor Manufacturing (now part of GlobalFoundries), in various customer-facing technology and engineering operation leadership roles. Chaw Sing is active in the deep-tech startup scene and global AM community. He co-chairs the ISO/TC 261 Additive Manufacturing Chair



Professor Zhou Kun

Nanyang Technological University, Singapore

Prof. Zhou is a Professor of Mechanical Engineering in the School of Mechanical and Aerospace Engineering at Nanyang Technological University, Singapore. He currently serves as Associate Chair (Research) in the school and Programme Director (Marine & Offshore) in Singapore Centre for 3D Printing. He received his B.Eng. and M.Eng. degrees from Tsinghua University, China and his Ph.D. from Nanyang Technological University. He was a postdoctoral researcher at Northwestern University, USA and a visiting scholar at Harvard University, USA.

Prof. Zhou has been conducting multidisciplinary research at the crossroads of mechanics, additive manufacturing, materials science, and molecular physics. He was elected Fellow of European Academy of Sciences as well as Fellow of American Physical Society, Institute of Physics (UK), Institution of Mechanical Engineers (UK), Royal Aeronautical Society (UK), Royal Society of Chemistry (UK), and Institute of Materials, Minerals & Mining (UK).

Prof. Zhou has authored more than 500 journal articles and two books "Metal Powder



Professor David William ROSEN

Georgia Institute of Technology, United States of America

David Rosen is a Professor in the School of Mechanical Engineering at the Georgia Institute of Technology, where he is Director of the Rapid Prototyping & Manufacturing Institute. Additionally, he is the Research Director of the Digital Manufacturing & Design Centre at the Singapore University of Technology & Design. He received his Ph.D. at the University of Massachusetts in mechanical engineering.

His research interests include computer-aided design, additive manufacturing (AM), and design methodology. Most of his research is focused on design for additive manufacturing, including conceptual design methods, design methods for part-material-process problems, and topology optimization methods. He is a Fellow of ASME and has served on the ASME Computers and Information in Engineering Division Executive Committee.

In the standards community, he chairs the ASTM F42 subcommittee on design for additive manufacturing. He is the recipient of the 2013 Solid Freeform Fabrication Symposium, International Freeform and Additive Manufacturing Excellence (FAME) Award and is a co-author of a leading textbook on AM.



Dr Mohsen Seifi

ASTM International, Washington DC

Dr. Mohsen Seifi serves as the Vice President of Global Advanced Manufacturing Programs at ASTM International based in Washington, DC, a role he has held since May 2022. He joined ASTM in September 2016 as Director of Additive Manufacturing Programs and has since demonstrated exceptional leadership and technical expertise. With over 15 years of experience in advanced manufacturing, materials engineering, and business development, he has been at the forefront of innovation in these fields.

In his current role, he oversees critical initiatives in Additive Manufacturing, Robotics & Autonomous Systems, and Wohlers Associates, directing a diverse team of experts to drive ASTM



Prof Shoufeng Yang

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

Yang Shoufeng received his Bachelor's degree in Mechanical Engineering from Tsinghua University in 1994 and his Ph.D. in Materials Science from Tsinghua University in 1999. From 1999 to 2000, he conducted postdoctoral research at Nanyang Technological University in Singapore. From 2000 to 2010, he served as a Senior Lecturer at Queen Mary University of London. From 2010 to 2023, he held the position of Chair Professor at the University of Southampton in the UK and KU Leuven in Belgium.

He has long been engaged in research on additive manufacturing and has pioneered new directions in the field of multi-material additive manufacturing, achieving numerous innovative results. He proposed and established the multi-frequency ultrasonic control theory for precise flow of trace powders, invented a series of Mandala micro-nozzle powder spreading technologies, and developed a novel additive manufacturing technique called "Simultaneous Mould/Part Fabrication." He has led over 40 research projects, including those funded by the EU H2020, UK EPSRC, and the Belgian National Science Foundation. He has published over 200 academic papers with more than 16,000 total citations and holds four international invention patents. He serves on the editorial boards of eight SCI-indexed international journals and is a review expert for science funding agencies in 11 countries, including the UK and the US. He has been recognized among the world's top 2% scientists in both lifetime scientific impact and annual scientific impact.

INVITED SPEAKERS

A

Professor Ahmad Baharuddin Abdullah, Universiti Sains Malaysia
Dr Aleksandr Ovsianikov, Technische Universität Wien
Dr Ali Ghasemi, National University of Singapore
Mr Andy Lu, ASTM International
Dr Asuka Suzuki, Nagoya University

C

Professor Changjin Huang, Nanyang Technological University
Professor Changjun Han, South China University of Technology
Professor Changquan Lai, Nanyang Technological University
Professor Charlotte A. E. Hauser, Graz University of Technology
Professor Chengguo Liu, Nanjing Forestry
Dr Ching-Yu Chiang, National Synchrotron Radiation
Professor Clodualdo Aranas Jr., University of New Brunswick

D

Professor Dafan Du, Shanghai Jiao Tong University
Professor Danlei Zhao, Dalian University of Technology
Professor Dawn Tan, Singapore University of Technology and Design
Dr Dermot Brabazon, Dublin City University
Professor Di Wang, South China University of Technology
Professor Dongfeng Qi, Shandong University

E

Professor Eleonora Ferraris, KU Leuven
Dr Eric Luis, Beijing Tsinghua Changgung Hospital

F

Professor Feng Chen, Hunan University
Professor Fulin Jiang, Hunan University

G

Dr Gopu Sriram, National University of Singapore
Professor Guanghai Fei, Zhongda Hospital, Southeast University
Dr Guglielmo Vastola, Institute of High Performance Computing
Dr Guo Dong Goh, Nanyang Technological University
Dr Guo Liang Goh, Nanyang Technological University
Professor Guoxin Fang, The Chinese University of Hong Kong
Professor Guoxing Lu, Zhejiang University

H

Professor Hae-Jin Choi, Chung-Ang University
Professor Haiying Wei, Hunan University
Dr Han Zhang, Nanjing University of Aeronautics and Astronautics
Professor Hao Wang, National University of Singapore
Professor Hesheng Xia, Sichuan University
Professor Hong Yee Low, Singapore University of Technology and Design
Professor Hongbo Li, Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences
Dr Hongtao Wang, Singapore University of Technology and Design
Dr Hongwei Gao, Singapore University of Technology and Design
Dr Hongyi Chen, University College London
Professor Hongyu Zheng, Shandong University of Technology
Professor Howon Lee, Seoul National University
Professor Hui Ying Yang, Singapore University of Technology and Design

I

Dr Im Doo Jung, Ulsan National Institute of Science and Technology
Professor Immanuel Koh Chee Beng, Singapore University of Technology and Design
Professor Iñigo Flores Ituarte, Tampere University

J

Dr Jaroslav Majko, University of Žilina
Professor Ji Tae Kim, Korea Advanced Institute of Science and Technology
Dr Jia An, Singapore University of Technology and Design
Professor Jie Tao, Army Medical University
Professor Jieping Wang, Hangzhou Institute for Advanced Study
Professor Jikai Liu, Shandong University
Dr Jingjing Wang, Nanyang Technological University
Professor John Hock Lye Pang, Nanyang Technological University
Dr Joon Phil Choi, Korea Institute of Machinery & Materials

K

Dr Kaihao Zhang, The Hong Kong University of Science and Technology (Guangzhou)

L

Professor Laurence Meagher, Monash University
Professor Lay Poh Tan, Nanyang Technological University
Professor Lechun Xie, Wuhan University of Technology
Dr Lei Yang, Huazhong University of Science and Technology
Dr Liren Wang, Shanghai Sixth People's Hospital
Mr Lisheng Sun, Southeast University
Dr Lixia Xi, Nanjing University of Aeronautics and Astronautics

M

Professor Maling Gou, West China Hospital
Dr Mehdi Jafary Zadeh, Institute of High-Performance Computing
Dr Miao Zhao, University of Electronic Science and Technology of China
Dr Michinao Hashimoto, Singapore University of Technology and Design
Professor Mika Salmi, Aalto University
Professor Ming Jen Tan, Nanyang Technological University
Dr Mingyang Li, Nanyang Technological University

N

Dr Namhun Kim, Ulsan National Institute of Science and Technology

P

Professor Pablo Valdivia y Alvarado, Singapore University of Technology and Design
Dr Pan Wang, Singapore Institute of Manufacturing Technology
Professor Pei-Chen Su, Nanyang Technological University
Dr Peifeng Li, University of Glasgow
Professor Peng Wen Tsinghua University

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Professor Qiang Yang, Xi'an Jiaotong University
Dr Qingchen Deng, Shanghai Jiao Tong University
Professor Qingcheng Yang, Shanghai University
Professor Qingxuan Liang, Xi'an Jiaotong University
Dr Qiu Hao, Guangzhou Academy of Sciences
Professor Quanquan Han, Shandong University

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Ms Ran An, Nanyang Technological University
Dr Raviduth Ramful, University of Mauritius
Dr Ri Han, National University of Singapore
Mr Ruiqi Wang, Nanjing University of Aeronautics and Astronautics
Professor Runsheng Li, Hong Kong Polytechnic University

S

Professor Seung Ki Moon, Nanyang Technological University
Professor Seunghwa Ryu, Korea Advanced Institute of Science and Technology
Dr Sha Yin, Beihang University
Dr Sharon Nai, Singapore Institute of Manufacturing Technology
Professor Shasha Liu, Shanghai Ninth People's Hospital
Dr Shenping Zhong, Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences
Dr Shihua Wang, National Metrology Centre
Dr Shuai Li, FastForm 美光速造
Dr Shufan Li, Xiamen University of Technology
Professor Shuhao Wang, Wuhan University of Science and Technology
Dr Soh Gim Song, Singapore University of Technology and Design
Professor Stylianos Dritsas, Singapore University of Technology and Design
Professor Suk-Hee Park, Pusan National University

T

Professor U-Xuan Tan, Upscaling of 3D Printing (Invited)
Mr Tao Li, Hospital Affiliated to Shanghai Jiao Tong University
Professor Teck Neng Wong, Nanyang Technological University
Professor Tegoeh Tjahjowidodo, KU Leuven
Mr Tiankun Liu, Institute of Zoology, Chinese Academy of Sciences

W
Dr Wang Chen, Singapore Institute of Manufacturing Technology
Professor Wei Long Ng, Nanyang Technological University
Professor Wei Zhai, National University of Singapore
Dr Wei Zhang, Chinese Academy of Sciences
Professor Wei Zhu, Hunan University
Dr Wenhui Yu, Shandong University of Technology
Professor Wonjoon Choi, Korea University

X
Mr Xiang Lin, University of Science and Technology Beijing
Professor Xiaojiang Liu, Southeast University
Professor Xiaolong Wang, Chinese Academy of Sciences
Dr Xiaopeng Li, The University of New South Wales (UNSW Sydney)
Dr Xuyang Chen, Institute of Engineering Thermophysics, Chinese Academy of Science

Y
Dr Yanhan Liew, Singapore Institute of Manufacturing Technology
Professor Yaoyao Fiona Zhao, McGill University
Dr Yi Cai, The Hong Kong University of Science and Technology (Guangzhou)
Professor Yi Xiong, University of Science and Technology
Professor Yi Zhang, University of Electronic Science and Technology of China
Professor Yicha Zhang, Université Polytechnique Hauts-de-France.
Professor Ying Chun Guan, Beihang University
Dr Yiting Lei, The Chinese University of Hong Kong
Dr Yong Xu, Shanghai Pulmonary Hospital
Professor Yongling Wu, Shandong University of Technology
Professor Yongqiang Hao, Shanghai Ninth People's Hospital
Dr Youqing Sun, Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences
Professor Yuchao Bai, Harbin Institute of Technology
Dr Yuman Zhu, Monash University
Dr Yunlong Tang, Monash University

Z
Dr Zhili Dong, Nanyang Technological University
Professor Zhiyuan Liu, Shenzhen University

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ABSTRACT

A Hamiltonian toolpath planning approach for processing of multi-void geometries in the Directed Energy Deposition Process

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Abstract

Toolpath planning is crucial in the effective implementation of the Directed Energy Deposition (DED) process and for ensuring the quality of the final product. This aspect assumes even higher importance during the fabrications of multi-void geometries (like components with conformal channels or components with multiple parallel tracks). Frequent start-and-stops during material deposition of these geometries add extra printing time and excess material build-up at the endpoints. Adopting continuous toolpaths is crucial for optimizing the process and minimizing these undesirable outcomes. However, conventional toolpath strategies exhibit limitations in generating continuous paths for multi-void components, where feature sizes may be comparable to the deposited bead dimensions. Using a Depth First Search (DFS) algorithm, this study presents a Hamiltonian path planning approach to address these issues. As the number of solutions and enumeration time increases with the grid size, a screening process utilizing path symmetry and turn count is implemented to reduce the search space. A new parameter called distance-of-separation was developed to assess the spatial heat distribution within the deposition zone. Subsequently, a comparative analysis of the thermal field distributions for various toolpaths was performed using Simufact analysis software. The algorithm was modified afterwards to handle more complex geometries. The successful implementation of these modifications was validated through the processing of parts with curved features. This study provides a methodology for identifying Hamiltonian paths within a specified grid, leading to improved deposition stability and, consequently, parts with lower defect densities and enhanced mechanical properties.

Formulation of a starch-based protein fortified three-dimensional construct utilizing different post-processing methods

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Abstract

Three-dimensional food printing, a rapidly emerging technology combines additive manufacturing practices with food industry for the purpose of creation of 3D designs layer by layer that are highly customizable both in terms of nutrition and visual appearance. Our previous works have detailed formulating fresh and frozen vegetable printable inks (formulations) suitable for dysphagia patients as well as facilitating alternative proteins acceptable for consumption through 3D printed designs. Presently, most of the research work is focused on the development of printable food formulations, processes and printer development. There are a few studies highlighting the effects of post-treatment techniques (post-processing) affecting the shape, stability and quality of the 3D-printed models. In this work, we aim to look more into the details of various post-processing techniques on the stability and texture of 3D printed constructs. A vegetarian friendly rice (starch) and lentil (protein) flour construct was created by formulating different inks and testing their printability using an extrusion-based 3D printer. Based on preliminary experiments, three inks were chosen for further testing. Four common post-processing techniques were employed, namely oven drying, steaming, microwaving and air-frying to compare the differences between the 3D-printed constructs. The selected inks were all shear thinning and had adequate yield stress to hold their shape on extrusion. The 3D constructs were analysed for their weight and dimensional properties, upon printing, freezing and post processing to determine the structural stability. Syneresis, drying rate, microstructural and texture profile analysis experiments were also conducted on the ink formulations. This work highlights the creation of a starch-based protein enriched formulations that can be 3D printed and processed into healthy vegetarian snacks using different post-processing methods. Sensory testing needs to be conducted in future to determine the taste and palatability to the consumers.

Post-Deposition Forging and Effect to Mechanical Properties of Wire Arc Additive Manufactured High Speed Low Carbon Alloy (HSLA) Steel

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Abstract

Direct energy deposition (DED) is one of the metals based additive manufacturing, where the metals are melted and deposited layer by layer at room temperature to produce 3D profile. Caused by the heat, properties of the deposited bead are affected. Pre-deposition controlled measure is the most effective approach by optimizing the heat input, however other option, which is post-controlled also can be done including heat treatment and work hardening. In this research, forging process is exploited at different process and design parameters to observe the effect on the properties including the tensile, hardness, tribological and impact toughness. The parameters to be studied are outlined using design of experiment and the specimens were prepared using custom-made MIG based additive manufacturing machine. The result depicted that the tensile, hardness properties are improved, while the impact toughness shows a decrement. The reduces is suspected due to crack at the inter-layer joint between layers worsen as the result of compression. In the future, further exploration on the other defects like porosity will be studied. Further analysis on inter-layer joint by shearing test is also on-going research.

No More Guesswork: Predictive Control for Silicone Printing via Vision and Machine Learning

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Abstract

3D printing RTV Silicones is challenging due to their unpredictable change in viscosity over time and dynamic flow behaviour, hindering the print quality and results in print failure. Manual tuning of print parameters is inefficient and inconsistent. This work presents a method combining in-situ vision-based line width monitoring and flow rate data collection with offline machine learning to predict optimal settings, enabling reliable RTV silicone printing with improved fidelity and reduced trial-and-error.

A fixed front camera was used to analyze the motion of extruded material. To estimate the flow rate, a contour tracking based time-distance analysis method was used. For data collection, various needle diameters, pressures, different combinations of material with thixotropic concentrations were used to study the extrusion dynamics in three distinct time zones with an interval of 30 minutes. The estimated flow rate results were cross validated by comparing the actual mass of the extruded material, showing agreement within a 10% margin of error.

Complementing this, a fixed top camera-based system uses image processing algorithms to measure the printed line widths for various print parameters. Measured widths for different process parameters were compiled into a dataset of 5,184 and utilized to train the predictive model. The camera-based width measurement was cross-validated against microscopebased line measurement with error margin of $\pm 100 \mu\text{m}$.

The predictive model accepts inputs such as desired needle diameters, material composition, and total print time to recommend optimal print settings that achieve the targeted quality. By learning from historical width measurements, the model generalizes the nonlinear relationship between extrusion behavior and print parameters.

An integrated monitoring system leveraging machine learning and vision-based sensing enables real-time data collection and dynamic adjustment of 3D printing parameters, transitioning from trial-and-error to a data-driven approach, thereby enhancing print quality and reducing failures.

Laser-Based High-Definition 3D Printing and Bioprinting– upscaling and addressing industrial applications

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Austrian Cluster for Tissue Regeneration (<https://www.tissue-regeneration.at>)

Abstract

Additive manufacturing technologies, often referred to as 3D printing, open exciting perspectives for biomedical applications and tissue engineering. Among the myriad of possible approaches multiphoton lithography (MPL) stands out as a technique enabling true 3D structuring with spatial resolution unmatched by other additive manufacturing technologies [1].

MPL relies on the nonlinear absorption of femtosecond laser pulses to induce photochemical processes, not necessarily limited to photopolymerization alone. An increasing portfolio of available materials enables utilization of the versatile capabilities of MPL, from producing complex volumetric 3D structures by means of cross-linking, to creating void patterns within hydrogels already containing living cells, via photocleavage. Among other things, high resolution of MPL recently enabled realization of a novel tissue engineering approach, employing scaffolded spheroids for bottom up assembly of tissue constructs with high initial cell density [2-3]. Our recent breakthroughs on the material development side enabled the use of MPL for direct fabrication of cell-containing constructs, giving rise to High-Definition Bioprinting [4-5].

Recent advances in system and material development allow to substantially increase the throughput of MPL, making this technology highly relevant for industrial applications. In this contribution, the recent progress in this area will be discussed. The presentation is supported by numerous examples.

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Leveraging Additive Manufacturing for Lightweight, Thermally Efficient Battery Casings in Electric Vehicles

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Abstract

The growing demand for high-performance electric vehicles (EVs) necessitates innovative solutions for battery pack design, particularly in enhancing thermal management while maintaining lightweight structures. This talk explores how laser powder bed fusion (LPBF), a leading additive manufacturing (AM) technology, enables the production of complex battery casing architectures that not only secure battery cells but also function as passive heat sinks—eliminating the need for active cooling systems such as air fans or liquid circulation.

Given the intricate geometries required, conventional manufacturing methods struggle to produce these casings efficiently. LPBF overcomes this limitation, offering unparalleled design freedom with minimal constraints beyond the designer's imagination. However, achieving high-performance aluminum (Al) and Al alloys (AlSi12, AlSi10Mg)—materials prized for their high specific thermal conductivity—requires overcoming challenges related to powder selection, oxidation, and process optimization.

This talk will systematically address these key challenges:

- Part I: Optimization of powder particle size by fabricating test coupons from various nominal powders to determine printability and defect formation.
- Part II: Investigation of in-situ oxidation during the LPBF process and optimization of process parameters to achieve high-density, low-oxygen-content parts.
- Part III: Measurement of thermal conductivity in LPBF-processed alloys to ensure properties comparable to conventionally manufactured counterparts.
- Part IV: Exploration of graphene incorporation into Al alloys to enhance thermal conductivity further.

By bridging advanced material design with AM capabilities, this research paves the way for next-generation EV battery casings that are lightweight, thermally efficient, and manufacturable at scale—offering a transformative impact on the automotive industry.

Addressing the Present and Future Research Gaps in Build Orientation Effects on Fatigue Properties of PBF-LB/M Components

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Abstract

Additive manufacturing (AM), specifically laser-based powder bed fusion (PBF-LB), has revolutionized metal component fabrication, offering design flexibility and material efficiency. However, the mechanical performance of AM parts, particularly their fatigue behaviour, remains a critical concern for qualification and certification in all industries. Fatigue strength is influenced by multiple process parameters, with build orientation emerging as a key variable due to its impact on surface and subsurface defects. Though industry has adopted standardized fatigue test methods such as ASTM E466 and E606, these standards do not account for the unique characteristics of AM. Hence, additional research is required to understand how unique aspects of AM, such as build orientation, influence the final mechanical properties of AM parts.

This review examines the current landscape of fatigue testing for metal PBF-LB parts, focusing on the effects of build orientation on fatigue performance. Studies typically evaluate fatigue properties across three standard build orientations—horizontal (0°), diagonal (45°), and vertical (90°)—highlighting trends in defect formation, microstructural variations, and fatigue failure mechanisms. While many studies suggest vertical orientation yields the best fatigue strength, emerging research indicates that the relations in the intermediate overhang angles are non-linear, emphasizing the need for further investigation for a comprehensive understanding of fatigue behaviour in metal AM parts.

Additionally, inconsistencies in test methodologies, such as support structure configurations and surface finishing processes, introduce variability in reported fatigue properties. Results from a preliminary study involving samples fabricated with intermediate overhang angles will also be discussed. To enhance standardization and qualification efforts, future research should prioritize systematic evaluations across a broader range of build orientations and adopt rigorous process reporting practices. Addressing these gaps is essential for developing comprehensive fatigue design allowables for AM components, ensuring their reliable application in safety-critical industries.

Dynamic mechanical properties and its mechanisms of fcc-type medium entropy alloys

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Abstract

Future critical engineering, such as landing gear and armor protection, requires structural materials withstanding instantaneous plastic deformation and high strength. Nanoprecipitate-strengthened high-entropy alloys (NS-HEAs) are considered as promising candidates for structural applications due to their high strengths and high ductility. At present, research on the NS-HEAs has mainly focused on quasi-static mechanical behavior. However, there is still little information concerning the dynamic loading behavior of these NS-HEAs under very high strain rates exceeding 10^3 s^{-1} and even exceeding 10^5 s^{-1} . In this work, we prepared a FeCoNiAlTi-type NS-HEA with a high-volume fraction of coherent and ordered $L1_2$ nanoprecipitates, and investigated the dynamic deformation behavior by multiscale characterization and molecular dynamics simulation. The results show that the designed alloy exhibits superior strength and damage resistance than other traditional alloys at very high strain rates by incorporating the ductile L12 nanoprecipitates. At high strain rates, additional and rare deformation mechanisms that are difficult to occur in such Fe-Co-Ni-Al-Ti HEA system, namely twinning and amorphization, appear in the NS-HEAs, contributing to the improvement of dynamic mechanical properties. In particular, it is important to note that the coherent nanoprecipitates can not only act as dislocation barriers during high-speed impact, but also serve as energy-absorbing islands, enabling the material to sustain high strength without sustaining damage, which is the main reason for its excellent impact resistance.

Design of cellular-structured heat sink for additive manufacturing based on Voronoi tessellation and machine learning

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Abstract

Additive manufacturing can intentionally control the cellular structures of architected materials. The cellular structures have a high specific surface area and can be applied to heat sinks. Therefore, it is important to construct a design methodology for optimizing the cellular structures of heat sinks. In this study, we propose a novel methodology to optimize the cellular structures based on the Voronoi tessellation and machine learning. The Voronoi tessellation divides a three-dimensional space by arranging seed points and drawing the perpendicular bisecting planes between the adjacent seed points. The strut-based cellular structures can be designed by replacing the edges of bisecting planes with struts. The advantage of this method is that diverse cellular structures can be designed by changing the number and coordinates of seed points. Therefore, machine learning is utilized to correlate the number and coordinates of seed points and strut radius with the properties of cellular structures. The machine learning model is inversely analyzed by optimization algorithms to optimize the number and coordinates of seed points and strut radius, obtaining the corresponding cellular structures. In this study, eight hundred cellular structures were designed by fixing the number of seed points at nine and randomly changing the coordinates of nine seed points and strut radius. The heat transfer properties of the cellular structures were evaluated by computational fluid dynamics (CFD). The data was used for constructing a neural network (NN) model that predicts the heat transfer properties from the coordinates of seed points and strut radius. The NN model was inversely analyzed by a genetic algorithm to optimize the cellular structure. The optimized cellular structures were validated by CFD and experiments using additively manufactured cellular structures. The reason why the optimized structure exhibits a superior property will be discussed in the presentation.

Impact of Scan Strategy and Beam Diameter on the Porosity of ASTM A131 EH36 Fabricated via Laser Powder Bed Fusion

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Abstract

Laser powder bed fusion (LPBF) holds significant potential for manufacturing intricate metallic components for marine and offshore applications, where high-strength low-alloy steels, such as ASTM A131 EH36, are widely used. This study aimed to optimize LPBF processing parameters to fabricate high-density EH36 coupons. A design of experiments (DoE) approach was used to optimize laser power, scan speed, hatch spacing, and scan strategy, achieving a relative density of 99.9%, as determined by Archimedes' method. Despite this high density, periodic porosity within planar layers compromised elongation during tensile testing. Scanning electron microscopy analysis of fracture surfaces highlighted large pores as stress concentrators, causing early failure. Subsequent analysis pinpointed laser scanning strategy, laser delay, and beam diameter as key factors influencing porosity. By implementing a larger beam diameter, periodic defects were eliminated, significantly improving the consistency of mechanical properties. Additionally, elevated surface silica levels were found to increase melt viscosity, exacerbating keyhole porosity formation. High melt turbidity at scan track ends further promoted porosity, accounting for its regular occurrence. These results underscore that, alongside laser power, scan speed, and hatch spacing, scan strategy and beam diameter critically influence defect mitigation in EH36 steel fabricated by LPBF. This optimized approach enhances the production of mechanically sound components, offering valuable insights for advancing additive manufacturing in marine and offshore industries.

Laser Powder Bed Fusion of Pure Copper Using Green Laser

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Abstract

Additive manufacturing of pure copper using the laser-based powder bed fusion (LPBF) process with a near-infrared (NIR) laser ($\lambda \approx 1070 \text{ nm}$) presents significant challenges due to copper's high reflectivity and thermal conductivity. These properties make it difficult to achieve high-density parts. To address this challenge and to harness the exceptional properties of copper for industrial applications, this study employs a green laser with a wavelength of 515 nm for the processing of pure copper. Pure copper components were successfully fabricated through LPBF using a green disk laser, and the mechanical properties of the resulting parts were comprehensively evaluated. Post-deposition, porosity analysis was conducted using micro-CT and optical imaging to assess both macro and micro-scale porosity. The maximum observed porosity was 0.2%, indicating that parts with densities of up to 99.8% can be achieved using the green laser process. Residual stress measurements along the build direction were performed using X-ray diffraction (XRD) at both the surface and 50 μm below the surface. These measurements revealed tensile residual stresses, with magnitudes of $80 \pm 5 \text{ MPa}$ at the surface and $180 \pm 8 \text{ MPa}$ at 50 μm depth. Further microstructural analysis was carried out via scanning electron microscopy (SEM) and XRD phase analysis, revealing a columnar microstructure composed of single-phase alpha copper. To evaluate the mechanical properties, Vickers microhardness testing was used to map hardness across the surface, showing a uniform hardness value of $75 \pm 6 \text{ HV0.05}$. Tensile testing along the build direction revealed a yield strength of $160 \pm 5 \text{ MPa}$, an ultimate tensile strength of $215 \pm 3 \text{ MPa}$, and a good ductility of $60 \pm 3\%$. These findings confirm that the green laser-based LPBF process is capable of producing high-density, high-performance copper components with excellent mechanical properties, suitable for a range of industrial applications.

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Real-time quality control and intelligent decision making for additive manufacturing

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Abstract

Additive Manufacturing (AM) technology stands as one of the most promising techniques in manufacturing processing. However, various unpredictable defects often arise during the manufacturing process, and a single, static optimization strategy is incapable of precisely eliminating these defects. Consequently, there is an urgent need for a real-time dynamic quality control method to fabricate defect-free parts. This study proposes an intelligent control framework that synergizes supervised learning with the Multi-Agent Deep Deterministic Policy Gradient (MADDPG) algorithm. By leveraging a supervised learning model to analyze melt track images and process data in real time, the framework achieves mechanistic modeling and forming quality prediction of process data. Simultaneously, multiple agents coordinate to dynamically optimize key parameters such as laser power and scan speed in response to detected deviations. Simulation and experimental results under typical laser power and scan speed conditions demonstrate that the framework not only suppresses common solidification defects but also maintains melt track continuity under abrupt parameter variations. Compared to PID control, it provides more adaptive responses, thereby lowering defect rates and stabilizing the overall build process. This approach addresses the challenges of multi-parameter collaborative optimization and dynamic decision-making in the Additive Manufacturing process.

Adaptive 3D Printing for Soft Electronics and Shape-Morphing Structures

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Abstract

The emergence of 3D printing has opened new opportunities in the fabrication of soft electronics, stretchable devices, and shape-morphing structures. These applications often require the integration of materials with distinct mechanical and functional properties, such as conductive pathways embedded within soft elastomeric matrices for electronics, or combinations of active and passive materials to achieve programmable deformation. However, current 3D printing approaches face key challenges. Printing functional materials on solid elastomer substrates typically requires a post-processing transfer step, which complicates fabrication and risks misalignment. On the other hand, embedded printing within highly viscous supporting liquids can suffer from limited printing fidelity and material compatibility issues. To address these limitations, we introduce an adaptive 3D printing approach by direct printing on uncured elastomer surfaces. The partially cured elastomer provides a compliant yet supportive interface, allowing high-fidelity patterning of inks without the need for transfer or embedded media, while the precipitation of the printed filaments facilitate controlled integration of the filaments with elastomer matrix after curing. We demonstrate the versatility of this approach in fabricating stretchable strain sensors and complex bilayer systems capable of programmable shape transformation. The method offers significant benefits: improved integration between printed and substrate materials, reduced processing steps, and compatibility with a wide range of soft functional inks. This adaptive 3D printing strategy opens up new possibilities for streamlined, high-resolution fabrication of multifunctional soft systems, with potential impact across wearable electronics, soft robotics, and biomedical devices.

Additive manufacturing of biodegradable zinc alloys: materials, structures, and applications

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Abstract

Biodegradable zinc alloys exhibit a moderate degradation rate and excellent biocompatibility, making them promising candidates for widespread application in the field of bone implants. Laser powder bed fusion (LPBF), as a representative metal additive manufacturing technology, facilitates the fabrication of zinc alloy implants with personalized geometries and complex multi-stage microporous structures. However, during laser processing, zinc alloys are susceptible to evaporation and elemental loss, which poses significant challenges to the forming quality and overall performance of the implants. This work investigates the influence of laser process parameters on the forming quality of zinc alloys and proposes a multi-mode prediction model for LPBF-fabricated zinc alloys, providing effective guidance for the production of high-density zinc alloy components. Through a heat treatment system and external field, zinc alloys with an excellent strength-ductility synergy were developed. The mechanisms of deformation control and multiple strengthening effects were analyzed, and the relationship between microstructure and mechanical properties was established. Based on these findings, a novel metamaterial design inspired by sea urchin shells, lattice Voronoi, and fractal gradient Voronoi structures was proposed. The resulting zinc-based metamaterial demonstrates mechanical and mass transfer properties highly compatible with natural bone, offering new insights into achieving macro and micro structural control of deficient bones. Furthermore, a personalized and biodegradable semi-permeable gel/zinc composite guided bone regeneration (GBR) membrane, as well as a GelMA composite hydrogel/zinc alloy bone scaffold loaded with NBIF drug, were successfully developed. The mechanical properties and corrosion behavior of both the GBR membrane and the bone scaffold were systematically investigated, while their osteogenic potential and antibacterial efficacy were thoroughly evaluated. Additionally, the promising application prospects of zinc scaffolds fabricated via laser powder bed fusion (LPBF) in bone defect repair were highlighted.

3D Bioprinting of Colorectal Organoid Models within Chemically Defined Peptide-Based Matrices for Therapeutic Applications and Disease Modeling

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Abstract

Organoids are three-dimensional (3D) structures that mimic the tissue architecture and cellular composition of their origins. These miniature organs possess considerable potential in precision medicine as predictive instruments for patient responses to therapeutic interventions and in tissue engineering as grafts for damaged tissues. The development of these cells is contingent upon the presence of suitable extracellular matrices. However, the use of commonly employed animal-derived matrices presents challenges, including immunogenicity and batch variability, which impose limitations on their therapeutic and modeling applications, particularly in immune-related contexts. Chemically defined matrices that are biocompatible and non-immunogenic offer a promising alternative.

A library of ultrashort self-assembling peptides was examined, and two tetrameric peptide sequences with a single amino acid variation were selected for further investigation. These sequences were chosen based on their gelation kinetics and mechanical properties. The formation of hydrogels under physiological conditions was observed for both peptides, characterized by a highly porous network of nanofibers with tunable mechanical properties. The stiffness of these peptide hydrogels ranged from 6 to 130 kPa at concentrations of 0.1% to 1% w/v. Peptide hydrogels have been utilized as bioinks for 3D bioprinting applications. The peptide hydrogel supported the growth and viability of primary colon organoids, as evidenced by immunofluorescent (IF) staining of F-actin, indicative of preserved cytoskeletal integrity and organization related to lumen formation. Furthermore, E-cadherin and ZO-1 staining of organoids cultured within the peptide hydrogel confirmed the integrity of epithelial cell junctions, indicative of proper tissue architecture compared to those grown in Matrigel. Furthermore, Ki-67 immunofluorescent staining revealed the retention of proliferative capacity in organoids cultured in the peptide hydrogel compared to those maintained in Matrigel. Our findings underscore the promise of tetrameric peptides as a three-dimensional (3D) platform for organoid development, facilitated by 3D bioprinting.

Enhancing degradation behavior, osteogenic capacity and angiogenic performance of additively manufactured porous Zn-Mg scaffold via a neobavaisoflavone-doped GelMA composite hydrogel coating

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Abstract

Additively manufactured Zn alloy porous implants hold remarkable potential and promise for bone defect repair, owing to their customizable structures and biodegradable features. However, the porous nature of these implants enlarges their exposed surface area, rendering them release excessive Zn²⁺, which has a detrimental impact on osteogenesis and angiogenesis. In this study, a neobavaisoflavone (NBIF)-doped gelatin methacrylate (GelMA) composite hydrogel coating was prepared on the Zn-Mg porous scaffold fabricated by laser powder bed fusion. The coating characteristics, degradation behavior, and cell responses were systematically investigated. The results indicated that a stable coating with a thickness of approximately 20 μm was chemically bonded to the scaffold surface. Moreover, NBIF were effectively anchored within GelMA matrix, enhancing its structural integrity and stability. This NBIF-doped hydrogel coating significantly decelerated the release kinetics of Zn²⁺. After immersion, the coated scaffold maintained favorable mechanical properties, with a compressive strength of 46.11 MPa and an elastic modulus of 1.84 GPa. Furthermore, the coated scaffold exhibited superior biocompatibility and osteogenic properties, as evidenced by the upregulation of key osteogenesis-related genes (COL1, OCN, RUNX2 and ALP). The NBIF-doped GelMA composite hydrogel coated Zn-Mg porous scaffold also demonstrated enhanced angiogenic capabilities, indicating a promising candidate for bone repair applications.

High-performance or functional UV-curing 3D printing materials derived from plant oils and natural phenols

Chengguo Liu

Nanjing Forestry

Abstract

The utilization of renewable biomass resources to prepare UV-curing 3D printing materials is of great significance for high-value utilization of biomass resources and sustainable development of the 3D printing material industry simultaneously. Currently, bio-based UV-curing 3D printing materials generally have several important problems, such as inferior thermal/mechanical properties, hard to be self-repaired and recycled, and serious pollution caused by the preparation processes. In an effect to deal with these problems, we used plant oils and natural phenols as starting materials, combined with green synthesis methods and dynamic chemistry, to construct UV-curing 3D printing materials with high performance, self-repairability, recyclability, etc., and reveal structure–property relationships and self-healing/recycling mechanism of the materials. For instance, using castor oil as the starting material, a chemically recycling UV-curing 3D printing material was prepared by introducing a dynamic hindered urea bond based on a dissociative mechanism. The degradation process of the material was very fast (completely degraded at 100 °C for only 2h), and the colors, viscosities, thermal/mechanical properties, and polymerization rates of the recycled resins were almost the same as those of the original resin. Our works can not only provide several bio-based UV-curing 3D printing resin products, but also provide new ideas and ways for the design and application of such materials.

Advanced Characterization of Additive Manufacturing Materials Using X-ray Nanodiffraction at the Taiwan Photon Source

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Abstract

The X-ray Nanodiffraction Beamline (XND) at BL-21A of the Taiwan Photon Source (TPS) employs both focused white and monochromatic beams to characterize material structures at the nanoscale. Delivering a 50 × 50 nm² focused X-ray spot, XND enables high-spatially resolved analysis of crystalline and chemical structures without altering sample geometry.

Additive manufacturing (AM) of alloys often results in complex microstructures, where crystal texture and grain boundaries critically affect mechanical properties. X-ray nano-Laue diffraction, combined with a field-emission scanning electron microscope (FE-SEM), provides powerful capabilities for correlating microstructure observation with precise, selected-area diffraction measurements. With a two-dimensional scanning stage, XND enables detailed mapping of crystal orientation, residual strain, and defect distributions, and advanced analysis of phase boundaries, twin boundaries, coherent grain boundaries, dislocations, and slip systems.

In addition, this beamline also provides scanning X-ray fluorescence spectroscopy (XRF) to reveal elemental distributions, while X-ray absorption spectroscopy (XAS) offers insights into local atomic structures and oxidation state within selected regions. In-situ thermal control (150 K to 800 K) further expands the range of material studies.

Beyond metallic alloys, XND is applicable to compounds, ceramics, and other advanced materials. It serves as a vital tool for advancing research in additive manufacturing, particularly in areas such as functionally graded materials, micro-AM analysis, texture gradient studies, and nanostructured interlayers. These capabilities position XND as a key facility for accelerating innovation across multiple fields in materials science and engineering.

Enhanced Laser Powder Bed Fusion for Lattice Structures: Integration of Wobble Scanning and Variable Laser Power Modulation

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Abstract

Laser powder bed fusion (LPBF) typically employs a continuous wave (CW) laser mode combined with a multi-scan strategy to fabricate lattice structures. However, this conventional approach is impeded by extended processing times and powder adhesion issues. This study introduces an innovative LPBF process that integrates a wobble scanning technique with variable laser power modulation along the scanning path. This method not only accelerates the fabrication of controllable lattice structures but also substantially reduces powder adhesion.

Experimental results reveal that under identical wobble scanning conditions, lattice structures produced using variable laser power exhibit significantly thinner walls and a marked reduction in powder adhesion compared to those fabricated with the CW laser mode. These findings underscore the potential for manufacturing lattice axial gap structures at smaller scales. Moreover, by fine-tuning the laser power distribution along the wobble scanning trajectory, holes with specialized geometries, such as parallelograms and layered structures, can be successfully produced.

Thermomechanical Behavior of Additively Manufactured Alloys Under Static and Impact Loads

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Abstract

The high-temperature mechanical behavior of additively manufactured (AM) alloys is increasingly important as industries seek materials capable of performing in extreme service environments. Thus, this work presents recent progress on the quasi-static and dynamic response of various AM alloys, fabricated via laser powder bed fusion (LPBF), including MS1, 420SS, M789, IN718, IN625, and Ti-6Al-4V, at elevated temperatures. These materials are widely used in aerospace and defense applications, where both strength and thermal stability are critical. Specifically, high-temperature compressive tests were conducted using a Gleeble 563 thermomechanical simulator for quasi-static conditions and a custom-built Split-Hopkinson Pressure Bar (SHPB) system for dynamic loading. The results provided insights into temperature- and strain rate-dependent deformation mechanisms, and the data were used to establish phenomenological, physically based, and neural network-driven constitutive material models. The mechanical performance under varying strain rates and temperatures is interpreted in terms of numerous metallurgical phenomena such as, but not limited to, dynamic recrystallization, dynamic recovery, and grain fragmentation. These findings are supported by microstructural analyses using electron backscatter diffraction (EBSD), transmission electron microscopy (TEM), and atom probe tomography (APT). This work highlights the link between processing, microstructure, and high-temperature performance of AM alloys, providing valuable data for materials selection and process optimization in demanding applications.

Synergistic enhancement of strength and ductility of laser-based powder bed fusion of metals (PBF-LB/M) AlSi10Mg alloy by in-situ magnetic field assistant and post-heat treatment

Dafan Du Anping Dong Baode Sun

Shanghai Jiao Tong University

Abstract

Owing to its high accuracy and good design flexibility, the application of PBF-LB/M has been rapidly increased in complex metal parts. However, the parts fabricated using PBF-LB/M exhibit cracks, pores and rough texture, which severely hinders the development of this technology. In this study, AlSi10Mg alloys were fabricated with PBF-LB/M with assistant of static magnetic field (SMF) of up to 0.2 T and post-heat treatment. The experimental results showed that the samples performed a higher density with SMF than the samples fabricated without SMF. Results show that the SMF refined the grain size for PBF-LB/M samples. Compare to the samples fabricated without SMF, the samples fabricated with SMF performs higher strength and lower ductility. Further, the low-temperature post-heat treatment was applied to slightly decrease strength and increase ductility. Simulation results suggest that at the melt pool scale, the depression zone depth increases with increasing SMF intensity, and the correspondingly increased laser absorptivity is the main reason for the decrease in the lack-of-fusion defects. Finally, with the assistance of SMF during PBF-LB/M and post-heat treatment, the strength and ductility of AlSi10Mg alloy synergistic enhanced.

Electrochemical Additive Manufacturing of Metals: Advances, Challenges, and Applications

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Abstract

Additive manufacturing (AM) of metals take on multiple forms and capabilities in a broad range of applications, from large-scale industrial structures to micro-scale electronics. However, conventional metal AM techniques being predominantly thermal-based methods utilising powder-form metals, introduces several process complexities and limitations, including material suitability for manufacturability of the metal powders, requirement for tight environmental control, induced thermal stresses in the fabricated part, and ultimately incompatibility with low temperature materials for multi-material design capability. Electrochemical additive manufacturing (ECAM) is a growing field of metal AM, depositing metal through localised reduction of metal ions generated through the potential-driven redox reactions analogous to the principles of conventional electroplating. This non-thermal process avoids issues commonly arising from thermal methods such as heat affected zones, while offering microstructural control in an energy efficient manner, as well as the potential for multi-material integration. This brief review aims to summarize the key developments and research efforts in ECAM. Emphasis is placed on the challenges and opportunities for fabricating conductive materials such as copper, for electronics applications. The capabilities in resolution and material choices are discussed, along with the characteristic working principles.

Laser-arc hybrid additive manufacturing of lightweight alloys

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Abstract

Lightweight alloys fabricated by single-source arc or laser additive manufacturing are highly prone to significant defects and coarse microstructures, making it difficult to achieve a balance between high strength and toughness in the formed samples. This severely hinders the engineering application of additive manufacturing technology for such alloys. To address these challenges, this work couples localized and controllable laser energy with high-efficiency arc energy, proposing a laser-arc hybrid additive manufacturing (LAHAM) technology for lightweight alloys and developing corresponding hybrid additive manufacturing equipment.

Key Findings:

- (1) The types of internal pores in lightweight alloy samples were clarified, process windows for low porosity were identified, and a porosity prediction model was established. Laser single-pulse energy was found to exert the most significant influence on porosity.
- (2) The growth mechanisms of microstructures under hybrid additive manufacturing were investigated. The intrinsic relationship between melt pool heat-mass transfer behavior and solidification microstructures was elucidated through thermal-flow coupled numerical simulation.
- (3) A “dual-stage solution treatment plus aging treatment” methodology was developed for synergistic control of microstructure and mechanical properties. The room-temperature tensile strength of Al-Zn-Mg-Cu alloy exceeded 600 MPa. A dual-robot collaborative hybrid additive manufacturing system was successfully implemented.

High-resolution integrated photonic devices realized using additive processes.

Dawn Tan, Gao Hongwei, George Chen and Ju Won Choi

Singapore University of Technology and Design

Abstract

Advances in two-photon polymerization technology and resins have greatly facilitated the development of 3D printed photonic devices. Operating in a paradigm distinct from conventional subtractive, lithographic processes typical in semiconductor manufacturing. 3D printing unlocks the third dimension, allowing more degrees of freedom for the design and realization of photonic devices. In this talk, we discuss high-resolution 3D printed photonic devices realized using two-photon polymerization. Nanostructured suspended air-bridge couplers circumvent the need for edge cleaving for light coupling from optical fibers while maintaining a low coupling loss of 1.6dB. Single and nested spiral waveguides showcase the three-dimensional optical path availed by 3D printing. High-speed measurements of 30Gbps non-return-to-zero data yield low bit error rates of 10⁻¹², indicating their high transmissivity and suitability for data transmission. We further demonstrate 3D printed Er-doped waveguide amplifiers where 1.3dB gain is achieved in 2.7cm waveguides. Resonant devices such as microring resonators and microtoroid resonators which have critical gaps as small as 150nm are achieved. Importantly, the ability to precisely 3D print the coupling waveguide next to the microtoroid circumvents the need for difficult alignment of a tapered fiber next to the microtoroid for excitation of resonant modes. High-resolution 3D printing is an important technology for the development of novel photonic devices toward diverse applications such as in high-speed communications, imaging and medicine.

Enhancing L-PBF processing efficiency for Ti-6Al-4V printing using a combination of machine learning and a decision support system

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Abstract

In-process monitoring of laser-powder bed fusion (L-PBF), is important for enhancing the quality and reproducibility of printed alloy parts. This research examines the use of an unsupervised and semi-supervised machine learning approaches, to facilitate the extraction and analysis of process monitoring data during the L-PBF processing of Ti-6Al-4V alloy parts. This data consisted of photodiode measurements, along with the monitoring of laser power input. The machine learning techniques evaluated are the unsupervised Search and TRace Anomaly (STRAY) algorithm, along with the semi-supervised 1-dimensional autoencoder (1-DAE) technique. The latter approach is considered semi-supervised, as it requires an unlabelled training dataset for the model to learn inherent latent features of the data. To this end, the techniques were assessed on their ability to detect defects, which were both intentionally and unintentionally induced during the printing of alloy lattice structures, with a range of unit cell shapes and sizes. Based on the analysis of the print datasets it was demonstrated that the 1-DAE achieved the lowest predictive accuracy (F1 score) of 0.80. Its accuracy was significantly higher than the unsupervised STRAY algorithm, which recorded F1 scores between 0.09 and 0.72, depending on the dataset analysed and the filtering parameter used. While 1-DAE requires an initial training dataset before it can be applied, its implementation time post-training, is only 1.92 milliseconds. This rapid processing speed facilitated its use in a rules-based decision support system called the Recommender System. This was used to both interrogated the L-PBF process data, to identify anomalous in-process sensor output, as well as to correlate the observed print data with that from previous print runs. This decision support system provides recommendations to L-PBF equipment operators, suggesting actions to address processing anomalies. The Recommender System's ability to provide close to real-time operator feedback was successfully demonstrated in a L-PBF production environment.

Pseudoelastic Response Prediction of NiTi TPMS Lattice Structures Using Deep Learning

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Abstract

Nickel-Titanium (NiTi) lattice structures based on Triply Periodic Minimal Surfaces (TPMS) offer remarkable pseudoelastic properties, making them ideal for biomedical implants, aerospace components, and actuators. However, accurately predicting the stress-strain response of these complex structures is computationally expensive using traditional finite element analysis (FEA). This study proposes a deep learning-based approach to predict the pseudoelastic response of NiTi TPMS lattices efficiently.

We designed NiTi TPMS lattice structures with unit cell types such as Gyroid, Schwarz, and Diamond using Python-based APIs. Finite element simulations were conducted to generate high-fidelity stress-strain data for various loading conditions. The data was voxelized into a 3D grid, encoding solid-void distribution, strain step, and lattice type using one-hot encoding. A 3D Convolutional Neural Network (CNN) was trained on the voxelized data to learn the stress-strain relationships, while stress and strain values were standardized to enhance model performance.

The trained model accurately predicts the pseudoelastic response of unseen NiTi TPMS structures, reducing computational time significantly compared to FEA. The CNN model generalizes well across different lattice types, capturing the complex stress distributions within the structures. This study demonstrates the potential of deep learning in accelerating the design and analysis of NiTi TPMS structures. Future work will focus on expanding the dataset to include experimental validation, optimizing neural network architectures, and exploring generative models for inverse design applications. This AI-driven approach can revolutionize lattice-based material design, enabling rapid, cost-effective, and reliable performance predictions for advanced engineering applications.

Machine learning-guided 3D printing optimization and heat treatment for high-density and enhanced performance refractory high entropy alloys

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Abstract

In this study, a Ti_{1.5}Nb₁Ta_{0.5}Zr₁Mo_{0.5} (TNTZM) high-entropy alloy was fabricated using laser powder bed fusion (LPBF). By integrating 63 sets of parameter trials with machine learning (ML) models, an optimized process window was identified, achieving a density of up to 99.9%. The combination of relatively high laser power and low scanning speed resulted in the formation of a stable cellular structure. Subsequent heat treatments at 700 °C, 850 °C, and 1000 °C showed that while small-angle misorientations developed at cell-wall interfaces and medium-entropy (Ti–Zr–Mo) second-phase particles precipitated preferentially in the cell walls, the overall cellular architecture remained intact. Mechanical testing showed that these heat-treated samples exhibited yield strengths over 150 MPa higher than the as-built samples, while still retaining nearly 50% ductility under short-term heat treatment. In particular, small-angle grain boundaries and nanoscale second-phase particles together reinforce the cell walls and promote intracellular dislocation accumulation, thereby improving the overall mechanical properties of the alloy. These results demonstrate that combining ML-guided process design with targeted heat treatment is an effective method for additive manufacturing of refractory HEAs with high density and mechanical properties.

Challenges in Large-Scale Part Fabrication via Multi-Laser Powder Bed Fusion

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Singapore University of Technology and Design

Abstract

Multi-laser powder bed fusion (ML-PBF) technology, characterized by its high efficiency and large-scale fabrication capabilities, has emerged as an inevitable trend in the development of laser powder bed fusion techniques. This advanced technology meets the manufacturing demands for large, complex, and precision-critical components in industries such as aerospace and nuclear power. However, as the number of lasers and the forming area increase, several critical challenges arise, including the control of formation defects, ensuring high-quality laser beam overlap, and maintaining consistency in the overall fabrication quality. This report systematically addresses the core technologies and challenges associated with large-scale part fabrication using multi-laser powder bed fusion. It focuses on three key aspects: optimization of gas flow fields and effective removal of spatter, refinement of process parameters and multi-laser overlap strategies, and practical case studies of component fabrication. The insights provided aim to offer valuable references for advancing the development and application of multi-laser powder bed fusion technology, thereby contributing to its broader adoption in industrial manufacturing.

Unraveling microstructure and mechanical response of an additively manufactured refractory TiVHfNbMo high-entropy alloy

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Abstract

Refractory high-entropy alloys (RHEAs) have attracted considerable interest due to their elevated melting points and exceptional softening resistance. Nevertheless, the ambient-temperature brittleness and inadequate high-temperature oxidation resistance commonly restrict the processability of RHEAs. Direct energy deposition (DED) additive manufacturing technology is ideal for fabricating refractory alloys due to design flexibility and oxygen-free environment. In this work, a novel Ti41V27Hf13Nb13Mo6 RHEA was successfully manufactured by DED, and a comprehensive investigation was conducted to explore the microstructure evolution and mechanical response during tension. The as-deposited RHEAs exhibit a grain-size graded microstructure with a body-centred-cubic (BCC) matrix and precipitates. Increasing laser energy density suppressed the grain boundary precipitation, effectively enhancing the ambient-temperature tensile ductility to ~11.3%. The optimized specimens achieved an unprecedented yield strength of ~1.2 GPa among the DEDed RHEAs, which can be attributed to a significant solid solution strengthening from the volume misfit of 5.03%. We revealed that dislocation interactions maintained the working hardening capacity. Moreover, in-situ characterization indicated that slip transfer, grain rotation, and kinking accommodated the plastic deformation. Crack nucleation was caused by slip inhibition at grain boundaries and dislocation pile-ups at intragranular precipitates. The kink band formation relieved stress concentration induced by intragranular precipitates and promoted a ductile fracture. These exceptional outcomes provide opportunities for additive manufacturing RHEAs and greatly advance the understanding of their strengthening and deformation mechanisms.

Nanosecond-femtosecond laser-materials processes and the functional structures preparation of thin film

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Abstract

Nanosecond pulsed laser is widely used in the area of microelectronics and optoelectronics. For the preparation of functional surface structure, laser direct writing technology has lots of advantages, for example, materials compatibility, non-contact processing, and low-cost performance. By adjusting the laser pulse energy density, a variety of thermodynamic processes will happen on the surface of materials, such as ablation, melting and oxidation. In this condition, the pulse laser processing technology plays a great role in the field of microstructure preparation. So in this report, Functional structures on metal thin films, which are induced by pulsed laser, have been used in the fabrication of the transparent electrode material, and through time-resolved imaging and in-situ pump probing technology, the transient changing surface morphology after nanosecond pulsed laser irradiation film can be recorded.

In-flight jet experimental study of Aerosol Jet® Printing by means of Phase Doppler Anemometry

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Abstract

Aerosol Jet® Printing (AJ®P) is a widely used digital printing method in the field of Printed Electronics (PE). The process mainly consists of four fundamental steps: i) atomization, ii) aerosol transport, iii) collimation, and iv) in-flight jetting. Although its industrial use is expanding, there is still a lack of comprehensive fundamental research on these individual stages.

In this study, Phase Doppler Anemometry (PDA) is utilized to visualize and analyze the in-flight behavior of silver and PEDOT:PSS inks between the nozzle exit and the substrate. PDA is chosen for its high spatial resolution, which enables precise measurement of particle diameters and velocities within a range of 1 µm to 1 mm for size and 1 to 1000 m/s for velocity. These measurements facilitate the calculation of dimensionless numbers—such as the Weber and Reynolds numbers—that are essential for analyzing jet flow characteristics, such as the transition between laminar and turbulent flow, droplet size, and velocity profile. These characteristics are examined as functions of process and input parameters like carrier gas flow, sheath gas flow, and their ratio (focusing ratio). Ultimately, this approach could help establishing a link between input parameters and the resulting print quality, including aspects like pattern morphology and line width.

From an industrial perspective, such fundamental studies are vital for both materials and equipment manufacturers. They support the optimization of process settings and the development of compatible inks, thereby advancing the efficiency and reliability of AJ®P technology.

Keywords: additive manufacturing, process monitoring and control, phase doppler anemometry

The 3D Human Bone Printer and Printing Technology

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Abstract

This study highlights the world's first ground-breaking patented 3D Human Bone Organ printer and patented printing technology.

The research also showcased i) the special features of the patented 3D Human Bone Printer functional prototype, ii) a successfully printed 3D proximal phalanx of the human thumb and iii) rat model study demonstrating the successful osteointegration of the 3D printed live bone, in comparison vis-a-vis conventional bone block surgery, via radiological means and serum markers. Future 2nd generation patented endoscopic 3D printing are also demonstrated and the challenges ahead discussed.

Combinatory Aerosol Jet and Digital Light Processing Printing for Advanced Bioelectronic Applications

Xin Chao Gao, Guo Liang Goh, Jia Min Lee, Wai Yee Yeong

Nanyang Technological University

Abstract

Multi-electrode arrays (MEAs) are essential tools for understanding the electrophysiological qualities of different cell types for a variety of physiological or pathological functions. Since the development of the first MEA, technological improvements have improved the quality of information gained from cells. However, conventional fabrication techniques are costly and lack the rapid customisation required for advanced bioelectronic applications. This study presents the integration of aerosol jet printing (AJP) and digital light processing (DLP) printing to generate flexible, high-resolution and customisable bioelectronic platforms. This strategy leverages the strengths of AJP to deposit gold electrodes with microscale precision onto a substrate that interfaces directly with DLP printed complex 3D architectures.

Electrochemical characterization of the printed gold electrodes exhibited impedance measurements at 1 kHz ($151.4 \pm 19.9 \Omega$), confirming suitability for detecting cellular electrical activity, with stability studies showing no significant degradation over 2 weeks. The stimulating electrodes demonstrated high-density electrical stimulation capability, with a maximal charge injection capacity of $31.8 \pm 0.4 \text{ mA/cm}^2$. Stimulatory stability studies showed endurance up to 200,000 pulses, sufficient for electrical stimulation experiments. The printed substrate supported various surface modification polymers, enabling successful adhesion of multiple cell types. In vitro biocompatibility assays confirmed cell viability after 7 days of culture. Additionally, we demonstrate electrical signal acquisition and electrical stimulation-induced cell alignment with 3 cell types: primary cortical neurons, C2C12 skeletal myoblasts, and HL-1 cardiac myocytes. DLP printing of the bioconstructs achieved a dimensional accuracy of $92 \pm 3\%$ at 100 μm resolution, indicating good precision for alignment with electrode placements.

By integrating AJP and DLP printing, this work establishes a versatile method for the rapid fabrication of customisable bioelectronic interfaces with a wide range of applications. Our findings showcase the potential of multimodal additive manufacturing techniques in advancing bioelectronic devices and developing disease-specific biomedical devices.

Machine learning driven additive manufacturing technology in metallic materials

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Abstract

Designing high-performance alloys and processes for additive manufacturing (AM) has become a prominent research topic in recent years. In this report, the recent progress of machine learning driven additive manufacturing technology in metallic materials will be reviewed briefly first. Then the typical works involved in the application of machine learning additive manufacturing in from our group will be presented, which included the AM metallurgy-guided machine learning alloy design and the optimization of support structures and process parameters in additive manufacturing by combining machine learning approach.

Effect of tantalum content on microstructure, mechanical properties and biocompatibility of titanium-tantalum alloy fabricated by laser powder bed fusion

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Abstract

Laser powder bed fusion (LPBF) in-situ additive manufacturing of titanium-tantalum (TiTa) alloys offers integration advantages for metal bone implants. In this study, effects of Ta content (0, 25, 50, and 75 wt.%) on printability, microstructure, mechanical properties, and biocompatibility of LPBF-fabricated TiTa alloys. The printing experiments demonstrated that via regulating laser scanning speed, the TiTa samples with varying Ta content achieved an optimal balance in relative density. Microstructural characterization revealed that through spatial modulation of TiTa alloys with varying Ta content via LPBF, heterogeneous microstructures were achieved, featuring unmelted Ta particles with distinct melting states and morphological dimensions. Mechanical testing demonstrated that increased Ta content resulted in higher ductility at the expense of reduced yield strength, with elastic modulus values approaching those of natural bone. Furthermore, TiTa scaffolds exhibited further reduced elastic modulus matching trabecular bone, while maintaining cortical bone strength, demonstrating exceptional biomechanical compatibility. Cell experiments, radiological examinations, and push-out tests demonstrated that compared to Ti scaffolds, TiTa scaffolds with high Ta content exhibits excellent biocompatibility and can effectively facilitate the bone healing and ingrowth.

3D Bioprinting, Artificial Intelligence & Microfluidic Strategies for Gum Health & Disease

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Abstract

The regeneration of gingival (gum) tissue defects around teeth and implants, is essential for restoring oral tissue form, function, and health. Gum tissues, uniquely positioned at the intersection of hard tissues, microbial flora, and a myriad of external factors such as dietary choices and oral-care products, play a pivotal role in oral and overall well-being. However, understanding their complex microenvironment and need for personalized regenerative solutions remains challenging. This talk will explore how advanced technologies such as 3D bioprinting, artificial intelligence, and microfluidics can be harnessed to gain new insights into gum health, disease, and personalized dentistry. I will delve into the application of 3D bioprinting for biofabrication of personalized defect-specific grafts with precise dimensions and layered cellular architecture. Further, the talk will highlight the integration of artificial intelligence-based tool to streamline the optimization process and analyze the interactions between bioprinting parameters. Finally, it will cover the integration of microfluidic platforms to study the effects of microbial interactions and oral-care formulations, offering new insights into gum tissue health.

Wafer-scale integration of metal oxide-based gas sensors via direct lithographic patterning

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Abstract

Nanomaterials-based gas sensors are essential due to their high sensitivity and scalability, enabling efficient gas detection across diverse applications. However, a key challenge hindering their practical applications is the variation in sensing performance between devices. Addressing this requires careful consideration of the relationship between on-chip sensing materials and miniaturized devices. As feature sizes reduce to the microscale, accurately and uniformly positioning sensing nanomaterials onto specific regions of device electrodes becomes increasingly difficult. This challenge arises from the incompatibility between the bottom-up nanomaterials synthesis methods and the top-down lithography-based fabrication processes. Herein, we introduce a cleanroom-compatible fabrication workflow for chemiresistive gas sensors, employing direct lithographic patterning of metal oxide nanocrystals. Gas sensors located across different regions of a 4-inch wafer exhibit highly consistent gas-sensing performances, highlighting the potential of this approach, which integrates the strengths of both top-down and bottom-up approaches. This approach opens new opportunities for integrating a wide range of bottom-up synthesized functional nanomaterials into diverse types of chemical sensors.

Model-based qualification of metal 3D printed components

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Abstract

Qualification and certification of 3D printed components is a crucial step to ensure part quality and fitness for use. Naturally, current methodology for qualification and certification leverages extensively on experimental characterization, where samples and complex parts are subject to numerous tests for part density, geometric tolerances, mechanical properties, to match specific thresholds or reference accepted values. Conversely, this approach carries significant costs, and required time. To alleviate such hurdles, modelling and simulation can provide a cost-effective, alternative digital route to qualification and certification. To reach this goal, a model-based digital twin of the L-PBF process is needed, which needs to be able to predict each of the quantities which are normally measured during qualification and certification. We have developed a model-based digital twin which combines a thermal simulation at the scale of the part, a discrete element method simulation of powder spreading, a ray-tracing simulation of laser-matter interaction, a powder-scale simulation of powder melting and solidification and microstructure evolution, two phase-field simulations of dendritic and precipitates formation, a crystal plasticity calculation for prediction of mechanical properties, and a part-scale simulation of residual stress and distortion. All capabilities were integrated into a single, multiscale platform where numerical computing is handled by an asynchronous, multithreaded server. User interaction occurs with a tcp/ip connected client, also developed in house. In this presentation, we will illustrate the platform, its architecture and features, and provide examples of parts for qualification and certification of metal 3D printed components.

Influence of Nozzle Geometry on Extrudate Properties in 3D Food Printing

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Abstract

Three-dimensional (3D) food printing has garnered significant interest due to its potential to create customized culinary products with complex shapes, flavor profiles, and nutritional content. Despite advancements in materials and printer hardware, the role of nozzle geometry in shaping extrudate properties has not been extensively studied. This paper explores how different nozzle shapes—ranging from simple circular apertures to more complex geometries like triangular, square, and star-shaped openings—affect key attributes such as flow behavior, layer adhesion, porosity, and final texture. A systematic investigation was conducted using various food inks, including protein and carbohydrate-based formulations, to evaluate how material rheology interacts with nozzle design. This paper will investigate how different nozzle shapes—ranging from simple circular apertures to complex geometries such as converging and diverging—will affect critical attributes, including flow behavior, layer adhesion, porosity, and final texture.

A systematic evaluation was conducted using various food inks to assess how material rheology will interact with nozzle design. The experimental findings revealed how nozzle geometry significantly influences extrusion performance, including flow consistency, shape retention, and surface quality. For instance, diverging nozzles will produce distinct cross-sectional profiles that may alter the fiber directions, thus changing the mouthfeel experiences.

Ultimately, these insights emphasized the importance of selecting or engineering nozzle geometries tailored to specific food formulations and desired textural outcomes. By illuminating the interplay between nozzle shape and printed food properties, this work contributed to more versatile and adaptive 3D food printing processes that can be readily harnessed for evolving culinary and nutritional applications.

Design and Fabrication of Sensor-Integrated 3D-Printed Toys for Early Childhood Cognitive Intervention: A Review and Case Study

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

Abstract

Early intervention during infancy is crucial for fostering healthy cognitive development, particularly in infants at high neurocognitive risk (e.g., ASD, ADHD, preterm birth, developmental delay). This work proposes a novel approach to home play-based intervention using AI-powered profiling tools and instrumented 3D-printed toys to enhance development of early cognitive and emotional skills. These toys are designed to facilitate swift cognitive and behavioral profiling, providing parents with real-time feedback to enable targeted, personalized interventions. The system integrates AI-driven sociometric profiling to assess parent-child interactions, capturing sensorimotor indicators such as gaze synchrony, speech patterns, emotional responsiveness, movement coordination, and neurophysiological data. Instrumented toys embedded with sensors collect and process these interaction metrics, offering a direct mechanism for cognitive monitoring and feedback delivery. The design process emphasizes material selection for safety and compliance, focusing on food-grade, child-safe materials suitable for infants. Advanced additive manufacturing techniques are employed to ensure customizable, durable, and functional designs that meet the requirements of cognitive intervention. This paper reviews the critical technical considerations for toy design and fabrication, including material selection, sensor integration, and real-time data processing frameworks. A case study illustrates the iterative design and production process, detailing the challenges and solutions in developing instrumented toys tailored for early childhood intervention. The findings highlight the potential for scalable, parent-led intervention solutions and provide insights into the broader application of such technologies in ameliorating early neurocognitive risks.

Ultrafast dynamic evolution of materials processed by femtosecond laser

Guodong Lv

Center for Advanced Laser Manufacturing (CALM), Shandong University of Technology

Abstract

With the development of science and technology, people have higher and higher requirements for the miniaturization, integration and portability of electronic devices and mechanical equipment, which poses new challenges to micro-nano manufacturing and processing technology. The rapid development of ultrafast lasers has changed the traditional processing and manufacturing methods, and has gradually become an important research direction of micro-nano manufacturing technology with its unique advantages. However, the interaction between femtosecond lasers and matter is a multi-physical evolution process across time and space. During the process of femtosecond laser processing of materials, a series of ultrafast phenomena will occur, affecting the quality of micro-nano structure formation. Therefore, transiently capturing and exploring the multi-physical evolution process of femtosecond laser processed materials will deepen the understanding of the physical mechanism of the interaction between femtosecond lasers and materials, realize the precision manufacturing and online monitoring of material micro-nano structures, and promote the rapid development of laser micro-nano manufacturing technology and its applications.

Multi-Axis Additive Manufacturing: Challenges and Opportunities

Jiasheng QU, Guoxin FANG

The Chinese University of Hong Kong

Abstract

Multi-axis additive manufacturing (MAAM) pushes the limits of conventional planar-based 3D printing by leveraging robot-based motion to deposit material in 3D space. This paradigm shift unlocks new functionalities, including support-free printing processes, enhanced surface finishing, and the control of anisotropic properties of filaments for strength reinforcement. MAAM also enables the opportunity for hybrid machining and printing of larger-scale objects. While these advancements create exciting possibilities, the high-dimensional material decomposition space also presents novel challenges in curved layer slicing, toolpath generation, hardware development, and material processing. This talk will demonstrate the effort in overcoming the challenges in multi-axis additive manufacturing and developing robot-assisted 3D printing systems with expanded capabilities. Specifically, it will cover topics including: (1) development of scalable and advanced computational frameworks for curved layer slicing and toolpath generation for MAAM, enabling volume-based decomposition to realize mechanical strength reinforcement in printed models; (2) exploration of MAAM with continuous fiber reinforced thermoplastic composites (CFRPTCs) using tailored toolpath design to achieve the highest mechanical performance; and (3) integration of robotic systems with MAAM technology to improve precision, control, and automation in manufacturing.

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Center for Advanced Laser Manufacturing (CALM), Shandong University of Technology

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With the development of science and technology, people have higher and higher requirements for the miniaturization, integration and portability of electronic devices and mechanical equipment, which poses new challenges to micro-nano manufacturing and processing technology. The rapid development of ultrafast lasers has changed the traditional processing and manufacturing methods, and has gradually become an important research direction of micro-nano manufacturing technology with its unique advantages. However, the interaction between femtosecond lasers and matter is a multi-physical evolution process across time and space. During the process of femtosecond laser processing of materials, a series of ultrafast phenomena will occur, affecting the quality of micro-nano structure formation. Therefore, transiently capturing and exploring the multi-physical evolution process of femtosecond laser processed materials will deepen the understanding of the physical mechanism of the interaction between femtosecond lasers and materials, realize the precision manufacturing and online monitoring of material micro-nano structures, and promote the rapid development of laser micro-nano manufacturing technology and its applications.

Design of High-Strength Dual Cure Resin for Digital Light Processing

Seungjae Han, Hae-Jin Choi

Chung-Ang University

Abstract

Additive manufacturing, commonly known as 3D printing, enables the fabrication of complex geometries and diverse structures. Recent advancements in this technology have significantly expanded its applications across various industries. Among the different additive manufacturing techniques, vat photopolymerization stands out for its high precision. Digital Light Processing (DLP), a type of vat photopolymerization, employs a Digital Micromirror Device (DMD) chip to selectively project UV light, curing resin layer by layer. This method offers ultra-fast printing speeds while maintaining a reasonable level of accuracy compared to other additive manufacturing techniques. However, despite its high precision and processability, the mechanical properties of photopolymer resins remain a major limitation for engineering applications. To address this, we developed an epoxy-based photo-thermal dual-cure resin and introduced a novel DLP 3D printing system for fabricating high-performance polymers. The dual-cure resin consists of a photo-curable component (P resin) and a thermal-curable component (T resin) mixed in optimized weight ratios. Additionally, we designed a specialized DLP printing system incorporating a layer coating system, heating module, wiping mechanism, and dispensing unit to enable the processing of high-strength dual-cure resins. The resulting dual-cure resin exhibited outstanding mechanical properties, including a tensile strength exceeding 100 MPa.

This work was supported by the Technology Innovation Program (or Industrial Strategic Technology Development Program-Industry Technology Alchemist Project) (20025702, Development of smart manufacturing multiverse platform based on multisensory fusion avatar and interactive AI) funded By the Ministry of Trade, Industry & Energy (MOTIE, Korea) and the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. NRF-2022R1A2C2003).

Defect Prediction with Multi-Sensor Monitoring in Laser-Directed Energy Deposition

Haiying Wei, Songjun Wang, Bin Li, Ye Li, Yi Zhang

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Abstract

The detection of multi-scale defects in Laser Directed Energy Deposition (LDED) remains a significant challenging due to complex thermo-mechanical interactions involving the melt pool, powder particles, and the limited availability of high-resolution data. This report highlights the recent progress of our research group in monitoring methods and experimental investigations targeting various defects, including macroscopic height instability and sidewall-adhered protrusions, mesoscopic porosity, and microscopic microstructural features. (a) A multi-scale defect monitoring system for LDED was developed to improve real-time data acquisition and enable accurate correlation between sensor signals and defect detection. (b) Optical enhancement techniques, combined with dual-laser beam illumination, were employed to ensure clear and complete capture of the deposited contour in ceramic LDED. Height instability and porosity rates were accurately predicted using a convolutional neural network. (c) In 316L stainless steel LDED, sidewall-adhered protrusions were investigated via high-speed imaging, which revealed the formation mechanisms of floating oxides, powder adhesion, and agglomerate adhesion. Furthermore, by fusing visual and thermal sensor data for melt pool monitoring, a dual-channel ResNet18 model was developed to predict grain size in 316L LDED and process optimization for forming quality was also experimentally explored.

Ultrafast Laser-Integrated Hybrid Additive Manufacturing of high-performance aluminum alloys: Achieving Superior Surface Integrity and Tailored Microstructure via In-situ Subtractive Processing

Han Zhang, Dongdong Gu

College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing, People's Republic of China

Abstract

Laser powder bed fusion (LPBF) faces challenges in achieving high surface integrity for aerospace-grade components due to inherent defects like powder adhesion, staircase effects, and residual stresses. This study pioneers an ultrafast laser-assisted hybrid additive-subtractive manufacturing strategy to address these limitations for Sc/Zr-modified high-performance Al-Mg alloys. By integrating in-situ picosecond laser ablation with conventional LPBF, the hybrid process achieved a remarkable 90% reduction in sidewall surface roughness (S_a from $53.7\text{ }\mu\text{m}$ to $5.2\text{ }\mu\text{m}$) through precise removal of melt spatter and adhered powder. Microstructural analysis revealed a fundamental shift from keyhole to conduction-mode melting under identical energy inputs, attributed to modified interlayer thermal cycles, which decreased porosity and promoted homogeneous $\text{Al}_3(\text{Sc,Zr})$ nanoprecipitates. The hybrid process enhanced mechanical properties significantly, with microhardness increasing by 23% (138 HV vs. 112 HV) and nanoindentation hardness doubling (8.79 GPa vs. 3.96 GPa), correlated with refined grains ($<1\text{ }\mu\text{m}$) and dense precipitation. Crucially, Williamson-Hall analysis and EBSD confirmed that ultrafast ablation induced negligible residual stress variations ($\epsilon = 0.3393$ vs. 0.3397) compared to conventional LPBF. This work establishes a microstructure-property linkage governed by thermal history modulation, demonstrating that synchronized subtractive processing not only improves geometrical accuracy but also tailors precipitation kinetics in heat-sensitive alloys. The findings provide a method for high-integrity fabrication of complex aluminum components, bridging the

Novel Post Processing with Augmented Machining (Machining+) for Metal Additive Manufacturing

Hao Wang

National University of Singapore

Abstract

Additive Manufacturing (AM) technology offers an efficient way to produce functional components with complex geometries and to explore new materials. However, the widespread adoption of AM-produced parts is hindered by issues such as poor surface quality and limited dimensional accuracy. As a result, post-processing or in-situ additive/subtractive methods are often necessary. The inherent difficulty of machining additively manufactured metal parts further complicates efforts to enhance quality. This presentation explores our recent study on the machinability of additively manufactured maraging steel. Our research includes examining the microstructural changes and mechanical properties affected by heat treatment and mechanochemical influences. Notably, cutting forces during machining for as-built and solution-treated SLMed samples are reduced significantly—by up to ~53%. This improvement highlights a promising approach to enhancing the machinability of additively manufactured metal components. Our findings contribute to advancing the integration and development of closed-loop additive/subtractive hybrid manufacturing systems.

Multiscale Phase-Field Modeling of Dendritic Growth and Dislocation Dynamics in Laser Additive Manufactured NiTi Alloys

Haodong Chen, Xun Li

Precision Manufacturing Institute, Wuhan University of Science and Technology

Abstract

During selective laser melting (SLM) processing, the rapid scanning of the high-energy laser beam induces non-equilibrium solidification of the melt pool, consequently forming heterogeneous complex microstructures. This study establishes a multiscale microstructure mathematical model that incorporates interpolated temperature field data from melt pool simulations into the phase-field framework, successfully reproducing the dynamic melt pool behavior, dendritic growth, elemental segregation, and precipitation phase effects on dislocation motion during SLM-fabricated NiTi alloys. The simulation results demonstrate excellent agreement with experimental validation. The results reveal that reduced volumetric energy density enhances cooling rates during melt pool solidification, resulting in decreased average primary dendritic arm spacing (APDAS), mitigated elemental segregation, and refined Ti₂Ni precipitates with dispersed distribution characteristics. The coupled phase-field and dislocation dynamics simulations incorporating thermal stress effects reveal that with increasing precipitate density, dislocation glide and propagation are effectively impeded, while dislocation multiplication and entanglement are concurrently promoted.

Key words: SLM; NiTi alloy; Phase field simulation; Dendrite growth; Dislocation motion;

Machine Learning-based Thermal Deformation Prediction for Laser Powder Bed Fusion

Li Haoyu, Liang Xuan *

Nanyang Technological University

Abstract

Laser powder bed fusion (LPBF) is a type of additive manufacturing (AM) technique by melting and fusing layers of metal powders into solid depositions. It can create complex three-dimensional (3D) geometries with fine structures. However, this process faces great challenge in managing thermal residual deformation caused by rapid heating and cooling cycles, which could cause defects like warping and cracking. Given this challenge, this study explores the application of machine learning (ML), especially recurrent neural networks (RNNs), to predict thermal residual deformation in LPBF. Building a model based on RNNs offers a more efficient approach to simulating the sequential layer-by-layer process and providing real-time predictions of thermal deformations. Capturing some factors such as thermal changes and geometric properties of the components, a home-made dataset will be established and used to train and test this model based on RNNs. This ML model successfully offers a computationally efficient solution for tuning and optimizing the LPBF process and will finally ensure high-quality production of 3D complex metal parts. It is promising to see some potential applications to the practical manufacturing industries in the future.

Electro-Mechanical Textile via Digital Knitting

Hong Yee Low

Engineering Product Development Pillar
Digital Manufacturing and Design Research Center
Singapore University of Technology and Design

Abstract

Digital knitting is a form of additive manufacturing process in which a digital file serves as an input to the knitting tool and through programmed mechanical needle movements, yarns are looped into various stitch patterns.¹¹ Digital knitting enables high degree of customization with the ability to integrate multiple yarns in various stitch patterns and stitch densities seamlessly into a single textile with minimal post-processing. Multiple yarn types can be knitted in a single knitting process hence the properties of the knitted fabric are the results of complex interplay between the intrinsic properties of the yarns (or combination of yarns) used and the knit structures (loop length and stitch patterns). In this talk, I will share the recent research in SUTD on digital knitting of electrical and mechanical functionalities through the synergy of functional yarns and stitch topology design. All knitted sensors, interconnect and resistor in a single garment-like wearables have been achieved with multiple sensors that enable real world, complex joint motion sensing. Traditional textile is soft and compliance materials. Here, digital knitting with multi-functional has been shown to achieve graded stiffness textile in a single knit. Garment-like electro-mechanical wearables have promising healthcare applications.

Two-Photon Polymerization Lithography: Enabling 3D Printing in Photonics

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Engineering Product Development, Singapore University of Technology and Design, Singapore, 487372, Singapore

Abstract

Two-Photon Polymerization Lithography (TPL) is a powerful technique for fabricating 3D and 4D photonic structures, offering true volumetric patterning with sub-diffraction resolution. Unlike traditional planar fabrication methods, TPL enables the direct writing of complex, free-form geometries, unlocking new possibilities in nanophotonic design and device integration. The versatility of TPL supports a wide range of applications, including full-color structural printing, multifocal 3D color displays, and high-resolution metasurfaces. It also facilitates the development of 4D photonic devices whose optical properties can be dynamically modulated after fabrication using shape-memory materials and mechanically reconfigurable architectures. These features are particularly advantageous for dynamic photonic systems, optical security, and responsive display technologies. Other representative demonstrations include submicron-resolution 3D color prints with spatial and angular multiplexing, mechanically stretchable structures for color tuning, and shape-transformable micro-architectures. Such examples illustrate how TPL can simultaneously achieve structural complexity, functional versatility, and high spatial precision—capabilities that are difficult to realize with other lithographic techniques. By combining nanoscale precision with the flexibility of additive manufacturing, TPL is emerging as a key enabler of next-generation photonic devices, where form and function are intrinsically linked.

Möbius Ring Resonators Fabricated by Two-Photon Polymerization

Gao Hongwei, Dawn Tan

Singapore University of Technology and Design

Abstract

We report the design and fabrication of a three-dimensional Möbius ring resonator using two-photon polymerization (2PP) of IP-Dip photoresist, engineered for operation at telecommunication wavelengths. The resonator features a waveguide with a cross-section of $2\ \mu\text{m} \times 6\ \mu\text{m}$ and an overall diameter of $88\ \mu\text{m}$, enabling relatively low-loss light guidance and high mode confinement at $1550\ \text{nm}$. IP-Dip, with a refractive index of 1.53 at this wavelength, provides both high optical transparency and sufficient refractive contrast to support single or few-mode operation in the near-infrared regime.

The Möbius topology, introduced through a half-twist along the ring's azimuthal path, breaks the spatial symmetry of traditional ring resonators and imparts a topological geometric phase shift of π per round trip. This unique configuration leads to parity-selective mode filtering, where specific resonant modes are either enhanced or suppressed depending on their field symmetry. Numerical simulations using finite-difference time-domain (FDTD) methods confirm the emergence of topologically modified resonances and altered free spectral range (FSR) characteristics, offering new degrees of freedom in spectral engineering.

The device was fabricated using a high-resolution Nanoscribe system, demonstrating the feasibility of printing optically functional, topologically complex structures at the microscale. Due to its enlarged size and robust geometry, the Möbius resonator is well-suited for practical integration in photonic platforms where high-Q filtering, mode control, and compact optical routing are essential. Applications range from mode-division multiplexing (MDM) and wavelength filtering to biosensing and chiral photonics.

This work underscores the potential of topological photonic structures enabled by 3D printing technologies, advancing the development of compact, robust, and functionally novel optical components for the telecommunication spectrum.

Microstructure refinement and strength enhancement of Ti-45Al-5Nb alloy via electromagnetic shock treatment

Hongxin Sun, Lechun Xie, Lin Hua

Wuhan University of Technology

Abstract

Electromagnetic shock treatment (EMST) has emerged as a highly promising clean-energy post-processing technology due to its high energy flux density and rapid energy transmission characteristics. Its appeal in enhancing the performance of advanced structural materials is growing steadily. However, the underlying mechanisms by which EMST modifies microstructures and improves mechanical properties—particularly in titanium aluminide alloys—remain insufficiently understood. In this study, the effects of EMST on the microstructure and mechanical behaviour of Ti-45Al-5Nb alloy were systematically investigated. Characterization methods included microstructural observation and mechanical property testing before and after EMST with varying treatment durations. The results revealed that the initial full-lamellar γ/α_2 microstructure with random orientations underwent significant refinement following EMST. No new phases were formed. The boundaries of the lamellar colonies transformed into interlocking structures. Coarse α_2 lamellae decomposed into finer γ/α_2 lamellae. The segregation of Nb was reduced, and its distribution became more uniform. Diffraction analysis showed peak shifts and intensity enhancements, indicating grain reorientation and texture weakening. Texture analysis confirmed a decrease in the maximum relative texture intensity and a more uniform distribution of grain orientations. Mechanical testing demonstrated improvements in both yield strength and fracture strain, attributed to the formation of refined γ/α_2 lamellar structures. This study provides new insights into the mechanisms of microstructural refinement and performance enhancement induced by EMST in TiAl alloys, highlighting its potential as a controllable and efficient post-processing technique for tailoring high-performance intermetallic materials.

Acoustic levitation for omnidirectional and multi-material in situ printing

Hongyi Chen, Shubhi Bansal, Diego Martinez Plasencia, Lucy Di-Silvio, Jie Huang, Sriram Subramanian, and Ryuji Hirayama

*Department of Computer Science, University College London;
Faculty of Dentistry, Oral & Craniofacial Sciences, King's College London;
Department of Mechanical Engineering, University College London*

Abstract

We report the design and fabrication of a three-dimensional Möbius ring resonator using two-photon polymerization (2PP) of IP-Dip photoresist, engineered for operation at telecommunication wavelengths. The resonator features a waveguide with a cross-section of $2\text{ }\mu\text{m} \times 6\text{ }\mu\text{m}$ and an overall diameter of $88\text{ }\mu\text{m}$, enabling relatively low-loss light guidance and high mode confinement at 1550 nm . IP-Dip, with a refractive index of 1.53 at this wavelength, provides both high optical transparency and sufficient refractive contrast to support single or few-mode operation in the near-infrared regime.

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This work underscores the potential of topological photonic structures enabled by 3D printing technologies, advancing the development of compact, robust, and functionally novel optical components for the telecommunication spectrum.

Two-photon polymerization-fabricated scaffolds: precise tools for regulating cell morphology and differentiation

Hongyu Zheng, Zheyu Yao, Wenhui Yu

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Abstract

Three-dimensional (3D) cell culture scaffolds serve as critical architectural platforms for directing cellular fate determination. Precise tunability of these biomimetic frameworks is fundamental for mimicking native tissue microenvironments and investigating cellular mechanisms. This research employed two-photon polymerization (TPP) to fabricate 3D scaffolds featuring three distinct architectures: conventional woodpile and honeycomb configurations, alongside biomimetic triply periodic minimal surfaces (TPMS). While woodpile and honeycomb structures represent established paradigms for 3D cellular studies, TPMS architectures exhibit closer structural resemblance to trabecular bone morphology. We systematically analyzed how scaffold topology and pore geometry regulate proliferation dynamics, morphological adaptation, and spatial organization of human mesenchymal stem cells (hMSCs). Advanced characterization methodologies, including scanning electron microscopy combined with multiplex fluorescence labeling and 3D confocal reconstruction, were implemented to assess cellular-scaffold interactions. It was revealed that hMSCs cultured within these 3D scaffolds demonstrated superior proliferation rates compared to their 2D counterparts. Notably, the cells on the scaffolds exhibited reduced nucleus areas, circularity, and aspect ratios, highlighting the profound impact of the scaffolds' physical characteristics on cellular morphology. Cells grown on the woodpile scaffolds displayed elongated morphology, aligning along the columns and forming an orderly arrangement. While hMSCs on honeycomb structures exhibit triangular and crescent cellular shapes with a more random orientation. TPMS variants induced architecture-specific morphological responses, suggesting surface curvature-mediated mechanotransduction. Furthermore, ALP staining showed a greater tendency for osteogenic differentiation with larger pore sizes. Different TPMS scaffolds exhibit varying effects on cellular morphology. These TPP-fabricated 3D scaffolds hold immense promise for advancing understanding of cellular behavior and offer a versatile platform for exploring tissue engineering strategies, disease modeling, and pharmacological assessments.

Accelerating Process Optimization and Design for Additive Manufacturing with Machine Learning

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² Department of Mechanical Engineering, Gachon University

Abstract

Additive manufacturing (AM) has revolutionized the fabrication of complex structures, yet achieving optimal process parameters and design solutions remains a persistent challenge due to the vast design space and inherent uncertainties in material and process behaviors. In this talk, we explore how machine learning (ML) can accelerate process optimization and design for AM, focusing on two key areas: high-precision digital light processing (DLP) 3D printing and AI-driven mechanical metamaterial design.

DLP 3D printing relies on digital mask images to selectively cure photopolymer layers, but uncertainties in optical phenomena and photopolymerization kinetics hinder precise pattern formation. We present an ML-driven inverse design approach that generates customized digital mask images to achieve highly accurate photopolymerized structures. By leveraging a high-speed data acquisition system that generates 10,000 training datasets in just 17 minutes, we train an ML model to predict optimal mask images for a given DLP system. This approach enhances printing accuracy, adapting to system-specific variations and improving the fidelity of fabricated structures.

The second part of the talk introduces a parameter-free ML framework utilizing point-cloud-based deep generative networks to explore and generate novel metamaterial designs. By constructing a latent space of known unit cell topologies and their mechanical properties through contrastive learning, we enable efficient design space exploration and smooth interpolation between different unit cell topologies. A dedicated regressor model further allows rapid property prediction, facilitating the discovery of new metamaterial architectures with tailored mechanical properties.

These ML-driven inverse design approaches illustrate how AI can break conventional design limitations, offering transformative solutions for AM process optimization and design automation. The synergy between data-driven learning and physical modeling paves the way for more efficient, accurate, and adaptable manufacturing workflows.

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

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Abstract

With advancements in additive manufacturing (AM) technology, researchers have identified that the high cooling rates and small-scale molten pool characteristics inherent to this process offer a viable pathway for fabricating bulk metallic glasses (BMGs). By precisely controlling processing parameters based on the energy density equation, molten pools in the Laser Powder Bed Fusion (LPBF) process can be systematically stacked, enabling the formation of fully dense final components.

Despite the theoretical advantages of LPBF for BMG fabrication, two primary challenges remain. First, the densification of printed structures is highly sensitive to process parameters, including laser power (P), scanning speed (v), hatch distance (h), and layer thickness (t). These four parameters collectively define the energy density, which governs molten pool behavior. Optimizing these parameters is critical to achieving a homogeneous arrangement of molten pools within the material, thereby maximizing densification. Second, the formation of a heat-affected zone (HAZ) due to heat conduction around the molten pool poses a significant risk to maintaining the amorphous structure. If the printed amorphous alloy is reheated beyond its glass transition temperature (T_g), crystallization may occur, compromising the material's desirable properties.

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.

3D printed strain sensors with organohydrogel-based structural

Hui Ying Yang

SUTD

Abstract

In this research, we demonstrate high-efficiency strain sensors fabricated via 3D printing. Organohydrogel-based strain sensors are gaining increasing attention for real-time healthcare monitoring and human-machine interaction due to their flexibility, stretchability, and skin-like compliance. However, their practical application is often limited by low sensitivity and poor stability, which arise from their bulk structure and strain concentration during deformation. To address these challenges, we designed and fabricated diamond-, grid-, and peanut-shaped organohydrogels with positive, near-zero, and negative Poisson's ratios, respectively, using digital light processing (DLP)-based 3D printing. Among these, the grid-shaped organohydrogel exhibited record-breaking sensitivity, achieving gauge factors of 4.5 (0–200% strain, ionic mode) and $13.5/1.5 \times 10^6$ (0–2% / 2–100% strain, electronic mode), along with full resistance recovery, indicating excellent stability. The 3D-printed grid structure also provided direct wearability and breathability, effectively overcoming key limitations of conventional sensors. When integrated with a robotic hand system, the sensor enabled precise monitoring of grasping movements in paralyzed patients, detecting motion with a minimum angle resolution of 5°. This structural design paradigm represents a significant advancement in flexible electronics, offering a synergistic combination of high sensitivity, long-term stability, wearability, and breathability for next-generation healthcare and human-machine interface applications.

AI Powered Metal Additive Manufacturing

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Abstract

Metal additive manufacturing (AM) enables the fabrication of complex 3D metal structures with minimal waste but faces challenges like residual stresses and warping due to rapid thermal cycling. AI has emerged as a powerful tool for optimizing process parameters and toolpaths, reducing trial-and-error inefficiencies. To enhance surface quality, an AI-driven virtual surface morphology prediction model using conditional generative adversarial networks (cGANs) accurately replicates real-world surface textures, improving mechanical properties and reducing anisotropy. Additionally, reinforcement learning-based toolpath optimization minimizes residual stresses and warpage by optimizing thermal distribution. AI-driven process optimization has also advanced AM applications in fields like smart metal components for nuclear microreactor development, where structural stability is crucial. Optical fiber sensors embedded in AM processes enable real-time structural monitoring, providing data for AI-driven thermal deformation analysis and early anomaly detection. These innovations make AM more cost-effective and efficient, paving the way for next-generation 3D-printed metal components with superior performance.

Embedding Lifecycle Intelligence in Additive Manufacturing: Multidisciplinary Optimization for Sustainable Design-to-Manufacturing”

Iñigo Flores Ituarte

Tampere University

Abstract

Designing for sustainability requires a paradigm shift—one where environmental considerations are embedded early and deeply within the digital design process. Traditional tools like Life Cycle Assessment (LCA) are often introduced too late, after key decisions regarding geometry, materials, and manufacturing processes have been made. This delayed integration limits their ability to influence sustainable outcomes. To address this, a forward-integrated approach is proposed—one that merges generative design, parametric modeling, and intelligent Computer-Aided Systems (CAx) to support real-time, multi-objective decision-making across the design-to-manufacturing continuum.

This paper presents three case studies that demonstrate a multidisciplinary design optimization framework combining generative design, sustainability assessment, and manufacturing process planning. The first case examines the large-scale production of wind turbine blade polymer molds using Large-Area Additive Manufacturing (LAAM), focusing on structural performance, material selection, and process efficiency under environmental constraints. The second explores the end-to-end workflow for a prosthetic device fabricated via material jetting, incorporating inverse design and environmental impact analysis. The third case investigates the generative design of a pressure vessel manufactured using duplex stainless steel via Wire Arc Directed Energy Deposition (DED), emphasizing manufacturability, mechanical reliability, and the minimization of material and energy usage.

By aligning digital design workflows with sustainability metrics from the outset, this integrated approach enables more than incremental improvements—it supports system-level transformation. The convergence of AI, simulation, and manufacturing-aware modeling empowers engineers to develop solutions optimized not only for performance and manufacturability but also for reduced environmental impact. Ultimately, embedding sustainability into early design decisions paves the way for more innovative, resilient, and responsible engineering outcomes.

Artificial intelligence-aided defect detection and healing in laser-based powder bed fusion

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Abstract

Metal additive manufacturing (AM) is gaining traction in academia, industry and mass media as a disruptive and general-purpose technology that is generally used to manufacture end-use parts, tooling, and rapid prototypes. However, its widespread adoption is hindered by its uncertainty in achieving stringent product specifications owing to the formation of defects, e.g., porosity, balling, cracking, lack of fusion, and geometric defects. The laser-based powder bed fusion (PBF-LB) process involves impinging laser energy that selectively fuses regions of powder bed. The hot laser-powder interaction zone ascertains a complex process which is not entirely understood. The process is inherent to large thermal gradients, heat absorption, local melting and re-solidification of particles, phase change, plumes, spatter, and Marangoni convection.

The aim of this study is to deploy artificial intelligence (AI) to detect and extract spatial and temporal defects (self-sensing) and compensate the anomalies (self-healing) in the AM process. Three designs of experiments are conducted with three different types of test specimens (n=32) to evaluate the impact of defect detection, defect healing, and both defect detection and healing. The results were verified with metallography and x-ray computed tomography. Optical tomography infrared images of each additively manufactured layer of test specimen were used to train multinomial logistic regression (MLR), artificial neural network (ANN), and convolutional neural network (CNN) machine learning models.

CNN yielded impeccable accuracy of up to 100% in detecting defective regions using independent test dataset unfamiliar to the model for unbiased evaluation. The outcome confirmed that Ti-6Al-4V can self-heal defective regions up to 7 ± 1 layers using the standard volumetric energy density. The high performance and low cost of computing observed in this work can have the potential to detect and eliminate defective regions by tuning the processing parameters in real time resulting in significantly decreased costs, lead-time, and waste. The proposed quality control can enable mass adoption of additive manufacturing technologies in a vast number of industries for critical components that are design- and shape- agnostic.

Tensile testing of thermoplastic composites printed by Fused Filament Fabrication – challenges, results, finite element modelling

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Abstract

Assessing the tensile properties of materials is crucial for understanding their mechanical behavior and ensuring their effective practical application. In recent years, thermoplastic composites produced using additive manufacturing technologies have gained increasing attention. These techniques introduce unique characteristics, such as novel material deposition methods and distinct layering processes, which significantly influence the mechanical properties of printed structures compared to conventionally manufactured products.

For evaluating the tensile properties of composites printed using Fused Filament Fabrication (FFF) technology, existing standards originally designed for conventionally manufactured composites and plastics—such as ASTM D3039, ASTM D638, ISO 527, and ASTM/ISO 52924—have primarily been used. However, practical experience indicates that these standards may not be fully suitable for additively manufactured materials. One recurring issue is the frequent failure of specimens outside the designated gauge section.

This study focuses on analyzing the applicability of these standards for tensile testing of printed plastics and thermoplastic composites reinforced with both chopped and continuous fibers. Various failure modes will be examined based on filament/reinforcement configurations, accompanied by a statistical evaluation of specimens that failed inappropriately. Based on these findings, measures will be proposed to eliminate stress concentrators that contribute to premature specimen failure.

The most suitable specimen geometry for tensile testing of FFF-printed plastics and thermoplastic composites will then be utilized to determine tensile properties across different material configurations within the printed structure. Furthermore, this optimized approach will be compared with conventional measures, such as tabs and tapers of various shapes. Finally, accurately determined tensile properties will also contribute to the development of a relevant finite element model for tensile test simulations, the preparation and validation of which will be presented.

Evaluation of machine learning methodology for predicting fatigue model data for metal additive manufacturing materials

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Abstract

The widespread adoption of Additive Manufacturing (AM) across various industries is driven by its exceptional design flexibility and rapid production capabilities. However, fatigue failure remains a critical concern in AM components, potentially resulting in catastrophic consequences if not adequately addressed. Fatigue testing of AM components is both time-intensive and laborious, with results highly influenced by the presence of various defect types inherent to AM processes. To overcome this challenge, a novel fatigue prediction model was developed using machine learning techniques, leveraging tensile properties as input features. The model was built, optimised, and validated through multiple methods, demonstrating high accuracy in predicting the fatigue constants of Basquin's Equation with narrow deviations from experimental data.

Nanoscale Additive Manufacturing for Photonic Anti-counterfeiting Labels

Ji Tae Kim

KAIST

Abstract

Counterfeiting threatens the global economy and security. According to the report issued by the United States Patent and Trademark Office (USPTO) in 2020, the value of global counterfeit and pirated products is estimated between US\$ 1.7 and 4.5 trillion a year. Despite enormous efforts, conventional anticounterfeiting approaches such as QR codes can be easily fabricated due to limited data encryption capacity on a planar space. How can we increase the encryption density in a limited space?

Here, we will present our nano-liquid 3D printing method of photonic materials [1] that can fabricate vertical nanopixels with programmed shape, composition, and crystallinity. The key idea of this method is to incorporate molecular assembly/crystallization pathways into the 3D printing process, providing unprecedented versatility and simplicity in micro-/nanomanufacturing of multilevel anti-counterfeiting labels. First, vertical stacking of optical elements in a single nanopixel enables the encryption capacity to be exponentially increased: For example, 211 can be stored in a single eleventh-segmented freestanding pixel on a tiny 4 μm^2 area. Second, by diversifying materials selection such as organic dyes [2], perovskites [3], peptides [4], we can utilize various light-matter interactions such as fluorescence, lasing, and birefringence to integrate security labels.

In this talk, I will discuss the prospects and potential applications of our work for advanced displays.

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Extrusion bioprinting via multi-nozzle syringe

Jia An, Zhixiang Ong, Qingyang, Tan, Jia Wei Tay, Aakanksha Pant, U-Xuan Tan, Chee Kai Chua

Singapore University of Technology and Design

Abstract

Extrusion bioprinting is an additive manufacturing technique that deposits bioinks layer by layer to create 3D biological structures. It is the most widely used bioprinting method due to its ability to print high viscosity bioinks, maintain cell viability, and fabricate large-sized tissue constructs. The conventional syringe used in extrusion bioprinting usually involves a single nozzle. Multi-nozzle extrusion requires integrating multiple conventional syringes, adding complexity to both hardware and software development. In this research, we proposed a novel syringe design to enable multi-nozzle extrusion in a single syringe, i.e. increasing the number of nozzles in a re-sized syringe (without using any tubing or connectors). A single syringe with 15 nozzles was designed and prototyped via 3D printing. This presentation aims to discuss some fundamental differences observed between single-nozzle syringe extrusion and multi-nozzle syringe extrusion.

Engineering Conductive PEDOT:PSS Inks for Bioelectronics

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SC3DP

Abstract

Conductive polymer PEDOT:PSS has shown great potential as material for combining electrical materials with bioprinted structures. Its flexibility, biocompatibility, and tunable conductivity make them ideal for introducing electronic features to biological systems. This study looks into PEDOT:PSS-based conductive ink, evaluating its printability, biocompatibility, and capacity to initiate biological responses. Additives are used to adjust the ink formulation, allowing for direct writing of conductive traces. Additives altered electrochemical properties while maintaining structural stability in printed patterns. Of the various additives assessed, the impedance values at 1kHz ranges from 78 – 282Ω which resembles closely to non-additives formulation (101 – 134Ω). The bioprinted conductive ink demonstrated a suitable environment for HL-1 mouse atrial cardiomyocyte cell survival, achieving 98% cell viability following culture. Fluorescence imaging using the calcium-sensitive dye Calbryte 520 showed that HL-1 maintained its biological responses in terms of electrical propagation. Bioprinting enables the selective deposition of conductive ink with cell-laden bioink, resulting in improved design and integration of electrical and biological components in bioelectronics. This work contributes to the development of bioelectronic platforms that link biological systems with electronics, with potential applications in tissue engineering, brain interfacing, and biosensing.

A material-agnostic and trustworthy meltpool states recognition based on in-situ acoustic emission monitoring in laser powder bed fusion

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Abstract

Monitoring the melt pool of laser powder bed fusion (LPBF) is a crucial step in achieving the stable and consistent quality of the formed parts. The combination of acoustic emission (AE) and deep learning (DL) methods has shown great potential in the process monitoring of LPBF. However, most DL-based methods of data-hungry face the generalization challenge, and fail to recognize the states of meltpool under cross-materials. Additionally, the untrustworthy prediction results cripple the real-world deployment of DL methods. In this work, we proposed a material-agnostic and trustworthy method based on AE for LPBF in-situ process monitoring. Specifically, we align distinguishable features of cross-material domains into a general embedding space to transfer domain knowledge. Furthermore, we utilize a simple and effective post-processing calibration method to improve the confidence of the DL-based model prediction. Massive experiments on the AE dataset have demonstrated our method can provide a promising track for materials-agnostic LPBF monitoring.

3D-printed tempeh for spatially controlled texture

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Abstract

Tempeh fermentation is a solid state fermentation process which utilizes fungi from the *Rhizopus* species to create a white, cake-like product. This product has been widely consumed in many South East Asian countries as it is an affordable source of protein. Traditionally, this process is done with dehulled boiled soybeans to create tempeh. In recent years, the same process has also been applied to various other seeds, such as cereals or legumes, to create unique textures and flavours. However, the tempeh fermentation process often requires the seeds to be packed into containers, this results in the density of the product to be limited by the default packing density of the seeds used. To address this limitation, we utilized 3D food printing to spatially control the density of the 3D-printed seed inks. Our study explored a wide range of infill densities (11-100 %) and found that tempeh fermentation performed best with infill densities above 45 %. In general, we found that increasing infill density resulted in a fermented product with higher hardness and adhesiveness due to the denser mycelium network formed. With the aid of 3D food printing, traditional food products such as tempeh could be revolutionized to create food with a wider range of texture and flavours.

Laser additive manufacturing of a novel NiTi thin-walled metamaterial for improving manufacturability and mechanical protection

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Abstract

Thin-walled thermo-mechanical protection structures manufactured by laser powder bed fusion (LPBF) have shown great potential for spacecraft development. However, the fabrication of thin walls remains challenging due to the high residual stresses inherent during LPBF. In this work, a series of thermo-mechanical protection structures based on doubly periodic continuous surfaces (DPCSs) were constructed and their laser printability, mechanical performance, and deformation behaviors were investigated. The results indicated that DPCSs effectively maintained structural integrity by dispersing the in-plane stress field and deformation field, while the solid parts exhibited more severe delamination and distortion. Samples without visible macro defects were successfully fabricated under the optimized strategy, exhibiting a size error of less than 3% and a relative density higher than 99%. DPCSs exhibited superior ultimate tensile strength (~93.5 MPa) to some triply periodic minimal surfaces (TPMSs) and honeycomb structures. Compared with the solid-wall chiral twisted structure (CTS), the DPCS-based CTS showed a unique double negative stiffness deformation behavior and achieved a 48.5% improvement in structural efficiency. Notably, the DPCS-based lattice structures showed superior mechanical flexibility with an ultra-low modulus of ~13.9 MPa approaching that of rubber-based TPMS, which can be attributed to the combination effect of wavelike deformations, high deformation degree of freedom, and effective stress transfer. The findings could serve as a valuable reference for the design and fabrication of mechanical protection systems.

3D bioprinting of high-performance hydrogel for cell therapy

Jie Tao
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Abstract

Digital light processing (DLP)-based bioprinting technology holds immense promise for the advancement of hydrogel constructs in biomedical applications. However, creating high-performance hydrogel constructs with this method is still a challenge, as it requires balancing the physicochemical properties of the matrix while also retaining the cellular activity of the encapsulated cells. Herein, we propose a facile and practical strategy for the 3D bioprinting of high-performance hydrogel constructs through the in-situ birth of stem cell spheroids. The strategy is achieved by loading the cell/dextran microdroplets within gelatin methacryloyl (GelMA) emulsion, where dextran functions as a decoy to capture and aggregate the cells for bioprinting while GelMA enables the mechanical support without losing the structural complexity and fidelity. Post-bioprinting, the leaching of dextran results in a smooth curved surface that promotes in-situ birth of spheroids within hydrogel constructs. This process significantly enhances differentiation potential of encapsulated stem cells. As a proof-of-concept, we encapsulate dental pulp stem cells (DPSCs) within hydrogel constructs, showcasing their regenerative capabilities in neovascular-like structures in vivo. The strategy in our study enables high-performance hydrogel tissue construct fabrication with DLP-based bioprinting, which is anticipated to pave a promising way for diverse biomedical applications.

Sustainable 3D Printing Based on A Multifunctional Photoinitiator

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Abstract

Thermosetting photopolymer resins constitute approximately 50% of the global 3D printing material market. Despite their widespread use, they pose significant sustainability issues due to their energy-intensive production, substantial carbon footprint, and inherent resistance to degradation arising from their crosslinked networks. Current alternative materials often target specific monomers or crosslinkers, which can compromise mechanical and thermal stability or lack broad applicability. We address these challenges through the development of a novel multifunctional photoinitiator. This photoinitiator enables the polymerization of various monofunctional acrylates into crosslinked thermosets that degrade under mild acidic conditions. Post-degradation, the resulting linear polymers can be dissolved in fresh monomers for closed-loop reprocessing, yielding materials with enhanced mechanical properties compared to their original state. Furthermore, this approach supports the precise 3D printing of complex structures, with printed objects demonstrating complete degradation in weakly acidic soil (pH 6) within approximately 75 days. Phytotoxicity and acute toxicity assessments confirm that the degradation products exhibit negligible environmental impact on plant growth and ecosystems. This presents a promising and universal strategy for creating recyclable and biodegradable thermosets for 3D printing.

The Influence of Rice Husk Biochar Particle Size on Printability, Performance and Sustainability of 3D Concrete Printing

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Abstract

Thermosetting photopolymer resins constitute approximately 50% of the global 3D printing material market. Despite their widespread use, they pose significant sustainability issues due to their energy-intensive production, substantial carbon footprint, and inherent resistance to degradation arising from their crosslinked networks. Current alternative materials often target specific monomers or crosslinkers, which can compromise mechanical and thermal stability or lack broad applicability. We address these challenges through the development of a novel multifunctional photoinitiator. This photoinitiator enables the polymerization of various monofunctional acrylates into crosslinked thermosets that degrade under mild acidic conditions. Post-degradation, the resulting linear polymers can be dissolved in fresh monomers for closed-loop reprocessing, yielding materials with enhanced mechanical properties compared to their original state. Furthermore, this approach supports the precise 3D printing of complex structures, with printed objects demonstrating complete degradation in weakly acidic soil (pH 6) within approximately 75 days. Phytotoxicity and acute toxicity assessments confirm that the degradation products exhibit negligible environmental impact on plant growth and ecosystems. This presents a promising and universal strategy for creating recyclable and biodegradable thermosets for 3D printing.

Self-Support Topology Optimization for Multi-axis Additive Manufacturing Incorporated with Curved Layer Slicing

Shuzhi Xu, Jikai Liu, Kentaro Yaji

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Abstract

Multi-axis additive manufacturing significantly surpasses traditional 3-axis systems by utilizing multiple axes of motion to construct complex three-dimensional structures with reduced support requirements. However, process planning for curved layer slicing critically determines the interactions between the part and supports. Consequently, self-support topology optimization necessitates a numerically tractable process planning algorithm to derive sensitivities, which has yet to be fully achieved. To address this gap, we develop a structural topology optimization method for multi-axis additive manufacturing, featuring the self-support effect through the deep integration of curved layer slicing. Specifically, a process scalar field is generated on a domain of pseudo-densities by solving a heat diffusion equation and a Poisson equation. The geodesics within the scalar field facilitate curved layer slicing, enabling the derivation of geometric information about the layers directly on the pseudo-densities via a numerically tractable processing routine. Self-support constraints for multi-axis additive manufacturing are then established by measuring the curved layer normal and part boundary gradients. Coupled with density variables for topology optimization, our proposed method concurrently optimizes the part structure and its curved slicing pattern, maximizing structural performance while eliminating the need for supports. Finally, we validated and demonstrated the effectiveness of our method through a series of numerical tests and provided a workflow illustrating the strong correlation between our optimized results and the actual spatial paths, as shown in the figure below.

3D printed Knot-Based Resonators Structures

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Abstract

Traditional Electron Beam Lithographic techniques are predominantly used for maskless lithography at the nanometre scale for ease of CMOS integration. However, it is constrained to two-dimensional fabrication with significant limitations in exploring complex resonator geometries. Recent breakthroughs in additive manufacturing technologies have significantly expanded the design freedom for fabricating architecturally intricate micro- and nanoscale structures with sub-diffraction-limit precision. Two-photon polymerization lithography has been shown to be particularly advantageous due to its ability to fabricate three dimensional nanostructures. Advances in topological photonics have demonstrated the potential of nontrivial structures, such as Möbius strip and Spherical-based resonators, enhancing waveguiding properties and challenging conventional design paradigms. However, extending such concepts into three-dimensional topological geometries is largely unexplored. Amongst such geometries, trefoil knots present an intriguing avenue for robust optical confinement and wave manipulation. In this work, we leverage two-photon polymerization laser lithography to fabricate three-dimensional resonator structures inspired by topological trefoil knots, which offers unique modal properties for optical data transmission. Theoretical studies suggest that trefoil knot resonators enable robust light confinement, showing promising uses in topologically protected data encoding and optical information transfer. Building on these insights, we experimentally realize such structures and assess their optical performance for fibre-based optical communication and data transmission. SEM images are presented, with characterization of their optical properties. By introducing a new class of resonator geometries, our approach extends the design space of photonic resonators beyond traditional constraints, offering new opportunities for applications such as high-capacity data multiplexing.

Reinforcement Learning Framework for Optimizing Random Voronoi Lattice Structures

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Abstract

We present a novel computational framework for the design and optimization of heterogeneous lattice structures inspired by biological systems. Leveraging reinforcement learning, the system explores non-periodic Voronoi-based architectures with spatially tunable properties. The proposed approach integrates automated geometry generation, performance evaluation, and iterative learning to improve target mechanical responses. Preliminary tests demonstrate the framework's potential to steer lattice morphologies toward enhanced structural characteristics such as stiffness and deformation control. The method's modular nature offers extensibility to a variety of design objectives and applications, serving as a promising foundation for intelligent design of architected materials.

Crack Control in Laser Powder Bed Fusion of Nickel-Based Superalloy Hastelloy X: Optimization of Scanning Strategies and Nano-Modification

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Abstract

In this work, we present new advancements in crack control during laser powder bed fusion (LPBF) processing of the nickel-based superalloy Hastelloy X (HX). LPBF, with its high flexibility, concentrated energy, and near-net-shape capability, has emerged as an effective method for fabricating complex nickel-based superalloy components. However, the rapid solidification inherent to LPBF leads to high thermal gradients and stress concentrations, resulting in a high susceptibility to cracking during the fabrication of HX, a challenge that has garnered significant research attention. To address this issue, we employed laser scanning strategy optimization and nano-modification techniques to mitigate and eliminate cracks in LPBF-manufactured HX. Results revealed that HX specimens produced using the unidirectional-remelting strategy exhibited significantly fewer and finer cracks, with equiaxed grain structures and compressive residual stresses. The addition of 0.2 wt% hexagonal boron nitride (h-BN) effectively modulated laser absorption, improving the temperature field and eliminating cracks. The optimized 0.2 wt% h-BN/HX specimens displayed negligible cracks or unmelted particles, a minimal surface roughness of 9.29 μm , and outstanding tensile properties, with a tensile strength of 1246.49 MPa and an elongation of 18.67%. Additionally, the modified samples demonstrated enhanced hardness (371.21 HV5) and a reduced friction coefficient (0.54). Notably, increasing h-BN content led to further improvements in strength and hardness while decreasing the friction coefficient, though at the expense of ductility. The 1 wt% h-BN/HX sample exhibited a tensile strength of 1503.14 MPa, hardness of 502.13 HV5, and a friction coefficient of 0.48 but exhibited limited elongation of 3.76%. These findings highlight the critical role of optimized composition and scanning strategies in improving the quality and performance of LPBF-manufactured nickel-based composites, particularly for aerospace and engineering applications.

Microstructure and enhanced wear and oxidation resistance of tungsten carbide reinforced Inconel 625 matrix coating using high-speed laser metal deposition

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Abstract

A tungsten carbide (WC) reinforced Inconel 625 coating produced via high-speed laser metal deposition (HS-LMD) with capability of scanning speed up to 30,000 mm/min was investigated. The resulting coating exhibits a refined cellular/dendritic microstructure with uniformly distributed WC particles within the Inconel 625 matrix, due to the high cooling rate associated with the HS-LMD process. A thinner layer of HS-LMD coating ($\sim 70 \mu\text{m}$) without pores and crack defects shows strong metallurgical bonding with 316L substrate. The wear volume is reduced by 75% compared with traditional LMD coating and a 67% reduction in wear rate. The hardness was increased from 334HV for LMD to 403HV for HS_LMD. The enhancement of the wear resistance of HS-LMD coating is attributed to the microstructural refinement with additional effect from the homogeneously distributed WC particles. Meanwhile the HS-LMD coating demonstrates minimal dilution and reduced micro-segregation, resulting in a high-quality, crack-free surface with improved mechanical properties and high temperature oxidation resistance.

Keywords: High speed laser metal deposition, metal matrix composites coating, tungsten carbide, Inconel 625, microstructure, tribology and oxidation behavior

Dual metabolic reprogramming of cancer cells and macrophages via a 3D-printed CuMn platform potentiates systemic anti-tumor immunity

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Abstract

Metabolic reprogramming is a hallmark of cancer, yet current cancer metabolism therapeutics primarily target cancer cell-intrinsic pathways while overlooking the metabolic interplay within the tumor microenvironment. Here, we reveal through pan-cancer bioinformatics analysis that cancer cells exhibit hyperactive glycolysis, while immunosuppressive macrophages display elevated fructose metabolism. This heterogeneous cancer metabolism niche motivates us to explore a dual metabolic reprogramming strategy simultaneously targeting glycolysis in cancer cells and fructose metabolism in macrophages. We screen various metal ions and identify Mn²⁺ as a selective and potent disruptor of cancer cell glycolysis, inducing pyroptosis via suppression of key glycolytic enzymes. Leveraging this finding, we engineer a 3D-printed nanoporous CuMn metalloplatform that enables sustained Mn²⁺ release to target cancer cells while delivering the fructose metabolism inhibitor KHK-IN-2 to reprogram pro-tumor macrophages. In a bilateral 4T1 breast cancer model, this dual metabolic reprogramming metalloplatform suppresses tumor glycolysis, triggers cancer cell pyroptosis, polarizes macrophages toward an anti-tumor M1-like phenotype, and initiates robust anti-tumor immunity, achieving potent regression of both primary and abscopal lesions. Our study highlights the therapeutic potential of coordinated metabolic reprogramming in both cancer and immune cells, offering a new strategy to reshape the cancer metabolism niche and potentiate systemic anti-tumor immunity.

A hybrid machine learning model for predicting residual stress and optimising process parameters in directed energy deposition

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Abstract

Laser-directed energy deposition (L-DED) is a transformative approach to metal remanufacturing, offering precise spatial control, superior thermal management, and high deposition rate, making it a promising alternative to traditional welding. A common technique for rectifying localised surface damage is filling repair. Despite its widespread use, this approach is susceptible to interfacial cracks attributed to high residual stress introduced by the high energy density of the L-DED process. Due to the complexity of the filling repair geometries, dedicated process parameter optimisation is essential to mitigate defects and ensure optimal repair quality. Recent advancements in hybrid machine learning (ML) models, which integrate data from multiple sources or fidelities, have shown promise in balancing accuracy and cost. However, their adoption has been largely restricted to single-track L-DED. This study aims to develop a hybrid ML model to predict residual stress and analyse its relationship with key L-DED process parameters for filling repair applications. Data were obtained from two sources, experiments and finite element (FE) modelling, both strategically sampled within a feasible process window using the design of experiment (DoE) approach to train a neural network model. The model was developed in two sequential stages using transfer learning: (1) pre-training with substantial FE modelling data to capture the physics and address initialisation challenges, followed by (2) fine-tuning with limited experimental data. Ultimately, response surface methodology (RSM) was employed to construct process maps for optimising process parameters with respect to residual stress. The reliability of the established relationship between the process parameters and residual stress was validated against an unseen experimental dataset, demonstrating the potential to minimise experimental data requirements without compromising accuracy. The current work focuses on a fixed repair geometry as a proof of concept, future work will extend the hybrid ML model to accommodate larger repair sizes and varied configurations.

Optimising Mechanical Performance in laser powder bed fusion of Ti-6Al-4V: Interplay of Powder Packing, Surface Orientation, and Predictive Modelling

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Abstract

In laser powder bed fusion (PBF-LB/M) of Ti-6Al-4V, the mechanical reliability of printed parts is influenced by the powder quality, local powder bed density, spatial orientation of surfaces, process parameters, and the final microstructure. This work presents a comprehensive study combining experimental characterisation, in situ analysis to decode the relationships between powder behaviour, build geometry, and part performance. Four commercial virgin powders were evaluated for particle morphology, surface chemistry, flowability, and size distribution, revealing that traditional bulk metrics insufficiently predict final part quality. A layer-wise powder-bed capsule approach coupled with micro-computed tomography quantified powder bed density (layer), confirming that values exceeding 65% of theoretical density significantly reduce porosity and enhance tensile strength.

To complement these findings, we deployed a custom machine learning framework trained on particle and flow properties to predict powder bed packing density prior to printing. This model, integrated into a user-accessible interface, demonstrated strong agreement with experimental layer values and enables rapid feedstock screening. Additionally, fatigue analysis of vertically and angularly oriented specimens revealed that surface orientation critically affects fatigue life. Downward-facing surfaces consistently exhibited inferior performance due to poor support and roughness accumulation. Surface enhancement strategies—such as Freefloat support software and brush recoaters—were tested, showing marked improvements in overhang quality and geometric stability. This integrated approach offers valuable pathways for optimising feedstock selection, build design, and process control to realise mechanically robust AM components.

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Strategies For Fatigue Design, Testing and Qualification of Parts Printed by Metal Additive Manufacturing

Pang Hock Lye John

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Abstract

Strategies fatigue design, testing and qualification of parts printed by Metal Additive Manufacturing (AM) for AM part design review, structural integrity assessment, asset life cycle analysis, and risk assessment for critical mission parts. An overview of the part classification and qualification requirements are presented for powder bed fusion of metal using laser beam (PBF-LB) and DED pre-process qualification for AM machine, in-process qualification for AM parts at specimen level and post-process qualification for AM parts.

For PBF-LB and DED, in-process and part qualification procedures for mechanical tests and fatigue test requirements for critical mission parts will be presented. Strategies for qualification of parts printed by metal AM and the related fatigue testing requirements for part fatigue performance assessment will be covered. AM process qualification aim to develop a baseline process parameter setting for the material-operator-machine qualification procedure to produce AM parts with the desired mechanical properties, dimensional accuracy, surface roughness, defects impact on fatigue life performance.

The test methods and standards, quantity of test specimens, build orientation and post-processing condition will be specified in the AM qualification plan with the acceptance criteria within an acceptable range. Strategies on designing the baseplate design for mechanical test (tensile, impact), fracture toughness, and fatigue test requirements will be presented. Post-processing qualification requirements for AM parts includes inspection; post-processing requirements for heat treatment; and surface finish requirements and its influence in enhancing 3D Printed Part fatigue performance.

Advances in 3D Printing of Magnetic Materials: Current Status, Challenges, and Future Directions

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Abstract

3D printing technology has the potential to innovate the design and manufacturing of precision components in aerospace, automotive, medical, and defense industries. Despite its widespread application in structural materials, its use in producing functional magnetic materials remains limited. Recently, with rising electrification from clean energy and electric vehicles (EVs), the demand for magnetic materials has grown significantly. In particular, soft magnetic materials (e.g., Fe-Si alloys) require complex 3D geometries with high efficiency and lightweight design for electric motors, which conventional casting and powder metallurgy cannot provide. Similarly, hard magnetic materials (e.g., NdFeB) benefit from intricate designs that enhance performance and enable more compact, efficient devices. By leveraging 3D printing, producing customized magnetic components with tailored properties is increasingly feasible, expanding possibilities for advanced magnetic applications. However, 3D printing of magnetic materials is still developmental.

This paper presents the current status and challenges in 3D printing of magnetic materials and provides an overview of their characteristics for electric machines. It also discusses research directions for developing magnetic materials, processes, and specialized 3D printing equipment. Additionally, machine learning and artificial intelligence are being integrated to enable effective process optimization, including complex dataset analysis, prediction of optimal parameters, and real-time adjustments to improve print quality and performance. Preliminary results indicate promising advancements in both the mechanical and magnetic properties of printed components, highlighting their potential for improved performance in electric machines. Specialized 3D printing equipment is being explored to enhance precision and efficiency, allowing intricate geometries not achievable by conventional methods. These developments may significantly improve the integration of magnetic components into electric machines, optimizing performance and enabling the development of lighter, more compact designs.

Microalloying at the melt-pool in Laser Powder Bed Fusion: A key technology to produce Shape Memory Alloy devices at Earth and in the Space.

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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, prevents to fulfil a good industrial productivity and also restrict the potential use of AM for the production of SMA devices in the space.

To solve this challenging problem, in the present work a new methodology of microalloying the SMA powders at the melt-pool during AM by Laser Powder Bed Fusion (LPBF), is presented. Starting from the atomization of the SMA powders, the LPBF is 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.

3D-printable poly(vinyl alcohol) for sacrificial molding in biomimetic matrices

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Abstract

Sacrificial molding in biofabrication involves the removal of 3D-printed sacrificial material embedded in extracellular matrix (ECM) hydrogels to create perfusable vasculatures for tissue engineering. Poly(vinyl alcohol) (PVA) is a common sacrificial material used for sacrificial molding due to its biocompatibility, water solubility, and mechanical strength. However, 3D-printed PVA structures faces challenges with preserving their structural fidelity, as they are prone to rapid swelling and deformation in the warm and aqueous environment of hydrogel matrices, and eventually dissolve with prolonged exposure. To address this problem, we developed a composite filament with improved water resistance based on multiple types of PVA to create biomimetic vasculatures within hydrogels. The composite material possesses greater inherent water resistance than commercial PVA filaments, while it remains compatible with fused deposition modelling (FDM) 3D printing. With the composite material, sacrificial molding was readily demonstrated to fabricate perfusable microchannels in various hydrogels including warm and slow-curing cell-seeded transglutaminase (TG)-gelatin. In addition, We also demonstrated developed a novel FDM method technique for printing PVA, that creates to create overhanging, highly smooth, and rounded PVA structures without the common 3D-printed layered stepping defects. With this capability, 3D microchannels with smooth and rounded profiles were demonstrated, representing the physiological characteristics of in vivo vasculatures. Lastly, complex 3D branching, intertwining, and interlocking microchannels were achieved using our printing technique. Overall, our work has enabled the biofabrication of vasculatures with unique geometries within a wider range of hydrogels that are unattainable with conventionally 3D-printed sacrificial molds.

Large-scale AI models optimize bone microstructure and enhance additive manufacturing artificial bone design

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Abstract

Background: Conventional artificial bone design struggles to replicate the hierarchical microstructure-property relationships of native bone tissue, limiting additive manufacturing (AM) applications in load-bearing implants.

Objective: To develop an integrated AI-driven framework for autonomous optimization of bone-inspired meta-architectures and their manufacturable digital twins.

Methods: We established a multimodal deep learning platform combining 3D conditional generative adversarial networks (cGANs) with physics-informed reinforcement learning (PPO algorithm). The system processed μ CT-scanned natural bone datasets ($n=287$) to extract topological design rules, then iteratively evolved trabecular geometries under finite element analysis (FEA)-validated biomechanical constraints (compressive/torsional loading). Multi-objective optimization targeted pore size (200-800 μ m), strut thickness (50-150 μ m), and surface curvature.

Results: AI-generated structures exhibited $99.2\pm0.3\%$ strain energy distribution fidelity versus natural bone ($p<0.001$) and 28.7% higher fatigue strength (10^7 cycles) than topology-optimized benchmarks. The differentiable pipeline simultaneously output gradient-adjusted AM parameters (layer thickness: 25-75 μ m, laser power: 80-120W) enabling direct fabrication of Ti-6Al-4V lattices with $96.4\pm2.1\%$ dimensional accuracy. In vitro testing confirmed enhanced osteoconduction (cell viability +34.1%, $p=0.002$).

Conclusion: This foundation model transcends trial-and-error paradigms by decoding implicit structure-property-manufacturing linkages, establishing an intelligence-driven orthopaedic implant design doctrine.

Keywords: Biomimetic meta-biomaterials; AI-driven inverse design; Multiscale biomechanical optimization; Laser powder bed fusion; Digital twin manufacturing; Bone tissue engineering.

Biofabricated Multiorgan-on-a-Chip for Disease Modeling and Therapeutic Screening

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Abstract

The advancement of precision medicine requires in vitro systems capable of capturing complex inter-organ interactions. Here, we introduce a biofabricated dual-organ microfluidic platform that models two clinically interconnected conditions: secondary hyperoxaluria (SH) and cardiorenal syndrome (CRS). To replicate SH pathophysiology, a gut-kidney model was engineered using multi-biofabrication and 3D bioprinting technologies, spatially integrating intestinal epithelium with a vascularized renal proximal tubule (PT) under dynamic perfusion. This model successfully mimicked SH-associated events, including intestinal barrier dysfunction, calcium oxalate (CaOx) crystal formation, and PT injury. Functional validation was achieved via glucose reabsorption assays and CaOx crystal behavior. Therapeutic relevance was demonstrated by evaluating the crystal-dissolving efficacy of trisodium citrate and grape seed extract. Building upon this, the platform was extended to simulate CRS by incorporating a 3D bioprinted myocardial unit with the PT. The PDMS-based microfluidic system supported real-time analysis under flow, while a 3.0 wt.% PEDOT:PSS-printed conductive structure enabled electrical monitoring of myocardial responses to PT-derived pathophysiology. This configuration allowed dual functional readouts—electrochemical sensing and PK/PD-based assessments—within a single chip. Altogether, this integrated system offers a scalable, physiologically relevant model for investigating disease mechanisms, screening therapeutics, and enabling real-time monitoring of multi-organ dynamics. It highlights the potential of additive manufacturing in advancing personalized diagnostics and therapeutic discovery in complex systemic disorders.

Computational investigation of a 3D-printed osteochondral interface scaffold with comprehensive interfacial mechanical properties

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Abstract

Osteoarthritis is a highly prevalent rheumatic musculoskeletal disorder that usually ends up with physiological malfunction and psychological hurt. Although many tissue engineering approaches have been proposed to provide a prospective strategy for tissue regeneration purposes, the improper mechanical properties of proposed scaffolds are unable to satisfy mechanical demands within the joint fully. This paper presents computational investigation and structural design for creating the osteochondral interface scaffold. A finite element method (FEM) based mechanics simulation model was proposed to evaluate the effect of load-bearing forces on various scaffolds, by which the stress distribution in the biomimetic osteochondral interface can be acquired. Several structures of osteochondral interface scaffolds were fabricated and demonstrated a controllable mechanical property. The proposed biomimetic osteochondral interface manifested comprehensive mechanical properties, of which the bonding strength, compressive strength, and shear strength respectively reached 128 kPa, 277 kPa, and 276 kPa.

Keywords: Mechanical properties; Computational modeling; Osteochondral interface; Extrusion-based 3D printing

In-Situ Additive Manufacturing of Graphene-Reinforced Metal Matrix Composites

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Abstract

The pursuit of high-performance metal matrix composites (MMCs) is confronted with substantial challenges, particularly in integrating high-quality reinforcements and designing complex heterogeneous architectures. A promising solution lies in the reinforcement of MMCs with graphene, which can leverage its exceptional intrinsic properties to enhance strength and toughness. This study introduces two novel approaches for in-situ synthesis of graphene-reinforced MMCs. The first approach focuses on thin film nanocomposites, essential for flexible electronics. Conventional ultrathin metal films suffer from low fracture toughness, limiting their electrical conductivity under significant deformations. To address this, we developed a method for in situ synthesis of a few-layer graphene wrapper onto micro/nano-scale seed metals via chemical vapor deposition (CVD). Utilizing ultrathin palladium films with pre-designed horseshoe patterns, we demonstrate that CVD-grown palladium-graphene films exhibit markedly improved electromechanical performance. Specifically, these films show a much slower increase in electrical conductivity when stretched beyond 60%, compared to a rapid increase in bare palladium films at 30% strain. Furthermore, these films display several times longer fatigue life under cyclic stretching with strain ranges up to 20%. The second approach involves bulk 3D structures, utilizing an in-situ laser powder bed fusion (L-PBF) technique to grow graphene directly during additive manufacturing. By using nickel as the matrix and introducing a solid carbon precursor into the powder bed, we control carbon diffusion and precipitation during the printing process. This results in uniform, continuous multilayer graphene growth on each printed layer, including complex outer surfaces. Preliminary mechanical testing of graphene-nickel composites reveals over 75% and 180% increases in ultimate tensile strength (UTS) and uniform elongation, respectively, compared to pure nickel. In conclusion, these methods for in-situ graphene synthesis significantly enhance the mechanical and electrical properties of MMCs, demonstrating their potential for applications in flexible electronics and advanced structural components.

Rapid Bioprinting of Biomimetic Tissues in Multi-Well Plates for High-Throughput Drug Screening and Complex Disease Modeling

Kar Perng Low

Abstract

3D bioprinting is reshaping drug discovery, personalized medicine, and cell therapy by enabling the fabrication of physiological mimetic human tissue models. Traditional methods – in vitro and animal models often yield unreliable preclinical data and are delayed by long development timelines. In contrast, bioprinted tissues offer improved predictive accuracy, reduced reliance on animal testing, and accelerated therapeutic breakthroughs. In this presentation, we will explore how CELLINK’s advanced bioprinting solutions enable researchers to construct predictive, reproducible, and scalable disease models. These technologies facilitate personalized treatment strategies and support the rapid identification of promising drug candidates. We will also showcase innovative applications—from complex disease modeling to regenerative medicine—that illustrate the potential of 3D bioprinting to drive the next generation of biomedical breakthroughs.

The preliminary clinical outcome results of total talus replacement for idiopathic osteonecrosis of the talus

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Abstract

Background: The pathological changes of talar osteonecrosis comprise of collapse of the talus body and associated osteoarthritis. The traditional treatment methods are difficult to restore the construction and subsequent function of the talus. Total talus replacement is an ideal option for the osteonecrosis of the talus with the advent of patient-specific implants using 3D printing based on CT scanning of the contralateral talus. The purpose of the study is to report the preliminary clinical outcome results of total talus replacement for idiopathic osteonecrosis of the talus.

Methods: A total of 10 ankles in 10 patients with idiopathic osteonecrosis of the talus who were treated with a total talar replacement between September 2021 and December 2023 were included in the study. The patients' demographic data, visual analog scale (VAS), American Orthopaedic Foot & Ankle Society (AOFAS) scores, and the 36-item Short-Form (SF-36) Health Survey, and complications were collected preoperatively and at final follow-up postoperatively.

Results: The mean follow up period was 18.9 (range 16 to 40) months. The postoperative VAS scores were significantly superior to the preoperative (7.5 ± 1.4 VS 3.2 ± 1.6 , $P < 0.05$) representing pain relief. The AOFAS scores significantly improved from 57.5 ± 18.3 points before surgery to 82.2 ± 21.5 points after surgery ($P < 0.05$). Higher postoperative SF-36 scores were showed compared to the preoperative scores (127.6 ± 21.4 VS 98.5 ± 19.3 , $P < 0.05$). One patient suffered delayed wound healing after the operation (the wound had healed by the last follow-up visit).

Conclusion: As to preserve the functions of ankle and subtalar joints, total talus replacement is a promising alternative to tibiotalaocalcaneal fusion. However, our research reports a preliminary result, further studies are required to ensure reliable outcomes, especially the long-term results.

Effect mechanism of electroshock treatment on mechanical properties of laser melting deposited Ti55531 alloy

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Abstract

A novel method of electroshock treatment (EST) is introduced to modify the tensile properties of LMD Ti55531 alloy, and the optimizing mechanism is revealed. These results provide insight into a further improvement of the EST process to prepare alloys with better strength and toughness. The microstructure of LMD Ti55531 showed a layer structure with alternating short columnar and equiaxed grains, the α phase at the interface was refined and uniformly dispersed after 0.06 s EST, and the α phase at the interface was transformed into β with EST increased to 0.08 s. The elongation of LMD Ti55531 increases from 14.5% to 17.6% with 0.06 s EST and the tensile strength increased from 826.7 to 937.8 MPa as well. The plasticity of LMD Ti55531 was obviously improved after EST, which corresponded to the variation of α -phase content and distribution. The effect mechanism of EST on tensile behavior of Ti55531 could be ascribed to the fine size α phase precipitated after EST with 0.06 s. The fine size α phase showed a "pinning effect" on the slip line, which hindered and stop the movement of the slip line and resulted in the improvement of elongation. All results indicated that EST can optimize the microstructure of LMD Ti55531, and improve the plasticity without the loss of tensile strength. It is an effective and novel way to optimizing the tensile properties of LMD titanium alloys.

Additive manufacturing of lattice metamaterials with both load-bearing and vibration isolation

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Abstract

Triply Periodic Minimal Surface (TPMS) lattice structures have shown potential for vibration isolation. However, their performance in low-to-medium frequency ranges remains suboptimal due to limited damping and energy dissipation capabilities. This study explores the design, fabrication, and performance of multicell interlacing TPMS lattice metamaterials with superior vibration isolation properties. This work not only provides a comprehensive understanding of the multicell interlacing design but also offers valuable insights for optimizing TPMS lattice metamaterials for advanced vibration isolation applications in engineering systems.

Durable Immunomodulatory Hierarchical Patch for Rotator Cuff Repairing

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Abstract

Introduction/Objectives

High re-tear rates exceeding 50% in degradable shoulder cuff patches, observed over a five-year follow-up, are attributed to the failure of degradable polymers alone to restore the inflammatory niche post-rotator cuff injury, hindering tendon-bone interface healing. Theoretically, a degradable polymer with durable immunomodulatory functions throughout its degradation procedure might address this issue.

Methods

Ferulic acid (FA) was introduced into the repeating unit fragments of polyurethane by skeletal copolymerization to construct a biodegradable polymer (poly(ester- ferulic acid-urethane) urea, PEFUU) with long-lasting anti-inflammatory effects. After verifying the anti-inflammatory function of PEFUU in vitro, hierarchical composite nanofiber patch (HCNP) with sustained anti-inflammatory niche was constructed by electrospinning and lyophilization of decellularized Wharton jelly tissue. The HCNP was used for rotator cuff repairing in rat model. The effectiveness of promoting iRCT repairing by the HCNP was also validated by imaging, histology, and molecular biology methods.

Results

Via employing the paradigm of polymer backbone functionalization, a hierarchical composite nanofiber patch (HCNP) distinguished by its enduring immunomodulatory properties, was fabricated, adept at sustaining a protracted anti-inflammatory microenvironment conducive to fostering tissue regeneration (Scheme 1). The synthesis process by fabricating (PEFUU) was initiated, wherein FA was incorporated as a bioactive constituent. PEFUU stably releases FA in vitro, reversing the inflammatory niche produced by M1 macrophages and restoring the directed differentiation of stem cells. Subsequently, PEFUU was subjected to the electrospinning process, yielding a bipolar fiber patch characterized by an organized, yet partially random, stratified architecture. Within this stratified architecture, the random layer was strategically imbued with the enzymatic hydrolysate derived from decellularized Wharton jelly tissue (HDWJT). In vitro experimentation demonstrated the propensity of FA to undergo a gradual release profile concomitant with the progressive degradation of the HCNP. In a compelling demonstration of the HCNP's therapeutic prowess, this study extended to an in vivo milieu, employing a rat model of tendon-to-bone injury, manifesting as the restoration of the microstructural continuity inherent to the tendon-to-bone interface, coupled with the establishment of a trinomial distribution of collagen ordering.

Conclusions

This study provides an idea for the use of an electrospun nanofiber mat in tissue regeneration. By introducing anti-inflammatory small molecules through copolymerization, the inflammatory niche of the damaged tissue can be altered persistently, effectively inducing tissue regeneration.

Enhanced manufacturing quality and mechanical performance of laser additive manufactured TiC/AZ91D magnesium matrix composites

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Abstract

The addition of ceramic reinforcements provides a promising approach to achieving high-performance magnesium matrix composites. In this work, AZ91D magnesium alloys and 2 wt.% TiC/AZ91D composites have been manufactured by laser powder bed fusion (LPBF) with variations of laser processing parameters. The effect of TiC reinforcement addition on the laser absorption behaviors, forming quality, microstructure evolution and mechanical properties of the magnesium alloys is investigated. The TiC addition improves the interactions of laser with alloy powder and laser absorption rate of alloy powder, and decreases powder spattering of powder bed. The results show that high relative density of ~99.4% and good surface roughness of ~12 μm are obtained for the LPBF-fabricated composites. The TiC addition promotes the precipitation of $\beta\text{-Mg}_{17}\text{Al}_{12}$ in the alloys and the transformation of coarse columnar to fine equiaxed grains, where the grains are refined to ~3.1 μm . The TiC/AZ91D composites exhibit high microhardness of $114.6 \pm 2.5 \text{ HV}_{0.2}$, high tensile strength of ~345.0 MPa and a uniform elongation ~4.1%. The improvement of tensile strength for the composites is ascribed to the combination of grain refinement strengthening and Orowan strengthening from $\beta\text{-Mg}_{17}\text{Al}_{12}$ precipitates and Al₈Mn₅ nanoparticles. In the composites, the unmelted TiC particles can act as an anchor for the network structure of $\beta\text{-Mg}_{17}\text{Al}_{12}$ precipitates, effectively impeding crack propagation and enhancing their performance. This work offers an insight to fabricating high-performance magnesium matrix composites by laser additive manufacturing.

3D printing for cell delivery using dynamic hydrogel

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Abstract

Effective cell delivery and tissue maturation remain major challenges in cartilage repair due to the limitations of conventional hydrogels. In this study, we developed a nanogelatin-based dynamic hydrogel featuring a self-assembled and photo-crosslinked network of interconnected nanospheres. This adaptive structure provides a permissive microenvironment, allowing seed cells to migrate, proliferate, and secrete extracellular matrix. Integrated with digital light processing (DLP)-based 3D printing, the hydrogel enables rapid fabrication of customized cartilage constructs. In vivo studies confirmed successful cartilage regeneration, including repair of joint defects and auricular reconstruction. This approach offers a promising strategy for functional tissue engineering and expands the clinical potential of 3D bioprinting.

Accelerating the design of novel alloys for hydrogen applications: an AI-driven Additive Manufacturing approach

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Abstract

Hydrogen (H₂) stands as a cornerstone of the global energy transition, offering a sustainable pathway to decarbonize industries, enhance energy security, and support renewable energy integration. In this framework, Additive Manufacturing (AM) provides unique opportunities to support the hydrogen revolution due to relevant features such as rapid prototyping, unmatched freedom of design and reduced costs for small production volumes. Nevertheless, materials' constraints still hinder this transition, including hydrogen embrittlement in metal components and corrosion issues related to the electro-chemical environments in which some of these parts are supposed to operate. These challenges are exacerbated by the limited amount of information about AM materials in H₂ environments. In this work, we present an effective approach linked to the design of innovative alloys for metal AM, to be deployed for hydrogen-related applications. To accelerate the design process, different Artificial Intelligence (AI) tools have been used in addition to commercially available software, such as JMatPro® and Thermo-Calc®. Initially, AI tools have been exploited to identify potential candidates for hydrogen applications, based on available data from literature. Then, modelling has been run to investigate specific properties of the candidates and simulate their behaviour in relevant operative conditions, addressing corrosion phenomena, structural response at the micro-scale and phase transition-induced effects. Eventually, the results from modelling have been enhanced through AI deep analysis techniques to define a chemical composition to be experimentally validated. The metal powder with such a composition has been produced by Gas Atomization and printed by means of Powder Bed Fusion Laser Beam (PBF-LB) technology. Specimens for mechanical and corrosion testing have been manufactured, to compare the performance of the novel material with the ones of similar alloys produced by conventional methods and commercially available AM alloys. Promising results have been collected from the preliminary characterization tests, supporting the methodology here introduced.

Miniaturized Mechanical Testing of Fused Filament Fabricated Alumina: Effects of Sintering Temperature and Anisotropy

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Abstract

This study examines the relationship between the sintering temperature (1475 °C to 1600 °C) and the mechanical properties of alumina fabricated via the Fused Filament Fabrication (FFF) technique using the Zetamix filaments that contain approximately 48 vol.% alumina particles. The Printing parameters were optimized to 100% infill density, a 0.2 mm layer height, and a rectilinear pattern. The results demonstrate that the mechanical properties improve with increasing sintering temperature. The relative density increases from 70% (at 1475 °C) to 95% (at 1600 °C) of the theoretical density, while the grain size grows from 0.62 ± 0.11 µm to 1.95 ± 0.64 µm. The compressive strength increases from 66-101 MPa to 575-734 MPa, the characteristic bending strength increases from 96 MPa to 238 MPa, and the Vickers hardness rises from 4 GPa to 18 GPa. The study observes anisotropy, as the samples loaded perpendicular to the print direction consistently exhibit lower strength than those loaded parallel to the print direction, due to weak interlayer bonding. The failure analysis reveals a transition from intergranular failure with triangular pores (1321 ± 559 µm² at 1475 °C) to mixed fracture modes with reduced porosity (309 ± 162 µm² at 1600 °C). The Weibull moduli range from 6.59 to 8.44, indicating acceptable reliability of the selected small-sized samples. Theoretical models such as Duckworth, Rossi, and Mackenzie successfully predict the mechanical properties based on porosity (R² > 0.79). The study achieves an 89.13% reduction in material costs and a 92.68% decrease in printing time through the adoption of miniaturised testing protocols, while also establishing the effectiveness of thermal debinding for components below 5 mm in dimension.

iTwin: Intelligent Twin for In Situ Monitoring and Real-Time Adaptive Quality Assurance in Metal Additive Manufacturing

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Abstract

Metal additive manufacturing (MAM) presents transformative opportunities to produce high-performance components with complex geometries. Yet, inherent process variability remains a significant challenge to repeatability and quality assurance. In our ongoing work, we introduce iTwin—an Intelligent Twin platform that integrates advanced sensorization, sensor analytics, and machine learning (ML) to address these challenges in real time.

iTwin creates a dynamic, data-driven twin of the MAM process by leveraging signals from various in situ sensors, including infrared cameras for thermal imaging, accelerometers for vibration analysis, and acoustic sensors for monitoring process dynamics. By combining statistical and physics-informed feature extraction methods, the platform correlates sensor data with key process states to enable rapid and accurate anomaly and defect detection. Unlike conventional physics-based digital twins, which often require intensive computation and simplified models, our ML-empowered approach learns directly from rich sensor data, capturing the complex nonlinear relationships within the process.

Our current implementation of iTwin has demonstrated robust performance in predicting anomalies and defects in laser powder bed fusion, though the adaptive control aspect remains a promising direction for future work. The insights from iTwin could form the basis for closed-loop process optimization that dynamically adjusts operating parameters to enhance quality.

In this talk, I will discuss the fundamentals of data-driven in situ monitoring in MAM and present our ongoing development of the iTwin platform. I will highlight how advanced ML algorithms and sensor analytics are being leveraged to transform process variability from a persistent challenge into a manageable factor, ultimately paving the way for real-time quality assurance and, potentially, adaptive control in metal additive manufacturing.

Generative Deep Learning Framework for Tailored NiTi TPMS Lattice Architectures

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Abstract

Nickel-Titanium (NiTi) lattice structures based on Triply Periodic Minimal Surfaces (TPMS) offer exceptional pseudoelastic properties desirable in biomedical implants, aerospace components, and actuators. While previous studies have successfully employed deep learning techniques to rapidly predict mechanical responses of these complex structures, exploring new lattice designs with targeted mechanical properties remains computationally demanding.

In this study, we propose an innovative generative design approach utilizing autoencoder-decoder neural networks to efficiently create novel NiTi TPMS lattice architectures. A 3D convolutional autoencoder captures a reduced-dimensional latent representation of voxelized NiTi lattice geometries, encoding their intricate geometric features. The corresponding decoder network then reconstructs new lattice designs from this latent space, enabling efficient exploration of the structural design space.

We integrate this generative model with finite element analysis (FEA) simulations to rapidly screen and identify lattice architectures exhibiting optimal pseudoelastic behaviour. Candidate lattices proposed by the generative network are evaluated using high-fidelity FEA, ensuring accuracy in mechanical performance predictions. This framework significantly streamlines the lattice design process compared to conventional trial-and-error methods.

Our generative approach showcases strong potential for automating inverse design and optimization of NiTi TPMS lattices tailored to specific functional requirements. Future research directions include experimental validation of generated structures, further enhancement of neural network architectures, and expansion of the methodology to encompass broader design constraints and functional properties.

Machine learning accelerated design of lattice metamaterials

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Abstract

Lattice metamaterials have excellent mechanical properties, which have potential applications in aerospace and automobile. However, the geometric characteristics of lattice metamaterials are complex, and the relationship between structure and mechanical response is nonlinear. It is still a challenge to accurately control the nonlinear mechanical response of lattice metamaterials and optimize their mechanical properties. This presentation introduces two new methods for accelerating the design of lattice metamaterials with specific mechanical responses using convolutional neural networks (CNN) and fully connected neural networks (FCNN). The dataset consisting of pseudo-random geometries and strain-stress curves of lattice metamaterials is obtained by the finite element method. The trained neural networks not only accurately predict the mechanical response of lattice metamaterials, but also explores new metamaterials with performance surpassing the original dataset, demonstrating a good generalization ability. Then, a novel lattice metamaterial with excellent energy absorption is generated using the trained model, and its specific energy absorption exceeds other lattice metamaterials reported in the literature. The new lattice metamaterial exhibits stretching-dominated deformation behaviors, with stress uniformly distributed in the regions of the vertical strut and supported by adjacent lattice unit cells, further enhancing the load-bearing capacity during compression. Overall, the proposed design methods are data-driven without relying on complex solid mechanics theories, making it more convenient to extend to different engineering applications.

Direct Ink Writing 3D Printing for Fabricating Microfluidic Devices

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Abstract

Three-dimensional (3D) printing technologies have become the new standard for fabricating microfluidic devices. Among them, stereolithography (SL) printing has been increasingly used to create fluidic channels, but these devices are limited by the properties of photoresins and photoabsorbers. In contrast, extrusion printing, particularly direct ink write (DIW) 3D printing, allows for the diverse selection of printable resins and the post-integration of additional materials, enabling the fabrication of microfluidic systems that would be difficult to achieve with simple replica molding. In this presentation, we introduce DIW 3D printing as an alternative and versatile method for fabricating microchannels. We first discuss the printability of silicone elastomeric materials, such as room-temperature-vulcanizing (RTV) silicone and addition-curing two-part silicone. The printability of these resins can be readily enhanced by using surrounding liquid media, which is collectively termed embedded 3D printing. These elastomeric resins can be printed onto a diverse range of substrates, enabling the fabrication of microchannels with 3D interconnections. To illustrate the unique capability of DIW-based fabrication in microfluidics, we present the development of (1) flexible and stretchable devices and (2) untethered soft robots. Overall, DIW 3D printing offers unique opportunities for fabricating microfluidic devices with advanced functions. This technique will be beneficial for developing sensors and actuators that meet unique requirements (such as conformability, flexibility, and lightweight) that can be challenging to achieve with other fabrication methods.

Desktop 4D printing of hybrid materials

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Abstract

In 4D printing, 3D-printed components transform into different structures when exposed to external energy inputs, such as temperature or light. Hybrid materials, which blend different types of materials like plastics, metals, and composites, have promising future capabilities in this process. By combining 4D printing with hybrid materials, it becomes possible to manufacture parts that can self-sense and react to environmental changes. This study will examine the results of such combinations from a manufacturing perspective and discuss future directions.

The materials used in the study include commercially available polymers and 4D printing filaments, thermochromic plastics, metal wires, and composite rods. The device utilized is an Anisoprint 4A continuous carbon fiber 3D printer based on material extrusion. Various parameters were initially tested to ensure proper material processing.

The self-sensing part is a shape structure consisting of polymer and continuous metal wire arranged in a back-and-forth pattern. The self-sensing capability was tested by bending the part and measuring changes in resistance. The 4D printing material, combined with continuous carbon fibers, was activated using heat by placing the part in hot water to achieve rapid and uniform heating. The 4D printing performance, precisely shape recovery, was optically measured and calculated. Thermochromatic parts were embedded in metal wires to bring local heat, and heat was utilized for color change.

The study demonstrated the production and functionality of self-sensing structures, 4D printed shape memory polymers with continuous carbon fibers and color-changing parts such as displays.

Future research will focus on combining self-sensing and color-changing capabilities with 4D printing behavior to explore the potential performance achievable with this material extrusion-based method, specifically looking at the combination of 4D printing filaments and continuous metal wires.

Biomimetic Design of Animal Skeletal Structures via Topology Optimization and Rapid Prototyping-based Physical Simulation

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Abstract

Bionics is a widely applied discipline in engineering design. The structures formed through millions of years of biological evolution can provide crucial inspiration for engineering design in similar environments. However, current research suggests that simply imitating biological structures often fails to achieve optimal results. To make the design outcomes of bionics more reliable and trustworthy, rather than merely relying on the observation and imitation of nature, and also to enhance our ability to interpret the design results, we need to develop novel and more advanced methods and techniques.

In this work, a novel engineering design method is proposed that integrates bio-inspiration, topology optimization, and rapid prototyping. First, a natural biological structure is identified and modeled in two-dimensional projection. Then, density-based topology optimization is employed to optimize the material distribution. Utilizing rapid prototyping technique, the optimized design is printed using materials similar to biological bones. Mechanical tests are conducted on the printed structures to further iterate and refine the design. Through this comprehensive optimization approach, we can achieve designs that surpass bio-inspired structures in performance. Compared to traditional topology optimization methods, this approach is faster because it eliminates the need for extensive initial optimization time, and the combination of rapid prototyping with mechanical testing makes the design more reliable and more realistic for practical applications.

The Future of Construction 3D Printing

Fadhel Bandar, Issam.Amr

NTU/SC3DP & Saudi Aramco Tech Centre

Abstract

Construction 3D Printing has made large strides in the last decade, from an afterthought with regards to other 3D Printing technologies, to realisation of many projects already being showcased or are already in the pipeline. What is next ? Are we there yet ? This talk will examine the different opportunities and challenges this technology presents.

Advancing Bioartificial Liver Transplantation: 3D Bioprinting for Functional Liver Grafts

Mingchang Pang, Huayu Yang

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Abstract

Liver disease causes over 2 million deaths annually, yet only 10% of patients in need receive a transplant due to donor shortages. To address this, our team explores bioartificial liver construction using 3D bioprinting. Our study in Gut (2021) demonstrated that 3D-printed liver organoids from HepaRG cells exhibited hepatic functionality comparable to primary hepatocytes and significantly prolonged survival in liver failure mice, with vascular networks forming post-transplantation to enhance efficacy. Building on this, we employed embedded 3D bioprinting to create liver tissues with hepatic and venous structures (Biomaterials), improving vascularization and metabolic function. In Science Advances, we developed a transplantation model using a bioink-based construct, which restored liver function and integrated with systemic circulation in rats. These findings highlight 3D bioprinting as a promising strategy for bioartificial liver transplantation, providing a foundation for clinical applications.

Effect of Printing Parameters and Material Rheology on the Filament Quality in 3D Concrete Printing

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Abstract

Unlike traditional construction processes, three-dimensional concrete printing (3DCP) requires more precise control of the pumping flow rate. This study investigates the effects of nozzle travel speed and material flow rate by adjusting key printing parameters. The findings indicate that the solidity ratio, defined as the ratio between actual and expected filament sizes, is significantly influenced by nozzle travel speed and material volume flow rate. By fine-tuning these parameters, it is possible to produce filaments with varying properties using a single type of building material. An approach was developed to achieve an objectively tailored, functionally graded concrete material by dynamically adjusting printing parameters during the 3DCP process. The optimized structure demonstrated an approximate 50% improvement in the strength-to-weight ratio. However, maintaining consistent printing parameters does not necessarily ensure a uniform material flow rate, as the rheology of cementitious material changes over time due to hydration. To address this, the influence of fresh material rheology on flow rate was experimentally analyzed in the 3D concrete printing process. Material viscosity was measured using a large-gap vane viscometer at different time intervals after mixing, while simultaneous printing tests were conducted to determine the flow rate based on the volume conservation principle. The results showed that changes in material rheology over time had a significant impact on flow rate. To improve printing quality, an open-loop control method was implemented to regulate the material flow volume per unit length during the 3DCP process. This study highlights various aspects of material flow rate in 3DCP and offers insights for optimizing printing parameters for different objectives.

Cavity-induced bubbles and pore formation of laser direct energy deposited titanium alloy: influence of powder melting degrees

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Abstract

Porosity defects and their impact on fatigue performance have become one of the key issues in the widespread application of laser direct energy deposited titanium alloy components. The present work focuses on the cavity evolution and bubble generation process of unmelted, partially melted and fully melted powder entering the melt pool. Firstly, an equivalent experiment, ice particle with different melting degree impact water, was designed and conducted on the basis of similarity criterion in fluid mechanics. Secondly, a numerical model of powder impingement melt pool was established by using dynamic mesh method to simulate the evolution of cavity with different melting degree. Finally, a deposition processing with different melting states of the powder, by adjusting the angle and height of the powder feeding nozzle, was engaged to verify the influence of the melting states of the powder on the pore formation. The equivalent test and simulation results show that for the unmelted powder with large diameter and high velocity, the impacted cavity pinches off near the surface and induces gas entrainment and bubbles formation. For comparison, the fully melted powder enters the melt pool with a crater-shaped cavity which collapsed in a contraction mode and has not residual gas and bubbles. The surrounding liquid surface of partially melted powder changes the shape of the cavity and extended the time of collapse. With the increase of melting degree of powder, the collapse of cavity changes from the pinch-off to contraction mode, which avoids the generation of cavity-induced bubbles. The deposition experimental results show that both the pore size and porosity of the deposited specimen decrease with the increase of powder melting degree. This study is significant to clarify of the mechanism of porosity formation and decrease of porosity defects of laser direct energy deposited titanium alloy.

Solvent-Free Additive Manufacturing of Electrochromic Patterns via Aerodynamically Focused Nanoparticle (AFN) System

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Abstract

Conventional solvent-based drop-on-demand patterning methods, including inkjet printing, offer high precision patterning capabilities. However, these methods face significant challenges: they involve complex multi-step processes that increase manufacturing costs and generate byproduct. Furthermore, the reliance on ink formulations introduces issues such as coffee ring effects and cracking after post-heat treatment. These drawbacks pose substantial barriers to scale up and maintaining sustainable advanced microfabrication processes.

To address these challenges, this study suggests a novel solvent-free additive manufacturing (AM)-based patterning method to enhance pattern stability, achieve high precision, and create unique microstructures for functional applications.

In this study, AM-based patterning system called Aerodynamically Focused Nanoparticle (AFN) system for fabricating electrochromic devices. The AFN system uses aerodynamic control to direct nanoparticle flow with precision. The research introduces key deposition parameters for pattern optimization and demonstrates their application in functional electrochromic patterns.

Through optimization of AFN system parameters, we achieved a minimum pattern width achieved was approximately 211 μm , which is only one-third of the nozzle's inner diameter (640 μm). The nanoparticles, deposited by aerodynamic forces, experienced sufficient force to cause morphological deformation, resulting in enhanced pattern durability. The fabricated patterns exhibited stable electrochromic behavior, maintaining uniform coloration and bleaching over 500 cycles with excellent substrate adhesion and no cracking. Additionally, the patterns adhered well to both glass and flexible ITO-PET substrates, with bending tests confirming stability under mechanical deformation. These results demonstrate that the AFN system enables highly precise patterning while eliminating challenges associated with solvent-based processes, such as additional processing steps and defect formation.

This study highlights the potential of AFN as an innovative AM-based patterning technology, offering a new pathway for functional applications. The scalability and sustainability of this method make it a promising approach for next-generation flexible displays, micropatterned electrochromic indicators, and other structured electrochromic device applications.

Surface-Aware Robotic 3D Printing via real-time RGB-D Mapping and Semantic Segmentation

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Abstract

3D printing directly onto non-planar and irregular surfaces presents a transformative opportunity for personalized fabrication, adaptive wearables, and real-time repair of soft systems. However, conventional 3D printing techniques are predominantly limited to planar surfaces and controlled environments, relying on pre-scanned models for tool path generation, restricting their applicability in dynamic, real-world settings. To overcome this, In-situ scanning of the print bed is necessary for understanding the surface and generating adaptive tool paths based on surface topologies.

The system integrates a 7-axis robotic arm, a wrist-mounted RGB-D-based vision system for 3D mapping, semantic surface segmentation, and surface-aware toolpath planning to enable printing on non-planar surfaces. The vision-based colour and depth information along with user-guided object selection helps in understanding the surface. Based on the user selected region of interest on the camera feed, the Segment Anything Model (SAM) outlines the desired object from the RGB data. The corresponding depth coordinates of the segmented contour were mapped for 3D point cloud visualization and surface-aware tool path generation. This real-time, modular pipeline enables the robotic arm to scan the print bed and print on any non-planar surface quickly.

We demonstrate this approach through printing decorative patterns on face masks and printing custom textures on real-world objects, such as a computer mouse. Furthermore, on-site repair of soft robots, such as printing missing skin segments for a stingray-inspired robot was also demonstrated. This study expands the possibilities of surface-aware printing by using vision-based systems in additive manufacturing and creates new

Optimizing Process Parameters Using Machine Learning and Finite Element Analysis to Enhance Dimensional Accuracy in Robot-Based Large Object Additive Manufacturing

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Abstract

LOAM (Large Object Additive Manufacturing) enables the rapid fabrication of large-scale components, attracting interest from industries such as shipbuilding, aerospace, and automotive. However, as the build size increases, thermal anomalies such as warpage become more prevalent, posing challenges to the production of high-quality parts and potentially rendering them unusable. Consequently, current research often focuses on optimizing process parameters to mitigate deformation. Nevertheless, these methods frequently exhibit limited transferability; even minor modifications in printing equipment specifications may require a complete repetition of experiments. An alternative approach is physics-based computational modeling, such as finite element analysis (FEA). However, the accuracy and reliability of such models heavily depend on the precise determination of model parameters, particularly material properties. This process involves extensive experimental procedures, including sample fabrication and destructive testing, leading to increased production costs, substantial labor, and significant time investment. In this study, we propose a novel process parameter optimization framework based on FEA to reduce thermal deformation in robot-based LOAM. The proposed framework consists of three phases: (1) developing a machine learning (ML) surrogate model for FEA, (2) integrating the ML model into an optimization algorithm to accurately calibrate material properties for reliable FEA, and (3) accelerating process parameter optimization under reconfigured machine settings. We validate the robustness of the proposed approach through experiments across various geometric configurations. Furthermore, comparisons with commercial material property data demonstrate that the optimized material properties significantly enhance the accuracy of warpage and residual stress predictions. This work streamlines the overall process by bridging the gap between experimentation and predictive simulation, paving the way for more reliable, efficient, and cost-effective LOAM processes.

Interaction of surface roughness and subsurface defects in laser powder bed fusion parts for fatigue life prediction

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Abstract

Laser Powder Bed Fusion (LPBF) is an Additive Manufacturing (AM) process that offers good geometrical accuracy. However, the roughness imparted by the process as well as subsurface pores have been found to adversely affect their fatigue (S-N curve) performance. This is especially important since most service failures are caused by fatigue, with parts not designed for yielding. This study demonstrates a way to characterize the fine surface roughness features in LPBF parts as well as subsurface pores, in addition to analyzing their interaction. LPBF superalloy IN718 High Cycle Fatigue (HCF) samples with as-built surfaces were subjected to detailed X-ray Computed Tomography (CT) scans before being tested in fatigue. Their fracture surfaces were analysed and a reverse engineering approach was used to pinpoint the origin of the fatigue crack in the X-ray CT model. The final fatigue crack did not start from the largest pores, showing a complicated competition among pores and surface notches. Detailed Finite Element (FE) simulations incorporating surface features and subsurface defects reveal the reason for the crack initiation location. From an academic perspective, this study provides new insight into the fundamental mechanics of critical notches and pores. From an industrial perspective, this comprehensive methodology can be used to predict fatigue life for LPBF components.

Effect of Deposition Sequence on Interface Evolution and Tensile Behaviour in WAAM-Fabricated Bimetallic Structures

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Abstract

Wire Arc Additive Manufacturing (WAAM) has emerged as a highly efficient technique for fabricating bimetallic (multi-material) components. This study systematically investigates the influence of deposition sequence on the microstructural evolution and mechanical performance of Inconel 625 (Inc 625) and Stainless Steel 309L (SS309L), both of which are widely employed in high-temperature applications due to their superior mechanical strength.

In this work, wall geometries were additively manufactured using WAAM with two distinct deposition strategies. In the first configuration, Inc 625 was deposited up to a height of 55 mm, followed by SS309L, without process interruption. In the second configuration, the deposition order was reversed, with SS309L deposited first, followed by Inc 625. To understand the evolution of mechanical properties along the build direction, the cooling cycles of each layer were monitored with temperature measurement during deposition. The effect of deposition order on the cooling rate was analysed, revealing significant differences along the build direction.

Microstructural analysis of the interface region revealed notable differences: in one case, a sharp compositional gradient was observed, while in the other, substantial elemental diffusion resulted in a gradual transition zone and the formation of a new alloy. Results showed that in samples extracted parallel to the build direction, the newly formed alloy in the gradual transition zone reduced the ultimate tensile strength by 15%, while in the perpendicular direction, an 8% difference was observed. Additionally, tensile specimens extracted perpendicular to the build direction in the SS309L-first deposited configuration exhibited up to 13% variation along the building direction. However, when deposition started with Inconel 625, these variations were significantly minimized.

These findings highlight the critical role of deposition order in controlling microstructural transitions and mechanical performance in WAAM-produced bimetallic structures, offering insights for optimizing multi-material additive manufacturing strategies.

Machine Learning-Based Defect Detection and Prediction in Laser Powder Bed Fusion via in situ Monitoring

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Abstract

As metal additive manufacturing (AM) progresses toward large-scale adoption, quality certification and its associated high costs remain significant barriers to the widespread implementation of metal AM. This study leverages in situ monitoring data from the EOS M290 optical tomography (OT) system, integrated with machine learning techniques, to predict defects in laser powder bed fusion (L-PBF) components. We utilized a Conditional Generative Adversarial Network (CGAN) for defect prediction, where OT images served as inputs and X-ray Computed Tomography (XCT) images provided conditional guidance. To ensure accurate model training, we first optimized image registration between OT and XCT scans, as misalignment was found to significantly degrade prediction accuracy. After comparative evaluation, we experimented with three different registration methods and, after comparative evaluation, selected the most effective one for our model. Additionally, we explored two data augmentation strategies, creating two additional datasets. Our experiments revealed that although data augmentation increased the dataset size, it also introduced erroneous data that negatively affected predictive performance. Ultimately, the original dataset yielded the best results. By refining image registration techniques and optimizing the CGAN model, we achieved a defect prediction accuracy of over 99.5%. This study highlights the potential of integrating machine learning with in situ monitoring for precise defect localization and size estimation. Our findings contribute to streamlining the certification process, reducing qualification costs, and accelerating the industrial adoption of LPBF-manufactured components.

Modelling the failure in lattices with fracture locus of additive manufactured metals

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Abstract

While damage models have been studied for conventionally manufactured metals, those of their additive manufactured (AM) counterparts have received little attention. Without such data, it is impossible to model the mechanical behaviour, especially the failure, of lattice structures, which can only be produced viably by AM techniques such as laser powder bed fusion (LPBF). In this work, both constitutive deformation and fracture equations of parent LPBF metallic materials were investigated to accurately predict the full response of lattices under different loads (tension or compression), capturing details of the response especially the failure. First, uniaxial tension experiments were performed to accurately measure the constitutive behaviour of LPBF struts, with the strain history tracked and recorded using high resolution imaging. The deformation behaviour can be quantitatively described using the Johnson–Cook constitutive hardening model, which were validated by the 3D finite element (FE) model and experiments of uniaxial compression on LPBF lattices. Crack initiation in lattices loaded in compression was observed in situ via a scanning electron microscope (SEM). It was found that the locations of crack initiation could be predicted by considering the equivalent plastic strain and stress triaxiality fields obtained by an FE analysis and assuming a monotonically decreasing fracture locus. A series of tests were designed such that various fracture loci could be calibrated for LPBF metals at a wide stress triaxiality range, while FE simulations of these tests were performed to extract the parameters for the fracture loci calibration at the critical elements. Finally, the calibrated fracture loci were applied to numerical simulations of lattices of the same material loaded in tension. There was good agreement between the numerically predicted and experimentally obtained force–displacement curves, deformation and failure mode.

Viability of vegetable waste as a 3D printable ink

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Abstract

On top of the million tonnes of food discarded by consumers, a third of food produced annually on a global scale is wasted. This accumulation of food waste leads to a continual increase in landfill waste and depletion of resources. Food wastage has become a time-sensitive issue with the rapid decrease in spaces dedicated to landfills. Fruits and vegetables account for the largest percentage of global food wastage. Reasons for the food wastage are due to the strict industry standards, perishable nature and by-products of cooking. Despite the high nutritional value of many vegetable by-products, they remained underutilised. While studies have looked into the conversion into animal feed, studies exploring the feasibility of repurposing these vegetable waste into sustainable products with 3D printing are limited. In addition, the physiochemical characteristics of vegetable waste make it unsuitable for 3D printing in its current state.

This study aims to investigate the viability of upcycling vegetable waste and its by-products with 3D printing technology. This research will utilise blemished and spent watercress stems that are commonly discarded at different phases of the supply chains. The methodology involved formulating stems with xanthan gum (rheological modifier) at different concentrations (1%, 2% & 3%). The rheological profile of these food inks was analysed and the inks were 3D printed.

The formulated food inks exhibit shear-thinning behaviour and possess sufficient yield stress to maintain their shape after printing. Food inks formulated with at least 2% of xanthan gum produce 3D-printed constructs with the best fidelity and precision. Texture profile analysis and international dysphagia diet standardisation initiative tests were also conducted on these inks to determine their suitability for consumers with swallowing difficulties.

Reducing Solidification Cracks and Enhancing Mechanical Performance in Additively Manufactured Cu-Ti Alloys via Chemical Fluctuation Manipulation

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Abstract

Additive manufacturing offers substantial design freedom for developing copper (Cu) alloy components with complex shapes. However, the extreme process conditions of this technique increase the risk of solidification cracking. Cu-titanium (Ti) alloy, a high-strength Cu alloy, exhibited solidification cracks due to the Ti segregation at grain boundaries when processed with laser powder bed fusion, reducing the appeal of Cu-Ti alloys in the additively manufactured Cu market. In this study, we incorporated chemical fluctuations via in-situ alloying in laser powder bed fusion to suppress solidification cracks. These fluctuations promote the transformation from coarse columnar grains to fine near-equiaxed grains, thereby mitigating solidification cracks at grain boundaries. Furthermore, we discovered that the degree of chemical inhomogeneity decreased with reducing the elemental powder size of in-situ alloying. Utilizing this novel strategy, we successfully in-situ synthesized Cu-Ti alloys devoid of solidification cracks and strengthened by cellular microstructures. Compared to Cu-Ti alloys without chemical fluctuations fabricated using pre-alloyed powders, in-situ synthesized Cu-Ti alloys exhibited significantly boosted tensile strength (from 300 MPa to 540 MPa) and fracture elongation (from 1% to 20%). This study presents a practical methodology to address the challenge of solidification cracking in additively manufactured Cu-Ti alloys.

Additive Manufacturing for Repairing and Remanufacturing of Metal Components

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Abstract

Laser additive remanufacturing technology integrates techniques such as 3D scanning and modeling, laser cladding, and post-processing machining. It enables the rapid restoration of a product or component's dimensions, achieving or even surpassing the performance of new parts. This technology offers the advantages of high repair precision, minimal workpiece damage, high bonding strength in repaired zones, and high material utilization efficiency. It provides a new solution for part repair and remanufacturing and serves as a crucial supporting technology for green remanufacturing. To address the critical need for emergency repairs in field environments, a mobile additive manufacturing repair system for the field environment has been developed. This system overcomes key technological challenges including intelligent computation and coordinate matching of defect models, miniaturization of the additive manufacturing system, and on-site applicability. It integrates functions for scanning damaged models, reverse measurement, additive repair, and post-processing, enabling rapid restoration of component failures in field conditions automatically. The mechanical performance of repaired components can exceed 95% of that of the original parts.

Design of peristaltic-based extrusion printer for high-throughput food printing

Tan Qing Yang, Professor Chua Chee Kai, Professor Tan U-Xuan

Singapore University of Technology and Design (SUTD)

Abstract

Additive manufacturing has expanded into food production through 3D food printing, offering opportunities for personalized nutrition and sustainable food solutions. Dysphagia is a condition where a patient has trouble in swallowing solid food and it affects up to 50% of nursing home residents. These numbers will continue to rise annually as the aging population grows. The use of food printing can enhance the visual presentation and appeal of food, which encourages consistent consumption and dignified feeding for the elderly. The existing commercial 3D food printers are inefficient at producing meals at a scale to meet the current demand for hospitals and nursing homes. These printers typically use a piston mechanism acting on a syringe-like capsule for extrusion, which has a limited capacity and requires frequent reloading of the capsule. This study focuses on designing a high-throughput peristaltic-based extrusion for food printing which addresses the current challenges and need for speed in 3D food printing. Unlike the piston extrusion mechanism which imposes a limitation on the maximum volumetric capacity, the peristaltic pump can extrude and be refilled simultaneously. This eliminates the need to stop the printing process and refill the food ink, hence increasing the overall throughput and overcoming the current limitation of commercial 3D food printers. By advancing a peristaltic-based extrusion food printer, this study enhances the feasibility of scaling 3D food printing by decreasing the overall time taken to print a meal.

Research Progress on Additive Manufacturing of Magnesium Alloys

Qingchen Deng, Yujuan Wu, Liming Peng

Shanghai Jiao Tong University

Abstract

Additive manufacturing (AM) of magnesium (Mg) alloy components with intricate geometries can achieve lightweight structure and material simultaneously, demonstrating significant application potential. In this talk, the research progress of AM technology for Mg alloys in Shanghai Jiao Tong University will be introduced, including new Mg-RE alloys design especially for AM, preparation technologies for Mg-RE alloy powders and wires, four types of AM techniques (laser powder bed fusion LPBF, laser directed energy deposition LDED, wire arc additive manufacturing WAAM, friction stir additive manufacturing FSAM), AM product development and application and so on.

Simulating Microstructure Evolution in Sintering and Additive Manufacturing Using Phase-Field Micromechanics: Model Development and Experimental Validation

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Abstract

In additive manufacturing, accurately simulating microstructure evolution is crucial for designing high-performance components and optimizing manufacturing processes. Sintering—encompassing both viscous and solid-state mechanisms—plays a pivotal role in defining the final properties of additively manufactured parts. However, at the mesoscale, capturing the complex densification and shrinkage deformation of powder materials remains challenging. Conventional sharp-interface models struggle to represent the pronounced morphological changes and to derive the underlying thermodynamic driving forces accurately. In this study, we introduce a novel phase-field micromechanics model tailored for additive manufacturing applications. By defining a unified energy law and using the variational principle, we derive governing equations that capture microstructure evolution, expressing the driving forces in terms of surface and grain boundary tensions. This thermodynamically consistent approach drives microstructural changes toward minimized system energy and is validated through comparisons with classical theoretical analysis and experimental results, highlighting its potential for optimizing sintering-based additive manufacturing processes.

Rapid Design and Manufacture of Low-Frequency Acoustic Absorption Metamaterials with Enhanced Coupling Characteristic

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State Key Laboratory for Manufacturing Systems Engineering, School of Mechanical Engineering, Xi'an Jiaotong University, Xi'an, People's Republic of China;

Abstract

The current designs of low-frequency acoustic absorption metamaterials suffer from inadequate prediction accuracy and low efficiency. Herein, by integrating impedance theory with artificial neural networks, we propose an optimisation method of unit impedance correction (UIC). Meanwhile, a mutated honeycomb structure with teardrop-shaped apertures (MHSTA) fabricated by stereolithography is proposed, which can enhance the low-frequency coupling performance through rationally arranging the relative positions of the apertures. To verify prediction ability of the UIC method, the 50 mm-thickness typical structures of MHSTA are designed for two low-frequency ranges (220–500 Hz and 230–550 Hz). Compared with the simulation, the UIC result can reach the maximum relative error of 3.9% and the maximum absolute error of 0.033, which ensures the accurate prediction commendably. The experiment also demonstrates that the acoustic absorption coefficients are highly consist with the UIC result. This work provides a novel strategy of precise design for low-frequency acoustic absorption metamaterials.

Additively manufactured Ta-based medical devices: Innovative study and exploration in industrial application

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Abstract

Additive manufacturing (AM) of tantalum (Ta) and its alloys has shown significant potential in medical applications, owing to their exceptional mechanical and biological properties. However, defect formation during AM process remains a critical challenge, significantly impacting the performance of implants. This work systematically investigates the selective laser melting (SLM) of Ta-based medical devices, focusing on processing parameter optimization, microstructure-property relationships, and biological performance. Single-track and bulk samples were fabricated under optimized processing conditions, and a powder-resolved computational fluid dynamics (CFD) model of pure Ta was developed to analyze heat transfer and fluid flow characteristics in the molten pool. The results reveal that laser energy density plays a critical role in determining temperature and velocity fields, which influence defect types and quantities. Higher energy density improves molten pool spreading and reduces keyholes but increases gas pores due to intense Marangoni convection. Innovations in powder preparation, including the development of a radio-frequency plasma spheroidization (RFPS) method, have enabled the production of high-quality spherical Ta powders for medical. Additionally, the establishment of a Ta-adapted “laser-powder-molten pool” model and the use of response surface methodology have optimized AM processing, achieving mechanical properties comparable to as-forged Ta. A database of Chinese bone structures was established, leading to the development of implants more suited for humans. These implants have passed comprehensive biosafety validations and clinical trials, with multiple registration certificates for AM-fabricated medical devices currently under application. This study highlights the advancements in AM of Ta, offering scientific and theoretical support for optimizing processing parameters, reducing defects, and advancing the applications of Ta-based implants in medical fields.

Direct-Ink-Write 3D Printing of Hierarchically Structured Composite Materials

Quyong Liu, Wei Zhai

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Abstract

Natural materials, though typically assembled under ambient conditions with limited chemical resources, can achieve extraordinary mechanical and functional performances by integrating structural features across multiple length scales. Inspired by nature’s designs, researchers seek to develop hierarchically structured materials that replicate or even surpass their natural counterparts. However, achieving this goal requires advanced fabrication strategies capable of precise multi-scale structural control.

This presentation explores direct-ink-write (DIW) 3D printing, an extrusion-based additive manufacturing (AM) process, for fabricating hierarchically structured materials. By integrating particle-stabilized emulsion templating, shear-induced alignment, and additional processing techniques such as freeze casting, these advancements expand the design space for diverse composite materials tailored to different applications.

Notably, DIW 3D printing of emulsion enables the fabrication of hierarchical porous structures that can enhance the mechanical and biological compatibility of bioceramic scaffolds. These structures can be further combined with hydrogel or polymer matrices to form interpenetrating phase composites, extending applications beyond tissue engineering to lightweight structural materials. In addition, the capabilities of DIW can be amplified by shear-induced alignment. By incorporating ceramic platelets into an elastic matrix, bioinspired flexible ceramic composites are prepared with programmable shape morphing capability for 4D printing. This technique can also be applied to composite organo-hydrogels, where platelet alignment works synergistically with hydrogel reinforcement methods to improve the mechanical and functional properties for flexible electronics applications.

By translating bioinspired designs into AM, this presentation highlights advances in material and process development for fabricating hierarchically structured materials. Various materials are designed and studied to establish process-structure-property relationships for different applications. Beyond the specific materials and techniques used, these studies demonstrate example strategies and principles applicable to other material systems.

Investigating the Influence of Laser Remelting Strategy in Laser-Based Additive Manufacturing via In Situ Pyrometer Data and Machine Learning

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Abstract

Laser-based additive manufacturing (LBAM) is a promising technology widely adopted in aerospace, automotive, and biomedical sectors for creating complex metallic components. Laser remelting (LRM), a layer-by-layer technique, effectively enhances the density and mechanical performance of printed parts. However, the current literature has limited exploration of combining real-time process monitoring via in situ sensors with machine learning (ML) techniques to optimize LRM parameters, leaving significant research gaps in adaptive control methods.

This study addresses these gaps by employing in situ dual-wavelength pyrometer sensors integrated with ML models to optimize the laser remelting of maraging steel. Pyrometer sensors recorded real-time spatial heat-emission data at each positional coordinate across layers during remelting, enabling a detailed analysis of melt pool dynamics. Spatial-statistical features (SSF), such as mean temperature, thermal gradients, kurtosis, and variance, were extracted from pyrometer data to train regression-based ML models, enabling accurate predictions of mechanical properties like relative density and hardness.

Systematic variation of LRM process parameters (laser power and scan speed) was performed, and mechanical characteristics of 10×10×10 mm cubes were measured using Archimedes' principle and Rockwell hardness tests. Compared to benchmark samples fabricated without remelting, the ML-guided remelting strategy significantly improved relative density (99.7%) and hardness (98.7%) while effectively reducing defects such as porosity. Additionally, pyrometer-derived insights enabled selective identification of critical regions needing remelting, optimizing processing time and energy consumption.

The novelty of this work lies in integrating real-time, in situ pyrometer sensor signals with ML-based predictive models for adaptive, intelligent control of LRM processes. The developed method facilitates efficient, data-driven additive manufacturing, ensuring high-quality production of complex metal parts.

Keywords: Laser Remelting, In situ Pyrometer, Machine Learning, Additive Manufacturing, Maraging Steel, Spatial-Statistical Features

Recent Advances in the Fatigue Behavior of Direct Energy Deposition-Fabricated Metals and Alloys

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Abstract

This review provides a comprehensive exploration of the fatigue behavior of metal components fabricated via directed energy deposition (DED), focusing on the key factors influencing the fatigue life and the effective enhancement approaches. The fatigue behavior of DED-fabricated metals is influenced by a complex interplay of factors, including microstructural characteristics, surface roughness and defects, residual stresses, building orientations and deposition strategies, as well as testing conditions. To enhance the fatigue performance, various post-processing techniques are explored, including heat treatments for microstructural refinement and stress relief, and surface finishing methods such as machining, shot peening, laser shock peening, and ultrasonic nanocrystal surface modification. Furthermore, microstructure tailoring via additives and the in-situ ultrasonic rolling techniques for fatigue resistance enhancement are discussed. This review provides valuable insights for researchers and engineers to optimize DED processes and fabricate metal components with superior fatigue performance.

Assessing and Predicting the Mechanical Performance, Durability Attributes and Degradability Trait of 3D-Printed Specimens in Tropical Climatic Conditions

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Abstract

3D-printed materials from the fused deposition modelling (FDM) and stereolithography techniques were found to experience significant material degradation, become susceptible to premature failure and undergo a reduction in mechanical properties when exposed to environmental conditions. In this study, an assessment of the mechanical performance of 3D-printed specimens, which have been exposed to climatic conditions observed in tropical countries, were conducted. Some of the key investigated conditions included varying humidity, ultra-violet exposure and water immersion. The varying humidity test was conducted by considering two batches of specimen exposed to different controlled environments. Ultra-violet exposure test was conducted by exposing the specimens to direct sunlight for a maximum duration of three months. The water immersion test was conducted via simple immersion test and by considering accelerated water immersion test. A final test to assess the degradability of the 3D-printed specimens was conducted by considering the soil burial test. Two main types of AM methods were considered to manufacture the specimens investigated in this study, namely the FDM and stereolithography (SLA) techniques. Four types of commonly used AM materials were investigated in this study, namely Polylactic acid (PLA), Polyethylene terephthalate glycol (PETG), Thermoplastic Polyurethane (TPU) and SLA resin. One batch of printed specimens were tested directly without exposure to any climatic conditions and would serve as control. The remaining exposed specimens were evaluated through a series of physical and mechanical characterization tests to assess their performance and durability attributes. The Digital Image Correlation (DIC) technique was concurrently employed with the Universal Testing Machine (UTM) to assess the regions of high strain concentration in the tested specimens following their exposure to varying climatic conditions. The findings of this study will be beneficial to product developers as it will provide useful information about the mechanical performance, durability attributes and degradability trait of 3D-Printed specimens.

3D Printed Self-folding Multi-Lumen Nerve Conduits for Neural Regeneration

Hu Renzhi, Prof. Yeong Wai Yee

Nanyang Technological University, MAE

Abstract

Peripheral nerve injuries (over 10mm gap) present significant challenges for nerve regeneration, necessitating advanced strategies to address the limitations of traditional nerve guidance conduits (NGCs). This research focuses on the development of a 3D-printed multi-lumen NGC with different degradation periods, designed to self-fold and replicate the natural architecture of nerve tissue. The project utilizes biocompatible, stimuli-responsive materials, such as alginate/methyl cellulose (Alg/MC) hydrogels, combined with 3D printing techniques to enable dynamic shape transformation. Experimental evaluations confirmed the biocompatibility of Alg/MC. The differential swelling behaviours of Alg/MC formulations were also validated as essential for the self-folding mechanism. The study also optimized layer configurations, and printing parameters to achieve effective multi-lumen structures. Initial results demonstrate the feasibility of creating NGCs that promote precise axonal guidance, paving the way for enhanced nerve regeneration. This research provides a promising foundation for advanced strategies in peripheral nerve repair.

Nature-Inspired Diatom Biosilica for 3D Printed Bioresorbable Scaffolds via Improving Mechanical Stability and Enabling Drug Delivery for Bone Tissue Engineering

Dr. Ri Han, Dr. Lauren Ford, Dr. Pamela Walsh and Prof Fraser Buchanan

*Dr. Ri Han, National University of Singapore;
Dr. Lauren Ford, Imperial College London;
Dr. Pamela Walsh, Queens University Belfast;
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Abstract

Additive manufacturing (AM) technologies have attracted attention as a transformative platform for developing bioresorbable scaffolds for bone tissue engineering. However, silica-based additives like Bioglass often induce polymer degradation and compromise mechanical performance when incorporated into thermoplastics for load-bearing applications. This study investigates natural diatom biosilica as an alternative silica source in 3D printed medical scaffolds for bone regeneration.

With the method of fused deposition modelling (FDM), poly(DL-lactide-co-glycolic) (PDLGA) was compounded with purified diatom biosilica (1 and 5 wt.%) to fabricate printable filaments and porous scaffolds. Mechanical testing showed that diatom-PDLGA scaffolds achieved compressive strengths comparable to cancellous bone and retained structural integrity for up to four weeks longer than Bioglass and pure PDLGA scaffolds during a 26-week in vitro degradation study. Further analysis revealed that diatom biosilica delayed the onset of acidic degradation and enabled a controlled and exponential release of Si^{4+} ions (up to 272 ppm), in contrast to the burst release observed from Bioglass-PDLGA scaffolds. Supporting data from NMR, ICP-OES, TGA, SEM, and BET confirmed enhanced thermal stability, reduced polymer degradation, and consistent microstructural performance.

In addition to improving mechanical retention and degradation behaviour, diatom biosilica also demonstrated excellent compatibility during filament extrusion and 3D printing processes. The unique porous nanostructure and high surface area of diatom biosilica not only promote better dispersion within the polymer matrix but also offer great potential for further surface modification or drug loading for future applications as a multifunctional carrier for bone regeneration. In summary, this work highlights the potential of diatom biosilica as a bioactive, thermally compatible filler for AM-fabricated bone scaffolds, which offers a novel pathway toward sustainable, high-performance implants in regenerative medicine.

Intelligent Wire Arc Additive Manufacturing System: Process Optimization, Multi-Sensor Fusion, Machine Learning Decision-Making, and Aero-Engine Maintenance Applications

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Abstract

This study develops an intelligent Wire Arc Additive Manufacturing (WAAM) system for aerospace manufacturing and maintenance, integrating three core modules: process parameter optimization, multi-modal sensing, and machine learning decision-making. For 316L stainless steel and TC4 titanium alloy arc additive manufacturing, the Heterogeneous Stacking Model algorithm optimizes process parameter combinations to enhance mechanical properties while reducing energy consumption. A five-dimensional collaborative sensing network is established by integrating infrared thermal cameras, acoustic emission sensors, molten pool cameras, CCD cameras, and line laser scanners. Real-time interlayer 3D topography feedback through line laser scanning combines with dynamic temperature gradient monitoring via infrared thermal imaging, enabling thermal accumulation prediction using Convolutional Long Short-Term Memory (convLSTM) networks to control layer thickness fluctuations. An improved You Only Look Once (YOLO) model achieves intelligent dynamic monitoring of multi-target features during welding, including arc light, wire feeding status, and molten pool conditions to prevent defect formation. Meanwhile, a multi-modal defect feature mapping system is constructed for detecting porosity, lack-of-fusion, and slag inclusion defects. This system significantly improves the efficiency and intelligence level of high-temperature alloy engine case repairs, providing a comprehensive, high-efficiency, low-cost solution for intelligent remanufacturing of aero-engines across the entire process chain.

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

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Nanyang Technological University, Mechanical and Aerospace Engineering

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. In order to boost the loading percentage, we propose using a photoacid which can selectively alter the pKa of the photoresin during the printing process, thereby increasing the absorption of metal cations. The printed organogels were then characterized by various techniques, such as inductively coupled plasma-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 pKa values, can affect metal absorption. 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 how pKa can be controlled during the printing process and its influence on as-printed structures. The potential of these compounds in developing new materials for applications in catalysis, electronic devices and biomedical applications would be discussed in future works.

Implicit Modeling-Based AM Feature Extraction Framework for Design for Additive Manufacturing

Sungmo Gu, and Sang-in Park

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Abstract

Design for additive manufacturing (DfAM) extends the principles of design for manufacturing to the domain of additive manufacturing (AM), enabling the optimization of design and manufacturing processes for layer-by-layer fabrication. While AM offers advantages such as reduced material waste, the ability to produce complex geometries, and suitability for personalized manufacturing, traditional computer-aided design systems face challenges in representing and modifying highly complex geometries. Implicit modeling has emerged as a promising approach for representing such geometries using function fields, facilitating unified data management and enabling seamless integration with AM processes. However, implicit modeling has limitations in applying traditional feature extraction methods, which restricts the efficient implementation of DfAM. This study proposes a framework for AM feature extraction based on implicit modeling. The framework employs a convolutional neural network (CNN) to directly extract AM features from implicit modeling. To enhance the performance of the CNN, a large dataset was automatically generated through Boolean operations between base and AM feature models. The trained CNN model successfully extracted five types of AM features from the given test models. The proposed framework supports the efficient application of DfAM, facilitating improved efficiency, flexibility, and quality in product development.

Machine Learning-based Process Parameter Optimization for Tailoring Mechanical Properties of Material Extrusion-fabricated Recycled Carbon Fiber Reinforced Plastic

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Abstract

The increasing applications of carbon fiber reinforced plastics (CFRP) in high-value-added industries have made the development of recycled CFRP (rCFRP) crucial for sustainable manufacturing. However, rCFRP exhibits unpredictable mechanical behavior due to property alterations during the recycling process, making it challenging for industrial implementation. Controlling mechanical properties is essential for reliable rCFRP production, which requires a thorough understanding of the relationship between process parameters and mechanical properties. This study comprehensively investigates the relationship between process parameters and mechanical properties using machine learning. An experimental approach is proposed to fabricate rCFRP specimens via material extrusion (MEX) with various process parameters and evaluate the mechanical properties of the rCFRP using tensile testing. A Multi-Layer Perceptron (MLP) model is trained on the experimental dataset to predict tensile strength as a function of process parameters, and the resulting surrogate model validated the consistency with experimental trends. The trained AI model successfully predicts tensile strength for different processing conditions, which allows optimal parameter selection for enhanced mechanical performance while ensuring manufacturability. This study establishes an AI based process parameter prediction model to achieve tailored mechanical properties of MEX-fabricated rCFRP. These findings advance both composite manufacturing technology and sustainable materials development, promoting industrial scalability in high-performance applications.

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Effect of Simultaneous CO2 & Steam Curing on the Buildability of 3D Concrete Printed Structures

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Abstract

The active integration of in-situ accelerated carbonation within 3D concrete printing (3DCP) presents a transformative approach to automated construction, addressing both efficiency and sustainability concerns. This study examines the impacts of CO2-steam integration on 3DCP process, particularly how different layer heights (10, 12.5, and 15 mm) influence printability performance. Building upon prior research, we find that CO2 integration at a 15mm layer height significantly improves buildability by over 30% compared to the control mix design (CTRL). While integration of both CO2 and steam also enhances buildability, the improvement is moderate at 15% due to a conflicting phenomenon attributed to condensed water-to-cement (W/C) ratios on interparticle friction. By exploring various layer heights, this research provides insights into optimizing print parameters in relation to CO2-steam integration, aiming to enhance carbon sequestration and construction efficiency. The advancements contribute to global efforts to reduce greenhouse gas emissions, promoting sustainable practices and encouraging the development of eco-friendly construction technologies

Data driven part quality prediction in additive manufacturing

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Abstract

In additive manufacturing (AM), due to large number of process parameters and multiple responses of interest, it is hard for AM designers to attain optimal part performance without a systematic approach. Surrogate modelling is a data driven technique to support design space characterization, prediction, and optimization. The objective of this research is to develop a data driven part quality prediction approach for achieving the targeted quality and performance by predicting part properties and optimizing AM process parameters. The proposed approach encompasses efficient sampling of design space and establishing the initial experiment points. Based on established empirical data, surrogate models are used to characterize influence of critical process parameters on responses on interest. Further, process maps can be generated for enhancing understanding on the influence of process parameters on responses of interests and AM process characteristics. Subsequently, multi-objective optimization coupled with a multi criteria decision making technique is applied to determine an optimal design point, which maximizes the identified responses of interest to meet the part functional requirements. A case study is used to validate the proposed approach for optimizing an additive manufactured part to meet its functional requirements. From the case study, results indicate that the proposed approach is able to achieve good predictive results for responses of interest with a relatively limited dataset. Further, process maps generated from the surrogate model provide a visual representation of the influence between responses of interest and critical process parameters for AM process, which traditionally requires multiple investigations to achieve the desired quality. The proposed approach can be applied to develop rules and guidelines for design for AM.

Data-Driven Design of Architected Materials: Enhancing Specific Stiffness through Multi-Objective Optimization

Seunghwa Ryu

KAIST

Abstract

Architected materials have redefined mechanical design by achieving outstanding properties through the manipulation of structural geometry rather than material composition. This study explores three cutting-edge strategies for developing materials with high specific stiffness: strut-based architectures, hybrid triply periodic minimal surface (HTAM) structures, and generative AI-enabled shape optimization. For strut-based designs, we applied multi-objective Bayesian optimization to fine-tune beam geometries, striking an optimal balance between stiffness and density. HTAM structures, which integrate multiple TPMS geometries, further broadened the design space, enabling configurations with enhanced mechanical performance. Additionally, generative AI techniques were used to explore novel architectural forms, offering unprecedented design flexibility. Finite Element Analysis (FEA) and experimental validation demonstrated significant gains in both modulus and strength across all design methodologies. This work highlights the powerful synergy between machine learning, advanced optimization frameworks, and additive manufacturing in addressing critical challenges in aerospace, biomedical engineering, and lightweight structural systems.

Toughening mechanisms of bioinspired dual-phase mechanical metamaterials by additive manufacturing

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Abstract

Nature materials, exhibiting superior mechanical properties, are generally hybrid composites typically consisting of a hard mineral phase within a soft phase of organic molecules with specified architectures. Inspired by the precipitation hardening mechanism and sinusoidal-helicoidal architectures observed in biological materials, we developed here dual-phase mechanical metamaterial composites, printed from austenitic stainless steel using additive manufacturing. Then, all the samples are compressed and their mechanical performance were compared with traditional lattice structures with uniform architectures. Dual-phase metamaterials experienced deformation stages contributed by matrix-phase and subsequently reinforcement-phase lattice structures, exhibiting greater specific energy absorption (SEA). Two deformation mechanisms, including “phase boundary slip” and “reinforcement phase rotation” were observed as the toughening mechanism, which could improve the energy absorption capability by increasing the stress level and postponing densification strain. Besides experimental tests, computational analysis was also carried out to examine effects of different geometrical ratios. Finally, design principles for mechanical metamaterials with dual-phase architectures were summarized for greater energy absorption capability. The study will provide guidance for the development and application of impact-resistant engineering structures.

Additive Manufacturing of Two-Stage Flexible Piezoresistive Sensors with Liquid Rope Coiling for Health Monitoring and Human-Computer Interaction

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Abstract

Flexible piezoresistive sensors are increasingly crucial for a variety of applications, including health monitoring, soft robotics, and human-computer interaction. This study introduces a novel flexible piezoresistive sensor featuring a two-stage structure designed to enhance both sensitivity and sensing range. The sensor is fabricated using a material extrusion-based process with a liquid rope coiling (LRC) effect, creating an open-cell foam structure at the top, while the lower section is constructed with a woodpile structure. The substrate of the sensor is composed of silicone, which is coated with multiwalled carbon nanotubes to improve electrical conductivity and enhance its piezoresistive properties. The top foam structure is developed using a specific process parameter that controls the coiling pattern to optimize sensor performance. The sensor exhibits a high sensitivity of 9.85 kPa⁻¹, a broad sensing range of up to 200 kPa, and demonstrates durability of up to 1,000 loading-unloading cycles. The sensor’s performance is further validated through its application in detecting human physiological signals and motion, highlighting its potential in real-time spatial pressure distribution and interactive control systems. These findings underscore the sensor’s promising capabilities for integration into diverse applications, particularly in health monitoring and human-computer interaction.

Optical Coherence Tomography Angiography Enhanced 3D Bioprinted Perfusion Platform for Vascularized Microtissue Dynamics

Chuanwei Mao, Hao Guo, Zeji Li, Yongkang Chen, Ling Wang, Mingen Xu, Shanshan Yang

Hangzhou Dianzi University

Abstract

In vascularized tissue engineering, the construction of functional tissues relies not only on the fabrication of complex biological structures, but also on the precise regulation and real-time monitoring of internal microfluidic environments. However, existing imaging approaches often fail to simultaneously achieve high spatial resolution, wide flow velocity range, and dynamic observation, posing a critical bottleneck to tissue maturation and functional reconstruction. To address this challenge, we developed a perfusion culture platform integrated with Optical Coherence Tomography Angiography (OCTA) and proposed a Complex Correlation Difference (CCd-OCTA) algorithm. By adaptively adjusting scan time intervals and scanning modes, the system can accurately measures flow velocities ranging from 0 to 600 mm/s. Using sacrificial-material-assisted multi-nozzle extrusion-based 3D bioprinter, vascular-mimicking scaffolds containing human hepatocellular carcinoma cell line C3A were fabricated in situ within PDMS-based microfluidic chips, forming perfusable and structurally complex microtissue constructs. The integrated OCT system enabled real-time 3D visualization of both tissue architecture and flow distribution within the chip. Flow measurements obtained via CCd-OCTA showed minor deviations from ideal CFD simulations, but matched closely with CFD results based on reconstructed geometries, demonstrating high measurement fidelity. Moreover, dynamic perfusion culture was assessed using OCT and confocal microscopy, revealing significantly increased viable cell number and volume under perfused conditions, particularly near flow channels. This work establishes a comprehensive workflow combining imaging, modeling, and bioprinting, offering a powerful tool for perfusion regulation and flow optimization in microfluidic tissue models. It holds significant potential for advancing long-term dynamic culture and the development of functional engineered tissues.

Advancing Additive Manufacturing: A*STAR's Innovation for Industry

Sharon Nai

A*STAR SIMTech & Additive Innovation Centre

Abstract

This presentation highlights A*STAR's latest innovations that are advancing the boundaries of additive manufacturing (AM) to meet the needs of next-generation industrial parts and their applications. Key developments include (i) the transition from 3D to 4D printing with the evolution from single-function to multi-functional printed parts, enabling smart and adaptive materials that respond to external stimuli, (ii) the advancement from single-material system printing to metal matrix composites, offering enhanced mechanical strength and functionality. These technological breakthroughs are part of A*STAR's integrated R&D strategy — combining design, materials, process optimization, sustainability, digitalization and AI with advanced modeling — to accelerate the translation of research into industrial solutions. This approach fosters strategic partnerships and drives innovation. This presentation will also share efforts to nurture the next generation of AM talent through collaborative training and research programs with industry and academia, reinforcing Singapore's vision of becoming a global leader in high-value, digitally driven manufacturing.

Experimental study on Magnetohydrodynamic driven liquid metal aluminium Drop-on-demand 3D printing

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Abstract

In magnetohydrodynamic (MHD) drop-on-demand (DOD) actuation, Lorentz force generated in different excitation stages are exerted on the liquid metal jet to form a "push-pull" mechanism, which is crucial for generating accurate and repeatable metal droplets. In this study, the important parameters of the excitation current waveform in the magnetohydrodynamic (MHD) process, including the influence of the excitation voltage pulse width ratio and current amplitude on the velocity, energy, volume, and breakup length of aluminium droplets are studied. The conversion process of surface energy and kinetic energy during the formation and fall stage of liquid droplets is analyzed. The results show that the negative and positive excitation voltage pulse width ratio of the MHD pump has a significant effect on the droplet velocity, breakup time, size, and sphericity. The amplitude of the excitation current and Hartmann number has a significant impact on the generation of stable droplets. The results show that the single droplet ejection state can be achieved within the Ha number between 319.5 and 391.1. As the Ha number increases, the volume, length, kinetic energy and surface energy of the droplets at breakup time also increase. The size of droplets can be adjusted by changing the amplitude of excitation waveform.

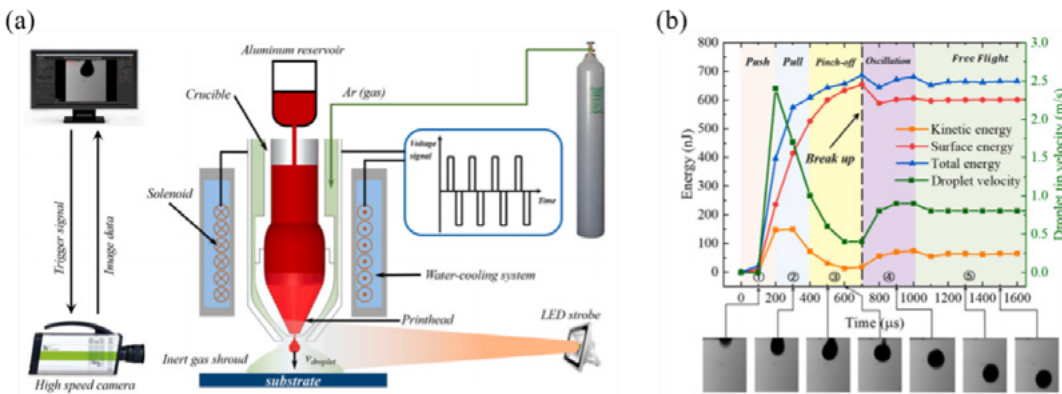


Fig. 1. (a) Schematic of the MHD DOD actuator setup. (b) Conversion between kinetic energy and surface energy of a droplet during formation and free flight.

The Transformative Role of Additive Manufacturing: Validated Framework for Biomechanically Optimized Patient-Specific Mandibular Reconstruction Plate

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Abstract

This study addresses the need for robust biomechanical evidence comparing patient-specific mandibular reconstruction plate (PSMRP), enabled by additive manufacturing (AM), with the conventional counterpart (MBMRP). We present a comprehensive evaluation using integrated finite element analysis (FEA) and biomechanical testing, supported by digital image correlation (DIC) for full-field strain measurement. Our approach assessed critical mechanical properties -yield strength, ultimate strength, fatigue strength, and system stiffness - under quasi-static compression and cyclic loading conditions.

Results demonstrate clear advantages for the AM-fabricated PSMRP. It exhibited 33% higher system stiffness under functional loads and achieved over 90% more life cycles before fatigue failure compared to MBMRP. Notably, a strong correlation was observed between FEA predictions and experimental outcomes, confirming the reliability of computational modeling for preoperative assessment in mandibular reconstruction.

These findings provide compelling biomechanical evidence supporting the clinical potential of AM-produced PSMRP. The observed improvements in stiffness and fatigue resistance suggest a pathway to reduce risks associated with plate failure and potential reoperations. Furthermore, this work establishes a practical translational framework that synergistically combines computational design optimization with experimental validation. This integrated methodology offers significant promise for advancing the development, evaluation, and clinical implementation of patient-specific implants in oral, craniofacial, and dental surgery, highlighting AM's transformative role in enhancing reconstructive outcomes.

A Review on 3D Biofabrication of Organ-scale Cardiac Models for Tissue Engineering

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Abstract

Cardiovascular diseases (CVD) are one of the leading causes of mortality and morbidity worldwide. The impairment of the ventricular filling and ejection fraction are the common causes of heart failure. This impairment is mainly due to structural and functional defects in the muscular layer of the heart. Hence, it is vital to understand cardiac performance by closely replicating the complex anatomical and pathological of a native heart. Consequently, several biofabrication processes stand out amidst the advances of organ biofabrication in tissue engineering. For instance, decellularization of extracellular matrix (ECM), focus rotary jet spinning (FRJS), and various 3D bioprinting and biofabrication processes. Decellularisation is a process of cell removal from an organ, hence, leaving the ECM scaffold for cell seeding and tissue regeneration. FRJS is a rapid manufacturing process using programmable controlled alignments of micro- or nano-fibres and cell seeding to fabricate 3D organs. 3D bioprinting is an additive manufacturing process where layers of biomaterials are deposited after each successive layer to create 3D structures. The biomaterials may contain various cells to attain complex organ structures with multiple cell types. A notable biofabrication process, the freeform reversible embedding of suspended hydrogels (FRESH), enabled the fabrication of a larger organ scale similar to the native organ size. These strategies aim to replicate a functional organ which is necessary for future applications to provide better diagnosis and treatment, development of new drugs, alternative surgical strategies, and dynamic medical modelling. This review aims to discuss and provide an overview of current 3D biofabrication of organ-scale cardiac model strategies for continuous improvement, and for researchers to create novel strategies for accurate biofabrication. Continuous improvements in 3D cardiac models will greatly enhance the effectiveness and efficiency of cardiology diagnosis and treatment.

Investigation of the Effects of Additive Manufacturing Parameters on Porosity Using X-ray Computed Tomography

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Abstract

With Selective Laser Melting (SLM) being more widely adopted as an Additive Manufacturing (AM) process, it is important to ensure consistency of the AM process and evaluate AM printed parts' quality associated with resulting pore defects. The utilisation of X-ray Computed Tomography (XCT) as a non-destructive and quantitative volumetric evaluation method is suitable to measure the size and distribution of the pores, as well as the corresponding porosity. This study aims to investigate the correlation between different printing parameters used to fabricate 38 maraging steel parts using SLM and their resulting porosities as determined by XCT. The printing parameters studied include Laser Power (LP), Laser Scanning Speed (LSS) and Hatch Distance (HD). From this study, it is found that the sample printed using LP: 228.75 W, LSS: 1010 mm/s and HD: 0.0825 mm has the smallest porosity (0.001%). On the other hand, the sample printed using LP: 381.25 W, LSS: 1262.5 mm/s and HD: 0.1375 mm has the highest porosity (2.569%). Based on the parts fabricated by SLM with different process parameters, the results obtained by the proposed XCT show that: 1) SLM parts printed in vertical building direction introduce lesser defects (smaller porosity) than parts built along a horizontal direction; 2) Lower LP results in more defects (higher porosity); 3) Faster LSS introduces more defects (higher porosity); and 4) Larger HD introduces more defects (higher porosity). The porosity repeatability test of 5 scans of a part (averaged porosity: 0.475%) was done to verify the porosity testing stability by XCT and it demonstrates that the standard deviation for testing porosity is 0.0103 %. In addition, some dog-bone shape samples fabricated by AM are tested also by the proposed XCT. The obtained internal pore defects and porosity results demonstrate XCT is an effective tool to quantify AM parts' defects.

Implementation of TPMS-Structured Multi-Airflow Channels in High-Performance Brake Discs

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Jiangsu Normal University

Abstract

With the rapid growth of the electric vehicle industry in recent years, the demand for high-speed braking performance has significantly increased. This study aims to enhance the heat dissipation capability of brake discs to improve friction efficiency and reduce wear. A novel heat dissipation module based on Triply Periodic Minimal Surface (TPMS) structures was fabricated using selective laser melting (SLM) with aluminum alloy. The TPMS modules were integrated into the brake disc using low-entropy alloy powders to weld the ventilated structures onto the disc surface. Finite element simulations were conducted to analyze the mechanical, thermal, and fluid dynamic behavior of the brake disc after the integration of TPMS structures. Comparative studies between conventional brake discs and those modified with TPMS modules revealed significant improvements in multiple performance aspects. The results demonstrate that the introduction of TPMS-based multi-channel structures enhances the thermal regulation and structural resilience of the disc, making it more suitable for high-speed braking in modern electric vehicles.

Computational Investigation of Powder-Induced Porosity in Laser-Based DED

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Abstract

Multi-physics modeling is one of the most powerful methods to study the metal additive manufacturing (MAM) technology. It can reduce the cost of trial-and-error experiments and provide many insights of the process, which are hard to directly obtain in the experiments. Directed energy deposition (DED) is one of the most commonly used MAM technology and holds significant potential for the manufacturing and in-situ repairing of critical metallic parts. However, the gas porosity defect is inevitably introduced in the DEDed parts, which severely affects the mechanical properties and fatigue performance. In this study, we innovatively combine the discrete element method (DEM) and computational fluid dynamics (CFD) model to investigate the powder-induced gas porosity defect in DED. The transient porosity nucleation and evolution are reproduced using the coupled CFD-DEM model. The results show that the fluid drag force is the dominate driving force for small bubble (smaller than 95 μm in diameter) migration in the molten pool. The generated bubbles have satellite-like rotational motions in the vortex regions of molten pool, but escape directly from the molten pool in the straight flow region. The motion behaviours of the bubbles increase the collision frequency and coalescence efficiency between bubbles and lead to higher porosity density at the top and bottom of the track. Finally, two methods, namely powder stream size tailoring and laser beam shaping are proposed to mitigate gas porosity. This work can further enhance the understanding of coupled physical phenomena and gas porosity formation in DED.

Melt pool dynamics and grain growth behavior during directed energy deposition additive manufacturing of high-entropy Cantor alloy by integrating in-situ and ex-situ monitoring

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Abstract

Directed energy deposition (DED) additive manufacturing (AM) technology enables the customization of materials, structures, and properties to meet specific design requirements, which is significantly flexible in material selection and suitable for the fabrication of high entropy alloys (HEAs) with the “cocktail effect” of multi-principal elements. However, direct connections between real-time deposition process and resultant properties remain ambiguous due to limitations of conventional methods. This study explores the melt flow dynamics and grain growth behavior of Cantor alloy during DED process by combining in-situ and ex-situ experimental approaches. The effects of various process parameters on melt pool dynamics, solidification behavior, and their influence on microstructural development were systematically analyzed. In-situ experiments utilizing high-speed synchrotron radiation X-ray imaging and diffraction techniques enabled real-time observation of melt pool dynamics and solidification processes during in-process fabrication. Ex-situ characterization, performed using electron backscatter diffraction (EBSD), provided post-solidification insights into the grain structure and crystallographic texture. The results demonstrate that melt solidification behavior can be tailored by adjusting processing parameters like laser power and scan speed. Additionally, a customizable grain structure and controllable crystallographic texture are achievable under specific processing conditions. These findings underscore the advantages of integrating in-situ synchrotron radiation and ex-situ characterization techniques, contributing to a more comprehensive understanding on AM processes and broadening the research scope of this technology. The synergy of these advanced experimental methods offers a deeper perspective on the interplay between process parameters, melt flow dynamics, and microstructural evolution. Future work will focus on further advancing these methodologies, including enhancing real-time monitoring techniques, improving data processing algorithms, and leveraging artificial intelligence (AI) for more precise process optimization and predictions, ultimately expanding future industrial applications.

Keywords: High entropy alloys (HEAs), Directed energy deposition (DED), Melt pool dynamics, Grain growth behavior, Integration of in-situ and ex-situ investigation

WAAM Certification of a Non-Production Inconel 718 Spacer Sleeve

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Abstract

Wire arc additive manufacturing (WAAM) is a direct energy deposition manufacturing process that builds near net shape parts layers by layers on a substrate using a motion system. It is a commercially viable way to fabricate medium to large scale parts and is increasingly being explored as a sustainable fabrication technique in the marine and offshore industries. This paper presents the certification journey of the WAAM of a non-production prototype of the spacer sleeve, a part commonly found within a tubing hanger that is used to hold metallic seals in position. First, we discussed the process study and design of the test coupon that leads to the build process qualification of a WAAM Inconel 718 material based on DNVGL-ST-B203. Next, we described the toolpath and process control used to print a topologically optimized spacer sleeve with closed contours of varying thickness, and as well as overhanging features. Then, we showed the results of the various prints performed and the inspection test of a post-processed spacer sleeve. Finally, we discussed the variety of gaps identified during the development process and possible future work towards a production ready spacer sleeve.

3D Printing Fungus-like Adhesive Materials

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Abstract

Synthetic polymers including thermoplastic and thermosets have dominated additive manufacturing, and particularly rapid prototyping, for several decades by now. Understanding that synthetic plastics have been environmentally detrimental, we developed a novel biopolymer extrusion process using exclusively natural components, namely cellulose and chitin. These are two of the World’s most abundant and widely available biological materials which when combined, produce Fungus-Like Adhesive Materials (FLAM), a family of bio composites with innately sustainable characteristics. This is because unlike generic bioplastics, FLAM do not require land for growing food sources to be later converted into thermoplastics that require specialized compositing. Instead, FLAM retain their components unmodified and biodegrade not unlike natural timber or biofoams. In this presentation we present the development of the FLAM3D technology, the challenges faced and its potential applications. The lessons shared offer a broader perspective into additive manufacturing with biological materials.

Autonomous process planning and monitoring in additive manufacturing using AI techniques

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Abstract

Cutting-edge artificial intelligence (AI) techniques, such as computer vision-based and data-driven algorithms, have revolutionized real-time quality control in additive manufacturing, enabling real-time detection and in-situ correction of defects. This presentation will show such advanced systems, which integrate an array of machine learning methods that address the intricate challenges of additive manufacturing. For anomaly detection, supervised learning techniques, such as object detection (e.g., YOLO) or semantic segmentation (e.g., U-Net), identify defects in printed surfaces or at the printing nozzle from labeled data in real time. Meanwhile, unsupervised approaches employing variational autoencoders detect potential defects stemming from inconsistencies in machine settings or material flow. By swiftly pinpointing the defective issues and facilitating the in-situ compensation, these AI-driven solutions enhance the overall reliability of the printing process. Additionally, reinforcement learning (RL) optimizes critical process parameters, such as printing speed, laser power, and geometrical features, by coupling physics-based models or finite element analysis simulations with RL environments. This not only increases printing efficiency and mechanical performance but also reduces the likelihood of deformation-related defects. By unifying supervised, unsupervised, and reinforcement learning approaches, AI-powered additive manufacturing systems significantly improve productivity and ensure higher-quality outcomes, ultimately enabling fully autonomous process planning and monitoring.

3D concrete printing with coarse aggregate: a study of mechanical properties and CO₂ uptake

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Abstract

Additive manufacturing (AM), commonly known as 3D printing, has garnered significant interest from researchers and manufacturers globally due to its potential to lower product costs and time, reduce manpower, and enhance design flexibility. Recent projects in the building and construction sectors have successfully utilized cementitious materials in 3D printing. However, there are limitations to this technology in construction. For example, the use of fine aggregate particles, typically less than 4 mm in size, requires a substantial amount of cement to produce 3D printable materials. Since cement production contributes to carbon emissions, the sustainability of 3D printing in construction is questionable. To address this concern, one potential strategy is to substitute fine particles with larger aggregates in the printable materials, which would significantly decrease the amount of cement used and, in turn, reduce carbon emissions.

Many existing studies on 3D concrete printing have involved large quantities of cement relative to the total weight of solid materials, with cement sometimes constituting over 50% of this total. In this study, we developed a 3D printable concrete material using coarse aggregates with a maximum size of 10 mm. We replaced approximately 7% of the fine aggregate with larger aggregate, resulting in cement accounting for about 29% of the total weight of solids. We then tested the mechanical properties and CO₂ uptake of the 3D printable material with coarse aggregates. During the printing process, CO₂ gas, and steam were sprayed on the surface of the printed layers, and Thermogravimetric analysis (TGA) was conducted to determine CO₂ uptake over several days. The results from the CO₂ and steam-sprayed 3D printed samples were compared with control samples that did not receive any CO₂ treatment. It was found that both mechanical properties and CO₂ uptake were enhanced in the CO₂ and steam-sprayed samples compared to the control samples.

Development of High-Silicon (6.5 wt.% Si) Fe-Based Soft Magnetic Cores via Dual-Nozzle Material Extrusion and Spark Plasma Sintering

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Abstract

High-silicon (6.5 wt.% Si) Fe-based soft magnetic cores possess high saturation magnetization and low core loss, making them highly suitable for power conversion devices, electric motors, and transformers. However, their brittleness significantly limits processability in conventional pressure-based manufacturing methods. In this study, a novel fabrication approach was developed by integrating dual-nozzle material extrusion (D-MEX) with spark plasma sintering (SPS). This method enables the in-situ deposition and sintering of Fe-6.5Si powder with a MgO-B₂O₃-SiO₂ (MBS) ceramic insulation layer, allowing for the fabrication of multilayered soft magnetic laminated cores in a single process.

The fabricated metal-insulator-metal (MIM) structures with a 0.2 mm-thick ceramic insulation layer exhibited a saturation magnetization of approximately 1.49 T and a coercivity of 600–700 A/m. Post heat treatment at 1,200 °C effectively removed residual porosity and promoted grain growth, reducing coercivity by up to 40% (from 685 A/m to below 400 A/m). Consequently, hysteresis loss, which increases with frequency, was also reduced by more than 20%. Microstructural analysis revealed that reaction products such as Mg₂SiO₄ were formed within the MBS insulation layer, enhancing interfacial bonding with the metal layers. The modified interface further decreased domain wall movement resistance, contributing to improved magnetic performance.

This study demonstrates that a multilayered, thin-film insulated structure can be successfully implemented using high-silicon Fe-based alloys, overcoming the processing challenges associated with their brittleness. The proposed D-MEX and SPS-integrated process provides a new pathway for developing high-efficiency soft magnetic cores for applications below 1 kHz, improving magnetic performance and reducing energy loss. These findings open new possibilities for the fabrication and application of advanced soft magnetic cores.

3D Bioprinted scaffolds for joints regeneration

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Abstract

Tissue engineering is theoretically thought to be a promising method for the reconstruction of biological joints, and thus, offers a potential treatment alternative for advanced osteoarthritis. However, to date, no significant progress is made in the regeneration of large biological joints. In the current study, a biomimetic scaffold for rabbit humeral head regeneration consisting of heterogeneous porous architecture, various bioinks, and different hard supporting materials in the cartilage and bone regions is designed and fabricated in one step using 3D bioprinting technology. Furthermore, orchestrated dynamic mechanical stimulus combined with different biochemical cues (parathyroid hormone [PTH] and chemical component hydroxyapatite [HA] in the outer and inner region, respectively) are used for dual regulation of endochondral ossification. Specifically, dynamic mechanical stimulus combined with growth factor PTH in the outer region inhibits endochondral ossification and results in cartilage regeneration, whereas dynamic mechanical stimulus combined with HA in the inner region promotes endochondral ossification and results in efficient subchondral bone regeneration. The strategy established in this study with the dual modulation of endochondral ossification for 3D bioprinted anisotropic scaffolds represents a versatile and scalable approach for repairing large joints.

Computational Fluid Dynamics Simulation of the Effects of Flow Conditions in 3D Concrete Printing

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Abstract

Compared to traditional construction processes, the flow behavior in three-dimensional concrete printing (3DCP) has a much greater impact on the final printing performance. However, accurately and affordably measuring concrete flow remains challenging due to the lack of suitable sensors. This study employs Computational Fluid Dynamics (CFD) simulations to analyze material flow in 3DCP. The Bingham Plastic model was used to describe the viscosity of concrete, and ANSYS Fluent was utilized to simulate flow conditions. The simulation setup was validated by comparing experimental and simulated extrudate formation under various conditions. The effects of nozzle shape, flow rate, printing path, and material properties were investigated through CFD simulations. The results indicate that the deformation of the printed filament is independent of plastic viscosity, whereas material yield stress and relative nozzle travel speed significantly influence filament deformation under straight printing paths. Additionally, rheological properties have little impact on the mass distribution ratio at corners of the printing path. However, achieving a uniform material distribution ratio is more feasible with a high relative nozzle travel speed, larger corner radii, and a lower nozzle aspect ratio. CFD simulations can also be used to study microstructures, such as fiber and pore orientation, which affect the anisotropic properties of 3D-printed concrete parts. These findings suggest that CFD simulations can effectively predict the formation and properties of 3DCP components under various conditions, providing valuable guidelines for improving print quality of 3DCP.

Construction of dynamic tumor microenvironment through bioprinting

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Abstract

Antitumor immunotherapy has advanced significantly, offering a systemic cancer treatment alternative to conventional therapies. A deeper understanding of the immune microenvironment and tumor cell interactions will further drive the field forward and breakthroughs. Dependent on the recognition of major histocompatibility complexes on cell membranes, tumor-immune interactions are highly time- and space-dependent by the regulation of different environmental signals. The current large-cell-based models often cannot predict intratumor diversity and immune communication between individual cells, resulting in differences between preclinical evaluations and clinical outcomes. A single-cell-scale model would help reproduce tumor heterogeneity and improve understanding of cell–cell interactions in tumors.

The single-cell-based immuno-oncology model includes individual dendritic cells, T cells, and melanoma cells and is constructed using a specialized single-cell printing technique. The limited spatial volume of the microscale 3D printing construction limits the cell interaction distance and improves the efficiency of cell contact. The reproduction of single cell scale interactions helps to reveal more information about cell subtypes and temporal heterogeneity.

The immune cells in the developed immuno-oncology model exhibit characteristics consistent with adaptive immunity, including recognition, presentation, cytotoxicity, and immunosuppression. In particular, the dendritic cells in the model regulate the movement of T cells upon recognition, and the duration required for cell contact can be increased by 4–6 times when the cell distance exceeds 60 μm . The reported single-cell-scale immuno-oncology model is anticipated to facilitate cellular immune function prediction for personalized immunotherapy by quantifying the contact efficiency with respect to the cell distance and actuation duration. With the capability of stably reproducing in vivo-like immune–tumor cell contact under controllable variables, the current in vitro model provides the feasibility of refining, expanding, and validating the current understanding of immune synapses and dynamic immune–tumor cell interactions.

Multi-Scale Analysis of Material Uncertainty and Its Impact on Mechanical Property Distribution in L-PBF Parts

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Abstract

Industrial production of high-quality components by laser powder-bed fusion (L-PBF) additive manufacturing requires careful assessment of the combined role of part design, material properties, and process parameters in determining the final component's mechanical properties. Various uncertainties arising throughout the L-PBF process affect the quality of the printed components. Therefore, understanding the impact of different uncertainties on part quality is crucial. To quantify such impact, modeling and simulation is a powerful tool to predict properties based on input parameters and thus provide a direct and low-cost route as compared to experimental testing. In this work, we present a multiscale framework for the quantification and propagation of uncertainty across the L-PBF process. Uncertainty can be classified as process-originated or material-originated. Here uncertainty in material property is considered, where thermal conductivity, specific heat, and density are considered random, and the effect of material uncertainty is studied at the scale of the powder and the scale of the part. The variation in material properties in part is modeled as Gaussian random fields, and the spatial variation of mechanical properties of the printed part is quantified. Also, we quantitatively show how uncertainty propagates from the scale of the part to the scale of the powder, and then back to the scale of the part. We demonstrate the framework with the case of two coupon bars, one printed vertically and the other horizontally on the build plate. We show that, because of the larger impact of heat loss through the baseplate, uncertainty is reduced in horizontal bars as compared to vertical bars, where overheating is possible. Our findings suggest that printing parts by maximizing contact with the baseplate is an effective way to reduce uncertainties in part characteristics, promoting part quality in practical applications of additive manufacturing.

Experimental and machine learning analysis of warping behaviour in LPBF-fabricated stainless steel cantilever beams

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Abstract

Additively manufactured structures produced via laser powder bed fusion (LPBF) process have gained significant prominence as a means to achieve net-zero manufacturing. However, challenges associated with thermal distortion and warpage have persisted within the LPBF process due to the presence of high residual stresses during both the building and cooling phases. Such dimensional errors limit further adoption of additive manufacturing in industry to build large-scale and thin-wall geometries. While extensive studies focused on complex and coupled effects of process parameters on thermal distortion of LPBF parts, the challenge remains consisting of correlating recoater orientation, air-flow direction and geometry factors with residual stress and warpage. In this study, we systematically designed a series of cantilever beams and fabricated by LPBF process with consideration of sample orientation. The warpage profiles of cantilever beams were measured by coordinate measuring machine after wire-cutting by various beam thicknesses. The residual stress distribution of LPBF samples were characterised to evaluate effect of sample orientations. More batches of experiments were conducted with different cantilever beam dimensions. Hereafter, the main factors that affect warping of cantilever beam were analysed under the same process condition. Subsequently, we trained the experimental data obtained with various machine-learning algorithms to predict warping behaviour of the cantilever beams. Finally, the performance of ML-based prediction methods was evaluated. The results concluded that process-induced warpage was affected by recoater and airflow directions, which can be explained by the residual stress distribution in as-printed cantilever beams. The warpage of the beam can be well predicted by machine learning models with input of its key geometric dimensions.

Advanced Bioprinting Strategies for the Fabrication of Biomimetic Tissues and Organs

Wei Long Ng

Abstract

Bioprinting is an emerging frontier in tissue engineering that enables the precise, layer-by-layer fabrication of three-dimensional (3D) tissue constructs. By integrating engineering principles with biological complexity, bioprinting offers unprecedented opportunities to replicate the structural and functional intricacies of native human tissues, thereby accelerating advances in regenerative medicine and personalized healthcare. This presentation highlights current challenges and key design considerations in fabricating biomimetic tissues, with a focus on the critical roles of anatomically relevant architecture, microenvironmental cues, and vascularization. It emphasizes the need for next-generation bioprinting strategies to overcome existing limitations in biofabrication fidelity, resolution, and scalability. It also discusses innovations in bio-inks and printing modalities that are central to maintaining cell viability and promoting functional tissue development. Particular attention is given to emerging directions such as multi-modal and in-situ bioprinting, as well as the integration of machine learning to optimize printability, structural accuracy, and biological outcomes. Post-printing strategies aimed at enhancing tissue maturation and function are also examined, underscoring their importance for translational applications. By critically examining recent advancements and identifying future directions, we aim to highlight the transformative potential of advanced bioprinting strategies in shaping next-generation solutions for tissue regeneration, disease modelling, and personalized therapeutic interventions.

Acknowledgements:

This paper is supported by the National Research Foundation, Singapore, under its NRF Investigatorship (NRF-NRFI07-2021-007, Funding Awardee: Wai Yee Yeong).

Advanced materials through structure and material design in 3D printing

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Abstract

3D printing is increasingly recognized as a versatile tool for developing advanced materials through the combined design of structure and composition. In this presentation, we showcase our research and capabilities in additive manufacturing, highlighting how structural architecture and material innovation can be integrated to achieve tailored and multifunctional properties. Our work spans a range of material systems and design strategies. We demonstrate how lattice structures can be used to control mechanical and acoustic performance, and how custom material formulations—including ceramics, soft filaments, and composites—expand the functional possibilities of printed systems. By uniting structural and material design, we unlock new opportunities for creating adaptive, responsive, and application-specific materials. This presentation provides an overview of how our research leverages additive manufacturing not only as a fabrication method but as a platform for materials innovation across diverse domains.

3D printed scaffolds with hierarchical biomimetic structure for bone defect repair

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Abstract

The repair and functional reconstruction of large bone defects that cannot heal themselves have always been a major clinical challenge in orthopedics, with a very high rate of disability and deformity. The current clinical use of traditional bone defect repair materials cannot effectively meet the clinical needs. Bone tissue includes cortical bone and cancellous bone, which is composed of a series of bone trabeculae in a loose porous reticular structure. In recent years, studies have found that porous bone repair scaffold materials have good bone conduction due to their biomimetic porous structure, which shows great potential to promote the repair of bone defects.

Focusing on the design concept of bionic porous bone repair scaffold, we have developed low temperature 3D printing technology for precise molding and manufacturing of personalized structure bionic, shape adapted, and mechanical property matched bone repair scaffold. Biodegradable polymer with good biological safety is used as the substrate material, and multifunctional bioactive inorganic micro/nano materials are composite. To construct bone repair materials for the treatment of traumatic bone defects, bone tumors, and steroid-induced avascular necrosis of the femoral head. By combining functional inorganic micro/nano components such as metal magnesium particles, magnesium peroxide nanoparticles, black phosphorus nanosheets, manganese dioxide nanoparticles, and polydopamine nanoparticles in the scaffolds, the precise treatment of specific bone defect diseases can be achieved. The clinical image-guided biomimetic structure design and multi-parameter regulation of biological materials precision molding technology have been realized. The mechanism study showed that the bioactive inorganic micro/nano materials combined with degradable polymer 3D printed scaffolds could promote bone formation, angiogenesis, cell adhesion and proliferation, stem cell differentiation, and immune microenvironment regulation through active ingredients and bionic 3D structure to achieve effective repair of bone defects.

Design and Preparation of Body-Temperature Responsive Biodegradable Polymer Materials for Laser-based 4D Printing

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Abstract

Biodegradable shape memory biomaterials hold substantial potential for application in fields such as intelligent drug delivery systems and minimally invasive implantable medical devices. By integrating smart materials with conventional 3D printing technology, 4D printing enables the precise fabrication of medical devices with personalized structures and controllable functionalities. This study explores the preparation of heterogeneous powder materials composed of poly(lactic acid) (PLA) and poly(ϵ -caprolactone) (PCL), fabricated via both physical blending (PLA/PCL) and copolymerization (PLCL) methods, specifically tailored for laser powder bed fusion (LPBF) processes. The investigation encompasses powder morphology, particle size distribution, thermal behavior, and their effects on mechanical and shape memory properties. During powder preparation, the composition of PLA and PCL components was systematically adjusted, and its influence on these properties was evaluated. Results indicate that the optimal PLA/PCL blend (PLA/PCL40) exhibits an elastic modulus of 500 MPa, tensile strength of 4.7 MPa, and elongation at break of 1%. Its optimal deformation temperature is 60 °C, with a shape recovery ratio (Rr) exceeding 66%; however, this relatively high temperature may pose risks to human tissues. Conversely, the optimal PLCL copolymer (PLCL20) demonstrates an elastic modulus of 220 MPa, tensile strength of 5 MPa, and elongation at break of 41%. Its optimal deformation temperature is 40 °C, with an Rr surpassing 95%, aligning more closely with human physiological conditions and minimizing tissue damage. Additionally, a finite element method (FEM) was employed to simulate the shape deformation process and predict the behaviors of shape memory polymers (SMPs).

Structural optimization design and mechanical performance analysis of porous bone scaffolds filled with secondary lattice structures

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Abstract

Bone scaffolds are crucial for treating bone defects, and suitable mechanical properties and pore structures are prerequisites for ensuring effective integration between scaffolds and bone tissues. To mitigate the stress shielding effect between porous bone scaffolds and human bones and enhance their mechanical performance, this study investigates the influence of pore shape and radial porosity gradient on the mechanical properties of Network-type Gyroid porous bone scaffolds based on the Gyroid minimal surface. A secondary lattice structure design method is proposed to optimize the mechanical properties of bone scaffolds, supported by finite element simulations and experimental results. Using fused deposition modeling technology and polyether ether ketone material, porous bone scaffold samples with radial porosity gradients and pore shape variations were fabricated. Finite element simulations and compression tests revealed that when the average porosity was designed at 50%, adjusting the pore shape of the Gyroid porous scaffold increased its Young's modulus from 247 MPa to 607 MPa and its yield strength from 8.89 MPa to 23.6 MPa. By introducing a radial porosity gradient, the Young's modulus and compressive yield strength were further improved to 677 MPa and 25.1 MPa, respectively, achieving mechanical properties compatible with human bone. Based on simulation and experimental findings, optimizing the fracture-prone regions of the porous scaffold struts with a secondary lattice structure reduced scaffold fracture and further enhanced mechanical performance.

Keywords: Gyroid minimal surface; Porous bone scaffold; Hybrid gradient; Secondary lattice structure; Mechanical properties

Unraveling crack formation and elimination in AA7075 alloy during laser remelting: insights from in-situ high speed X-ray imaging

Wenhui Yu, Jiaxing Xiao, Hongyu Zheng

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Abstract

The inherent susceptibility to hot cracking of AA7075 alloy presents a significant challenge in its laser powder bed fusion (LPBF) manufacturing, limiting its application in aerospace and automotive applications. However, the mechanisms of how solidification cracks in the melt pool form and propagate remain inadequately understood. In this study, in-situ high-speed X-ray imaging was used to monitor the laser remelting process on LPBF-fabricated AA7075 and 7075-Er-Zr substrates. The remelting process emulates the sequential layer scanning characteristic of LPBF. The microstructure of the substrates and the processing parameters were found to be related with the crack formation. Two different crack formation modes were identified in the AA7075 substrate: one originates from pre-existing defects and propagates upward through vulnerable areas, and the other starts within the final depression zone of the melt pool, extending downward through weak regions. In substrates with a higher density of defects, cracks are more prone to originate from these inherent flaws. Er and Zr addition were found to reduce the number density of cracks. Another key observation is that the rupture of gas pores can cause melt pool fluctuations, which may lead to crack elimination. The effectiveness of crack elimination in the melt pool is largely influenced by the inherent microstructure of the substrate, the processing parameters, and the alloy composition. These findings provide valuable insights into strategies for reducing and eliminating cracks in LPBF.

Multiscale Architected Structures with Tailored Thermal, Mechanical, and Electromagnetic Functions via Additive Manufacturing

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Abstract

The escalating demands of next-generation electronics, energy storage, portable/wearable devices and mobility platforms necessitate multifunctional materials capable of concurrently addressing thermal management, mechanical robustness, and electromagnetic wave (EMW) shielding/absorption. However, achieving seamless integration of these disparate functionalities within a single hybrid composite remains a formidable challenge due to intrinsic trade-offs between the multiple properties, as well as interfacial instability and material incompatibility.

Here, we present recent advances in multiscale metamaterial composites fabricated via multi-material additive manufacturing, which enable the co-design and concurrent control of thermal-mechanical-electromagnetic functionalities. First, we introduce a meta-sandwich structure comprising functional faceplates and a dielectric lossy octet-truss (OT) core. This lightweight architecture serves as a broadband EM wave absorber with ~95% average absorption and ≤ -10 dB reflection loss, while simultaneously providing mechanical load-bearing capability.

Second, we demonstrate a multiscale porous architecture that integrates 3D-printed OT lattices and graphene aerogels as a robust framework for sustainable phase change materials (PCMs). The OT structures offer directional support and leakage resistance, while graphene aerogels provide high-surface-area scaffolding to retain paraffin wax. This architecture delivers bulk-like thermal energy storage performance and enhanced mechanical-chemical stability over extended thermal cycling.

Finally, we present a structurally engineered metastructure combining OT frameworks with anisotropic MXene/TEMPO-oxidized cellulose nanofiber aerogels and n-eicosane as PCM. The OT framework significantly enhances mechanical resilience, stabilizing the composite during phase transitions. Meanwhile, the anisotropically aligned MXene aerogel facilitates directional heat transport, suppresses PCM leakage, and augments EMW control. The composite demonstrates superior active thermal regulation and thermal buffering, prolonging heat release or delaying temperature rise, thereby maintaining temperatures within a stable operating range.

This multifunctional, multiscale architecture overcomes key limitations of conventional composites, enabling their application in advanced electronic and energy systems, including wearable devices, autonomous technologies, and future mobility, where integrated thermal, mechanical, and electrical functionality is essential.

Unraveling the Creep Behavior of Inconel 718 Lattice Metamaterials: A High-Throughput Approach

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Abstract

Additively manufactured mechanical metamaterials (MMs) represent a class of elaborately engineered materials. They exhibit remarkable mechanical attributes, including a lightweight nature, high strength, and excellent energy absorption capabilities, thereby showing vast application potential across diverse fields, especially in aerospace. Despite this promise, the current body of research predominantly centres on MMs' uniaxial compression or tensile properties, largely overlooking their creep performance during long-term service. In this study, the focus is on the creep behavior of Inconel 718 alloy-based MMs. By utilizing the high-throughput compression creep method, in combination with finite-element simulations and the quasi-in-situ CT technique, an in-depth and detailed exploration is carried out regarding the creep performance and deformation mechanisms of BCC/FCC strut-shaped MMs, BCC/FCC plate-shaped MMs, and Gyroid/Primitive surface MMs. The findings reveal a strong correlation between the creep rate of MMs and their yield strength. Specifically, plate-shaped MMs display the slowest creep rate and the longest creep duration, which can be ascribed to their favourable elastic modulus and uniform stress distribution. In contrast, strut-shaped and surface MMs follow a shear failure mode, while plate-shaped MMs experience minimal deformation, with only a few cracks emerging. This research systematically assesses the creep performance of MMs. This not only paves the way for further investigations into the mechanical behavior of MMs under complex service conditions but also provides a solid theoretical basis for their practical applications in real-world engineering scenarios.

Deep learning for self-calibrated bioprinting

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Abstract

In the rapidly evolving field of bioprinting, optimizing printing parameters for specific bioinks presents a significant challenge, often requiring extensive trial-and-error experimentation. This process consumes valuable time and resources, making it inefficient for practical applications. To address this issue, we have developed a novel self-calibrating system leveraging deep learning and reinforcement learning techniques. While traditional methods often require ink composition adjustments, the bioink is often tailored for specific applications and thus undesirable. This work focuses on calibrating printer parameters without modifying bioink composition to achieve optimal printing result. The system begins with the acquisition of a single image of the printed hydrogel, enabling the deep learning model to determine key characteristics such as printability, width, and height of the sample. These values are then fed into a deep reinforcement learning framework, which dynamically adjusts the printing parameters to attain the desired printed width. By automating the calibration and optimization of printing parameters, the approach will reduce the time and material costs associated with conventional empirical testing. The integration of deep learning techniques into bioprinting technology offers a pathway towards highly efficient, customizable printing solutions without compromising on the specialized properties of bioink compositions.

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Abstract

Owing to the low crystallinity, entropic elasticity, high deformability and damping ability, elastomers are widely used in various fields, such as shock absorption, sealing, medical equipment, and tensile electronic devices. 3D-printed elastomeric materials endow themselves with design and processing capabilities beyond traditional rubber materials, enabling the preparation of multi-scale structures, and combining them with functional composites to prepare gradient materials. Therefore, starting from the processing characteristics of thermoplastic elastomer materials, we are pursuing the efficient, high-strength, and high-precision 3D printing process for the melt-extrusion-based printing technology of elastomeric materials. From the perspective of processing principles, mechanical properties, and microstructure evolution, the followed improvement methods of elastomer materials that are different from plastics were emphasized. However, additively manufactured rigid thermoplastic specimens with typical layer-wise structure generally exhibit mechanical anisotropy (mostly tensile anisotropy), which was reportedly corrected by eliminating the overestimation of the geometrical size of the sample. An insight into the mechanical anisotropy of 3D-printed deformable elastomers is required for guiding high-quality printing process. Currently, the structure–property relationship of 3D-printed elastomers is discussed to provide an in-depth understanding of their intrinsic mechanical dependence, on which the orientation degree induced by wall shear, the elimination of internal voids and the deformation behavior during tensile process are emphasized. Tensile samples fabricated by melt-extrusion-based printing technology with varying specific microstructures were employed to explore the dependence of tensile properties on the microstructure. The microstructure of the printed samples is suggested to be responsible for the mechanical degradation as well as anisotropy.

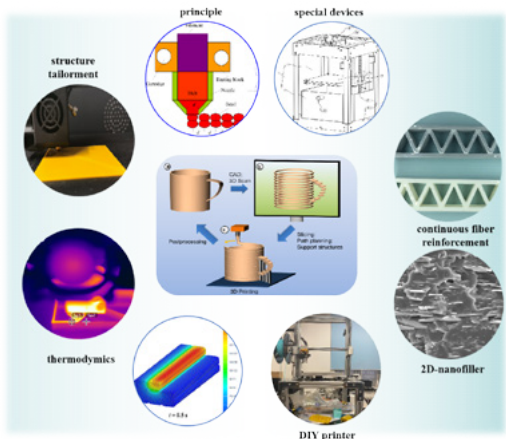


Fig.1 An overview of additively manufactured elastomers.

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Abstract

Radiation injuries (RI) have long been studied since the atomic disasters. With the wide applications of radiation therapies in tumor treatment. RI, in particular, Cutaneous radiation injuries, including skin and mucosal damage, are among the most common complications, affecting over 70% of patients undergoing radiotherapy, therefore, there is an urgent need for accurate assessment, effective treatment and prevention. Traditional RI models, such as in vitro cell cultures and animal studies, face limitations in translational relevance. Recent advancements in bioengineering—including 3D bioprinting, organ-on-a-chip systems, and patient-derived organoids—offer innovative platforms to better recapitulate human pathophysiology. In this review, the advances of RI models have been discussed, in particular, 3D bioprinted skin models, skin-on-a-chip and skin organoids.

A Generic Calibration Method for Volumetric Heat Source Models in Additive Manufacturing

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Abstract

Numerical modelling plays a crucial role in analyzing the thermal and mechanical behaviour in additive manufacturing (AM) processes. An accurate representation of the heat source is essential for reliable simulations. Various heat source models, such as Goldak’s single and double ellipsoidal models, the three-dimensional Gaussian conical model, and Gaussian cylindrical model, had been proposed. However, all heat source models require precise calibration to match experimental results, as they are highly sensitive to process parameters, material properties and laser-material interaction characteristics. Accurate calibration enhances the applicability of numerical simulations in AM analysis. A significant challenge in heat source modelling is the uniqueness of the calibrated heat models, which has not been thoroughly addressed in prior research. Recently, we developed a parameter optimization method to uniquely calibrate Goldak’s single ellipsoidal model using cross-sectional and mid-front melt pool profile. In the current work, we demonstrated that this method can also uniquely calibrate any other heat source model, regardless of the number of parameters applicable for a given model. To demonstrate its broader applicability, three heat source models, i.e., Goldak’s double ellipsoidal model, Gaussian conical model, and Gaussian cylindrical model, were calibrated for several single-track experiments conducted under different laser powers and scan speeds. The simulation results showed strong agreement with experimental melt pool profiles, although the performance varied across the different heat models.

Design and High-Precision 3D Printing of Capillary-Confined Microfluidic Chips

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Abstract

Capillary-confined microfluidic chips leverage surface tension and wettability control to enable self-driven liquid transport within microscale channels, eliminating the need for external pumping systems and significantly simplifying fluid manipulation. High-precision 3D printing, with its submicron to submillimeter fabrication resolution, facilitates the rapid prototyping of complex microfluidic architectures, meeting the stringent geometric and material requirements of capillary confinement designs. The integration of these two technologies not only enhances fabrication accuracy and design flexibility but also shortens development cycles, demonstrating broad application potential in fields such as biosensing, drug screening, and chemical analysis. Currently, microfluidic chips achieve liquid confinement primarily through microstructural elements such as capillary barriers, micropillars, and porous membranes. This report further explores the potential of suspended microstructures and lattice architectures in enabling capillary confinement. It also reviews various advanced 3D printing techniques suitable for fabricating such delicate suspended structures. These capillary-confined microfluidic chips based on suspended microstructures hold great promise for emerging applications in organ-on-chip systems, flexible electronics, and beyond.

Vat Photopolymerization 3D Printing of Self-Lubricating Polymer Composites

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Abstract

Two additive manufacturing strategies for self-lubricating polymeric composites are proposed, namely the vat photopolymerization 3D printing of microemulsion (microemulsion-3DP, solid-liquid composites) and three-dimensional (3D) target-region-lubrication printing (solid-solid composites). The microemulsion-3DP is applied for one-step fabricating self-lubricating parts with microdroplets of oil filled in polymer, where talc, as an emulsion, was incorporated into the microemulsion to ensure the oil-droplets evenly and stably dispersed for Vat photopolymerization 3D printing. And the oil-droplets were fixed in the microemulsion in the process of the ink from liquid to solid in the subsequent 3D printing, that enable the one-step filling of liquid oil-droplets. Then, the complex self-lubricating structures would be fabricated via 3D printing, which realized the forming of oil-containing self-lubricating composites with complex structures in one step. For three-dimensional (3D) target-region-lubrication printing, photosensitive polyimide filled with poly-tetrafluoroethylene (PTFE) with excellent tribological properties for self-lubricating devices. The surfaces with lubricating only in regions where needed were readily realized due to the layer-by-layer manufacturing manner of 3D printing. The two novel manufacturing strategies for polymeric composites provide new ideas for manufacturing self-lubricating parts and presents new opportunities for self-lubricating 3D architectures with rapid manufacturing, low-cost and free manufacturing.

Interpretable machine learning approach for exploring process-structure-property relationships in metal additive manufacturing

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Abstract

Establishing process-structure-property (PSP) relationships is essential for optimizing manufacturing techniques, yet it often requires extensive, costly experimentation. This is particularly true for additive manufacturing (AM), where numerous process parameters complicate the task. Our research introduces an interpretable machine learning strategy to predict and refine the process window for laser powder bed fusion (LPBF), while also delineating PSP relationships. We utilized Gaussian process regression (GPR) to model various inputs, such as process parameters and microstructural features, to predict key mechanical properties. The adaptability of the GPR model, through hyperparameter tuning for each input, facilitates feature selection and enhances model transparency. This methodology not only identifies pivotal factors influencing mechanical performance but also clarifies PSP relationships in AM alloys, offering insights for customizing final material properties. Our approach is versatile, applicable across different AM techniques and materials, and opens the door to achieving new mechanical properties and deeper PSP understanding.

Keywords: Additive manufacturing, Laser powder bed fusion (LPBF), Metals and alloys, Interpretable machine learning, Process-process-structure relationship

3D Printing of Bioelectronic Components for Tissue Engineering

Gao Xinchao, Yeong Wai Yee

Abstract

The integration of bioelectronics with engineered tissue constructs has demonstrated significant potential for promoting functional tissue regeneration, particularly in electroactive tissues. Electronic components can modulate and enhance cellular behavior via endogenous or exogenous cues, yet current fabrication methods often involve complex, multi-step processes. These approaches can result in poor integration and limited spatial accuracy between bioelectronics and tissue constructs, hindering their functionality and applicability.

In this study, we present a novel one-step approach for fabricating engineered skeletal muscle tissues with embedded soft electrodes using extrusion-based 3D coaxial printing. The coaxially printed electrodes consist of a highly conductive core encased within a biocompatible conductive shell. These soft electrodes enable precise electrical stimulation, effectively guiding cellular orientation within the hydrogel matrix. Compared to traditional fabrication techniques, our method enhances the design flexibility of bioelectronic-tissue constructs by using multi-material 3D printing, allowing for intricate 3D architectures with improved integration. This innovative approach has the potential to advance the development of bioelectronic platforms for tissue regeneration and repair, offering a versatile and scalable solution for bioengineering applications.

Exceptional strength and ductility in heterogeneous multi-gradient TiAl alloys through additive manufacturing

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Abstract

Heterogeneous alloy designs have come to the forefront of material science due to their potential in achieving a superior combination of strength and ductility. To harness this potential, we proposed a structural strategy for the fabrication of a novel heterogeneous multi-gradient α -TiAl alloy through in-situ modulation of aluminium concentration during the additive manufacturing process. Compared with homogeneous Ti (with yield strength (σ_y) of 440 MPa and elongation to fracture (ϵ_f) of 37.6%) and homogeneous Ti-10Al [at%] ($\sigma_y \sim 910$ MPa, $\epsilon_f \sim 6.1\%$) fabricated using the same methodology, this heterogeneous multi-gradient α -TiAl alloy achieved a significant improvement in yield strength ($\sigma_y \sim 760$ MPa) but with only a minor reduction in ductility ($\epsilon_f \sim 33.4\%$). Comprehensive experimental characterizations were carried out to probe the underlying mechanisms. The findings elucidate that the diffusion of aluminium in different printed layers promoted the formation of an innovative heterogeneous multi-gradient structure, engendering a synergy of multi-gradient strains that contribute to an exceptional combination of strength and ductility. These findings not only furnish an efficacious avenue for substantially augmenting the mechanical properties of α -Ti alloys but also applicable broadly in other alloy systems. The novel implementation of heterostructure design could potentially overcome the enduring challenge of reconciling the trade-off between strength and ductility.

Isogeometric Topology Optimization for Nonlinearities in 4D Printing Design

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Abstract

Topology optimization has been a crucial tool for improving the performance and efficiency of 3D additive manufacturing (AM) products. However, current topology optimization methods developed for 3D AM are insufficient when applied to four-dimensional additive manufacturing (4DAM) processes. This inadequacy arises from the complex nature of 4DAM, which involves nonlinear deformations, nonlinear material behaviors, and nonlinear loading conditions — factors that are not adequately addressed by existing 3D AM optimization frameworks.

Isogeometric analysis (IGA) offers significant advantages for such challenges, including better convergence for nonlinear problems, cost-effective simulations compared to traditional finite element methods (FEM), and straightforward multi-level discretization for integrated design and analysis. Building upon these strengths, this study proposes a multi-resolution isogeometric topology optimization framework to tackle the nonlinearities inherent in 4DAM design, aiming to balance high computational cost and convergence issues effectively.

The proposed framework employs a NURBS-based material density field in the design space, based on the same NURBS representation with varying resolutions for nonlinear simulations in the analysis space. A refined resolution in the design space ensures sufficient geometric detail, while a coarser resolution in the analysis space enables efficient nonlinear analysis to accelerate the optimization process. However, significant disparities between design and analysis resolutions can lead to unrealistic solutions due to incompatible interpolations of material density. To address this issue, an adaptive analysis resolution strategy is introduced to improve design quality across different optimization stages.

Numerical examples, including sensitivity analysis via the adjoint method, are presented for both structural compliance minimization and compliant mechanism design, demonstrating the effectiveness of the proposed framework. Furthermore, soft robotic designs with embedded actuators, potentially fabricable through 4DAM, are explored. To facilitate fabrication, a post-processing tool for generating smooth and editable models will also be developed.

Polyurethane Nanocoating for Improving the Mechanical Performance and Comfort of 3D-Printed Elastomeric Materials

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Abstract

With the increasing use of elastomeric lattice structures produced by multi-material 3D printing in applications such as helmets and footwear, improving both comfort and durability has become increasingly critical. This study introduces a polyurethane-based nanoscale coating designed to enhance the performance of elastic resins within lattice architectures. The coating effectively addresses surface defects that arise during the printing process and suppresses the development of microcracks caused by repeated mechanical deformation, including compression and stretching. These improvements lead to enhanced tensile strength and extended material lifespan. In parallel, the coating improves surface characteristics by reducing friction and significantly enhancing abrasion resistance. To evaluate comfort in human–material interaction, functional near-infrared spectroscopy (fNIRS) was employed. Results indicate that the coating not only improves tactile perception but also increases the overall comfort level during contact with the human body. This multifunctional coating approach offers a promising strategy to improve the mechanical resilience and user experience of 3D-printed elastomeric lattice structures for wearable and protective applications.

Laser powder bed fusion of oxide dispersion strengthened copper for sub-100micron component fabrication

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Abstract

Laser powder bed fusion of pure copper (Cu) with complex geometries opens vast opportunities for the development of functional devices in microelectronics and telecommunication. However, laser additive manufacturing of high-resolution pure Cu remains a challenge. Here we report a facile oxide-dispersion-strengthening (ODS) strategy that enables additive manufacturing of Cu with sub-100 μm ($\sim 70 \mu\text{m}$) resolution by laser powder bed fusion. This ODS strategy starts with oxygen-assisted gas atomisation to introduce ultrafine Cu₂O nanoparticles into the pure Cu powder feedstock. These nanoscale dispersoids not only improve the laser absorptivity and the viscosity of the melt but also promote dynamic wetting behaviour. The ODS Cu exhibits a remarkable yield strength of $\sim 450 \text{ MPa}$ and a large uniform elongation of $\sim 12\%$, while preserving a high electrical conductivity ($> 80\%$ IACS). As a technology demonstrator, we printed an ODS Cu micro-architected terahertz antenna, which demonstrates a 2.5-fold improvement in signal intensity compared with traditional 3D-printed pure Cu antennas.

Improving Copper–Steel Interfacial Quality in Multi-material Laser Powder Bed Fusion via Process Parameter Optimization

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Abstract

Key words: Laser Powder Bed Fusion, Multi-material, Additive Manufacturing

The emergence of Multi-material Laser Powder Bed Fusion (MMLPBF) has significantly expanded design and manufacturing freedom, enabling functional customisation for a wide range of applications, including aerospace, biomedical, and automotive fields. As a one-step additive manufacturing process, MMLPBF allows each material to contribute its unique properties within a single integrated component, maximising overall functionality and performance. However, the intrinsic heterogeneity between dissimilar materials poses challenges to interfacial integrity and overall performance.

In this study, we investigate the influence of laser spot size and hatching direction on the interfacial quality of stainless steel 316L (316L) deposited on CuSn10 during the initial five layers. By varying the spot size from 80 to 320 μm , the interfacial relative density was improved, and a more continuous, strip-shaped interface was achieved compared to a discontinuous, island-shaped morphology. Cracks were observed at both low and high volumetric energy densities, indicating a narrow process window. Changes in hatch direction further affected melt pool morphology and grain structure at the interface. These findings provide a process-based strategy to tailor interfacial microstructure and mitigate defects in multi-material LPBF components.

Engineered Hierarchical Porous Structures in SLS-Fabricated PLA/HA Scaffolds for Enhancing Capillary Force-Driven Hydrogel Infiltration in Bone Regeneration

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Abstract

This study investigates the influence of laser energy density during selective laser sintering (SLS) on the hierarchical porous structures of poly(lactic acid)/10% hydroxyapatite (PLA/HA) bone scaffolds, with a focus on open and closed pore structures. A series of scaffolds were fabricated by varying laser energy densities, and their hierarchical porosity characteristics were quantitatively analyzed through high-resolution micro-computed tomography (μ CT). A computational fluid dynamics model is developed to correlate pore architecture with fluid transport behavior (permeability, capillary force-driven hydrogel infiltration). The optimized porous structures are leveraged to exploit capillary forces for adsorbing gelatin methacryloyl (GelMA) hydrogel into the scaffold matrix. This approach aims to mitigate post-implantation inflammatory responses by enhancing biocompatibility and enabling localized drug delivery. Results demonstrate that tailored porosity achieved through controlled SLS parameters significantly improves hydrogel infiltration efficiency, governed by pore interconnectivity and permeability. The integration of GelMA into PLA/HA scaffolds presents a promising strategy for dual-functional applications in reducing inflammation and facilitating sustained drug release, offering potential advancements in bone tissue engineering. This work highlights the critical role of process-induced porosity in designing bioactive implants for regenerative medicine.

Machine learning-driven simultaneous optimisation of support structures and process parameters in additive manufacturing

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Abstract

Support structure is a critical aspect in design for additive manufacturing (AM), as it significantly impacts the part quality with overhanging features. While optimising support geometry can enhance part quality and reduce material usage, the effects of AM process parameters on support performance—such as peak residual stress (RS), residual displacement (Disp), and allowable unsupported spacing—remain inadequately understood. To address this challenge, this study employs a hybrid approach combining experiments, finite element method (FEM) simulations, and machine learning (ML) techniques to simultaneously optimise process parameters and support structures in laser powder bed fusion (LPBF). FEM simulations, validated by experimental data, demonstrate that wider support width and reduced support spacing can improve structural stability and heat dissipation, thereby significantly reducing RS and Disp. Meanwhile, higher laser power and lower scan speed can also reduce RS and Disp by ensuring better melting of unsupported regions. ML surrogate models—including K-nearest neighbors, support vector regression, decision trees, AdaBoost, and random forest—were employed for surrogate modelling of RS and Disp prediction, with the random forest model achieving the highest accuracy ($R^2 = 0.947$ for RS and $R^2 = 0.965$ for Disp). Lastly, shapley additive explanations provide interpretable insights into the random forest model. This integrated methodology demonstrates the simultaneous optimisation of process parameters and support structures, offering valuable guidance for improving the quality and efficiency of LPBF-fabricated parts with overhanging features.

Matal Additive Manufacturing Process Monitoring and Defect Detection Based on Physics-Constrained Dictionary Learning

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The Hong Kong University of Science and Technology

Abstract

Metal Additive Manufacturing (MAM) has emerged as a crucial technique due to its ability to provide significant design flexibility for parts with complicated geometries. However, the qualities of manufactured parts are various due to the complicated manufacturing process. Thus, there is a pressing need to develop an efficient and reliable real-time monitoring technique to ensure normal operation in the manufacturing process. Compressed sensing combined with dictionary learning could simultaneously compress collected signals into a few measurements, enabling efficient defect monitoring. However, to achieve optimal compression and classification results, the measurement selection methods for distinct signals should be different. In this work, we present a physics-constrained dictionary learning method that incorporates different constraints for training dictionaries based on physical requirements. This new approach is proposed to solve the compression and classification problems simultaneously in monitoring MAM processes. Besides, A new active dictionary learning strategy is developed to optimize the measurement matrix, where the reconstruction errors are gradually reduced with the new measurements taken adaptively at the positions where the largest reconstruction errors occur. Important features such as edges are also incorporated to further improve classification accuracy. The algorithm is demonstrated to identify powder spatter in melt pool images and classify porosity degrees in copper micro-structure images in monitoring the laser powder bed fusion process.

Binder Jet 3D Printing of Ceramic-Based Composites: Enabling Functional Materials for Advanced Applications

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Abstract

Binder jetting (BJP) is gaining recognition as a scalable and cost-effective additive manufacturing method for producing complex ceramic-based composite components. This work presents ongoing research focused on developing hybrid manufacturing routes that integrate binder jet 3D printing with post-processing techniques—specifically, polymeric infiltration with pyrolysis and reactive melt infiltration. These hybrid pathways enable the transformation of porous green parts into dense, functional composites by promoting in-situ reactions and tailored microstructural evolution.

In this presentation, emphasis is placed on the development of an Si–SiC ceramic-composite system, selected for its potential in a range of functional applications including thermal management, stiffness, wear resistance, and chemical stability, relevant to semiconductor, energy, and other advanced sectors. Binder jetting was used to fabricate near-net-shape green parts, which were subsequently densified via polymer-derived ceramic transformation and melt infiltration techniques. Experimental results demonstrate that relative density values exceeding 99.5% were achieved, with true densities reaching up to 3.15 g/cm³ for select specimens. These high-density outcomes, combined with microstructural analysis and flexural strength testing, provide insight into the material's functional capabilities and the effectiveness of the hybrid manufacturing route.

Preliminary exploratory work on W–Zr-based composites is also presented, demonstrating the extension of this hybrid manufacturing approach to metal–ceramic systems designed for high-temperature and extreme environments. The presentation further discusses key processing–structure–property relationships, challenges specific to ceramic-based binder jet printing, and potential application pathways across aerospace, semiconductor, and energy sectors. Future directions include scaling production, expanding compatible

Advancing Osteoarthritis Therapy via Stem Cell-laden 3D Bioprinting: From Bioink Innovations to Anti-inflammatory Functionalization and Clinical Applications

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Abstract

Osteoarthritis (OA), a global health burden characterized by irreversible cartilage degeneration, demands innovative regenerative strategies due to the tissue's limited self-repair capacity. Stem cell-laden 3D bioprinting holds transformative potential in OA therapy by enabling the engineering of biomimetic cartilage scaffolds with precise spatial and biochemical control. Current advances in bioprinting methodologies, bioink compositions, and induction strategies reveal the synergistic effects of small molecules, growth factors, and exosomes in guiding stem cell differentiation. Notably, anti-inflammatory functionalized bioinks, such as diclofenac sodium-loaded MeHA/PCL scaffolds, achieve dynamic equilibrium between inflammatory microenvironment modulation and tissue regeneration, demonstrating reduced IL-1 β levels and improved joint functional parameters in preclinical models. While bioprinted biomimetic scaffolds integrated with stem cells show clinical promise, key challenges remain, including optimizing bioink mechanical properties, ensuring long-term stability, and controlling vascularization. By reviewing recent progress in this field, we suggest that future efforts should focus on advanced material development, hybrid printing systems, and personalized therapeutic design to accelerate the clinical translation of 3D bioprinting technology, offering tailored solutions for OA management.

In-Situ Alloying Modulation in Laser Powder Bed Fusion of Titanium-Tantalum Alloy: From Melt Pool Modelling to Process Development

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Abstract

In-situ alloying enhances the practical value of additive manufacturing (AM) by simplifying processing and reducing raw material costs [1, 2]. However, current research offers limited guidance when applying this concept to applications with differential or complex compositions. Most studies focus on comparing the microstructure and properties of AM samples with those produced by traditional methods, without quantifying or controlling the in-situ alloying process itself [3-5]. As a result, the degree of in-situ alloying, a crucial factor for guiding fabrication, remains underexplored.

This study presents a novel research approach to in-situ alloying, emphasizing the degree of alloying as the key evaluation criterion. Using Ti-30Ta as a model system [6, 7], first a combination of the random forest model and the Eagar-Tsai model was employed to analyze melt pool dimensions (depth and width) of single-track samples [8, 9] and a process map was constructed. Nanoindentation was then performed on single-track samples to measure Young's modulus. The degree of Ta particle melting under varying processing conditions was quantitatively evaluated through the linear correlation between Young's modulus and Ta content [10]. These findings were integrated with the process map to define a comprehensive process window for in-situ alloying of Ti-30Ta. Subsequently, bulk samples were fabricated within this process window and subjected to tensile test, synchrotron characterization and cell culture analysis. The results confirmed that samples processed within the identified process window exhibited optimal microstructural characteristics and superior mechanical and biological properties.

This study provides a systematic, data-driven methodology for optimizing processing parameters to control the degree of in-situ alloying. The introduction of the concept of the degree of in-situ alloying is also expected to be replicated in other alloying systems and to further promote the field of in-situ alloying as a guide for practical production applications.

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Machine Learning-Enabled Additive Manufacturing: Advancing Process Optimization, Intelligent Design, and Knowledge-Driven Engineering

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Abstract

The convergence of artificial intelligence (AI) and additive manufacturing (AM) is revolutionizing modern manufacturing by enabling design automation, process optimization, and material innovation. Machine learning (ML) has emerged as a powerful tool for addressing key challenges in AM, including process monitoring, defect detection, data-driven design, and performance prediction. This talk presents recent research advancements in ML-driven methodologies for manufacturability assessment, in-situ process monitoring, and intelligent design optimization. Key developments include audio-visual cross-modality learning for defect detection in laser AM, hybrid deep learning approaches for auxetic metamaterial design, uncertainty-aware active learning for data-driven design refinement, and knowledge transfer to support reusability and deployment of machine learning applications. Additionally, large language models (LLMs) and vision transformers are being leveraged to extract and structure engineering knowledge from technical documents, demonstrating AI's potential to support design exploration, manufacturability analysis, and automated knowledge transfer in AM.

Beyond technical advancements, this talk will discuss critical challenges in AI-driven AM, including data quality, bias mitigation, knowledge transfer, and scalability of AI models. While most ML research in AM has focused on static model selection, there remains a significant gap in the deployment and real-world adoption of ML-driven solutions. Effective deployment requires transfer learning, domain adaptation, and robustness-aware techniques to enable ML models to generalize across different materials, machine conditions, and manufacturing environments. Bridging this gap is essential for accelerating AI adoption in AM and ensuring that ML tools can be seamlessly integrated into industrial workflows. This talk will present case studies to demonstrate that knowledge transfer can enhance the affordability and reusability of in-situ AM process monitoring and quality assessment systems in real production environments.

Control of Droplet Formation in Inkjet 3D Printing Using Deep Reinforcement Learning

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Abstract

Inkjet 3D printing is a versatile additive manufacturing technology capable of precise material deposition for applications ranging from electronics to bioprinting. However, achieving consistent droplet formation remains challenging due to the complex interplay of nonlinear fluid dynamics and material-dependent behaviours. Traditional control methods, such as PID based controllers, struggle to maintain performance across varying materials and operating conditions, compromising both print quality and process reliability. To address these limitations, we propose a hybrid physics-guided and data-driven approach. First, we establish a universal Re-Oh parameter space that quantifies the interplay of inertial, viscous, and surface tension forces across materials. This framework enables generalizable control policies without material-specific retraining. Second, we develop a Twin Delayed DDPG (TD3)-based deep reinforcement learning system based on Re-Oh parameter space that formulates droplet formation as a Markov Decision Process (MDP). The architecture leverages dual critic networks and target policy smoothing to achieve real-time, stable parameter optimization even in multi-material environments. Experimental results demonstrate 94.3% volumetric accuracy, elimination of satellite droplets, and sub-millisecond responsiveness to parameter changes, with consistent performance across diverse materials. By bridging fluid dynamics principles with adaptive intelligent control, this work provides a comprehensive solution that significantly advances high-precision inkjet 3D printing capabilities for complex, multi-material applications.

Using AI and Machine Learning to Correlate Microstructure with Printing Parameters in LPBF Aluminum Alloys

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Abstract

This study explores the relationship between printing parameters and microstructure in Laser Powder Bed Fusion (LPBF) aluminum alloys using artificial intelligence (AI) and machine learning techniques. The investigation focuses on Scalmalloy, analyzing the distribution of equiaxed and columnar grains, as well as fine grain regions, and AlSi10Mg/SiC composites, examining SiC dispersion and eutectic silicon distribution. The research involves data acquisition through Electron Backscatter Diffraction (EBSD) and Backscattered Electron Imaging (BEI) in Taiwan, followed by extensive data analysis. Machine learning models are developed to predict microstructural evolution based on LPBF parameters, facilitating the optimization of process settings for improved mechanical properties and consistency. This approach enhances our ability to control microstructure formation in metal additive manufacturing, contributing to advancements in high-performance material development for aerospace, automotive, and biomedical applications.

Design for Additive Manufacturing of Continuous Fiber-Reinforced Composites

Yi XIONG

Southern University of Science and Technology

Abstract

The development of additive manufacturing (AM) has revolutionized the fabrication process of continuous fiber-reinforced polymer (CFRP) composites with its outstanding ability to create products that are complex in material, structure, and function. This talk presents a design methodology for CFRP-AM and its associated CAD/CAM tools aimed at advancing structural-functional innovations in composite materials for robotics. For lightweight design, we will present a structure-process co-design approach that simultaneously enhances both the mechanical performance and manufacturability of composite structures. For structural-functional integration, we explore how an integrated design framework combining design, manufacturing, and control can be leveraged to develop load-bearing yet morphable electrothermal origami structures. Finally, we will present multi-axis and intelligent additive manufacturing techniques that enable the realization of the complex designs described above. These advancements are particularly relevant for applications in emerging fields such as morphable metamaterials, multimodal robotics, and intelligent aerospace system

Application of Hybrid Additive Manufacturing to Produce a Novel Adaptive Fixture for Railway Track Emergency Maintenance

Yi ZHOU, John Hock Lye PANG, Fook Fah YAP, Kok Ee TAN

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

Abstract

This paper presents the hybrid additive manufacturing (AM) and laboratory testing validation of a novel adaptive rail fixture developed for clamping fractured tracks and restoring track integrity during train service hours. The proposed fixture is geometrically adaptive to both thermite-welded and plain tracks, featuring a three-degree-of-freedom locking mechanism by a sleeve-shaped support structure. The hybrid AM methodology employs the high-precision subtractive machining technique to fabricate the track surface-conformal fishplate portion and applies the AM technique to produce the complex-shaped support structure, ensuring the precise fit between the adaptive fixture and railway tracks and providing stable three-dimensional clamping for fractured tracks. Laboratory vibration testing shows that the hybrid AM-processed adaptive fixture maintains comparable vibration resistance to conventionally manufactured counterparts with a 46% cost reduction, exhibiting a similar vibration attenuation process under identical pulse shock acceleration inputs, with output vibration signal peak values differing by less than 6%. Cyclic point loading testing further evaluates the stability of fractured tracks restored by hybrid AM-processed adaptive fixtures under simulated train passage conditions. Test results show that the clamped tracks remain intact, with deformation at the loading contact point measuring less than 2.5 mm after 10,800 cycles at a maximum load of 1.12 times the carriage weight, demonstrating the reliability, endurance, and exceptional anti-deformation capability of the fractured railway tracks aligned and clamped by hybrid AM-processed adaptive fixtures. The combination of hybrid AM flexibility and high-performance adaptive fixtures enhances maintenance efficiency, structural stability, and anti-vibration capability of fractured railway tracks.

Generative Construction of Toolpaths for Additive Manufacturing Driven by Principal Stress Lines

Shujie Tan, Liping Ding, Chenyu Shen, Yicha Zhang*

Abstract

Conventional toolpath planning in additive manufacturing (AM) is predominantly based on the STL data processing pipeline, which relies solely on computational geometry. This approach suffers from limitations such as accuracy loss and the exclusion of design and manufacturing knowledge, often resulting in discrepancies between the printed part and its original design. To address this issue, this paper proposes a novel toolpath construction method driven by principal stress lines (PSLs). The method integrates stress fields from the design stage and surrogate models of melt track width and laser scanning parameters from the manufacturing stage. This integration ensures both the manufacturability of the part and consistency between the manufactured outcome and the design model in terms of geometry and performance. Additionally, a cantilever beam structure is used to validate the feasibility of the proposed method. Compared to the STL-based method, the cantilever beam printed using this method more closely matches the design result in both geometry and performance.

Arc Additive Manufacturing of High-Strength Aluminum Alloy with Lamellar Heterogeneous Structure for Enhanced Strength-Toughness

Zhou Yinghui
Xi'an Technological University

Abstract

Large-scale high-strength-toughness aluminum alloy propellant tanks constitute critical components for hundred-ton-class heavy-lift launch vehicles. Conventional manufacturing technologies face significant challenges in fabricating aluminum alloy tanks exceeding 10 meters in length. While wire arc additive manufacturing (WAAM) offers a promising route for forming ultra-large components, the compromised mechanical properties of WAAM-fabricated aluminum alloys limit their practical implementation. This study focuses on regulating the unique lamellar columnar/equiaxed grain heterogeneous interfaces in WAAM aluminum alloys and elucidating their strengthening-toughening mechanisms. By leveraging the exceptional strength-toughness synergy of heterogeneous structures, this work provides novel insights into achieving active control over microstructure-performance relationships in WAAM aluminum alloys.

Key investigations include:

1. Analyzing the influence of thermal control parameters on heterogeneous interface characteristics to establish interface regulation criteria;
2. Employing multi-modal in situ synchrotron analysis to probe macro/micro-scale plastic deformation mechanisms under coupling effects of loading direction and columnar/equiaxed grain interfaces;
3. Revealing the mechanistic roles of heterogeneous interfaces in hetero-deformation induced (HDI) strengthening and strain hardening;
4. Elucidating intrinsic linkages among "process parameters – heterogeneous interfaces – mechanical properties".

The outcomes will advance strengthening-toughening strategies for heterogeneous microstructures in WAAM aluminum alloys and guide high-quality, efficient integrated manufacturing of large-scale aerospace components.

Keywords: Wire Arc Additive Manufacturing (WAAM); Heterogeneous Microstructure; Strengthening-Toughening Mechanisms

Multiscale Composite Materials in Bone and Joint Diseases

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Abstract

Multiscale composite materials hold significant potential for treating bone and joint diseases, particularly osteoarthritis (OA), a chronic degenerative condition affecting over 520 million individuals worldwide. This study highlights the development and application of advanced hydrogel-based composite materials that integrate nanoscale and microscale components. These materials combine hydration lubrication mechanisms with bioactive agents to reduce joint friction, promote cartilage repair, and maintain cellular homeostasis. The composite hydrogel microspheres are designed to recruit endogenous stem cells, support chondrogenic differentiation, and provide sustained release of therapeutic agents. By leveraging the synergistic effects of multiple scales and functionalities, these materials offer a versatile and targeted approach to treating OA and other bone and joint disorders, potentially improving patient outcomes through minimally invasive interventions.

Integrating coaxial electrospinning and 3D printing technologies for the development of biphasic porous scaffolds enabling spatiotemporal control in tumor ablation and osteochondral regeneration

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Abstract

The osteochondral defects (OCDs) resulting from the treatment of giant cell tumors of bone (GCTB) often present two challenges for clinicians: tumor residue leading to local recurrence and non-healing of OCDs. Therefore, this study focuses on developing a double-layer PGPC-PGPH scaffold using shell-core structure nanofibers to achieve "spatiotemporal control" for treating OCDs caused by GCTB. It addresses two key challenges: eliminating tumor residue after local excision and stimulating osteochondral regeneration in non-healing OCD cases. With a shell layer of protoporphyrin IX (PpIX)/gelatin (GT) and inner cores containing chondroitin sulfate (CS)/poly(lactic-co-glycolic acid) (PLGA) or hydroxyapatite (HA)/PLGA, coaxial electrospinning technology was used to create shell-core structured PpIX/GT-CS/PLGA and PpIX/GT-HA/PLGA nanofibers. These nanofibers were shattered into nano-scaled short fibers, and then combined with polyethylene oxide and hyaluronan to formulate distinct 3D printing inks. The upper layer consists of PpIX/GT-CS/PLGA ink, and the lower layer is made from PpIX/GT-HA/PLGA ink, allowing for the creation of a double-layer PGPC-PGPH scaffold using 3D printing technique. After GCTB lesion removal, the PGPC-PGPH scaffold is surgically implanted into the OCDs. The sonosensitizer PpIX in the shell layer undergoes sonodynamic therapy to selectively damage GCTB tissue, effectively eradicating residual tumors. Subsequently, the thermal effect of sonodynamic therapy accelerates the shell degradation and release of CS and HA within the core layer, promoting stem cell differentiation into cartilage and bone tissues at the OCD site in the correct anatomical position. This innovative scaffold provides temporal control for anti-tumor treatment followed by tissue repair and spatial control for precise osteochondral regeneration.

Laser powder directed energy deposition of FeCoNiCrMox high entropy alloys for high performance protective coatings

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Abstract

High-entropy alloys (HEAs) are excellent candidate materials for high performance coatings. Mo-containing HEAs exhibit higher strength, good corrosion resistance, oxidation resistance, and wear resistance. Laser powder directed energy deposition (LP-DED) technology employs a high-energy density laser beam to sequentially melt and accumulate powders onto the surface of the substrate layer by layer, achieving metallurgical bonding between the layer and substrate forming an additive-deposited coating. LP-DED technology possesses the characteristics of fast melting, fast solidification with narrow heat-affected zone and fine microstructures, which is suitable for a variety of deposition powders and substrates. In this research, LP-DED technology was employed to prepare FeCoCrNiMox ($x = 0.1, 0.3, 0.5, \text{at.}\%$) HEAs coatings on low carbon steel. The effects of Mo content on the microstructural evolution of the coatings were characterized by using scanning electron microscope (SEM) and electron backscatter diffraction (EBSD). The corrosion resistance of the coating was characterized using an electrochemical workstation obtaining potential dynamic polarization curves and impedance spectra. The role of Mo in the passivation and corrosion processes was extensively discussed by combining the electrochemical corrosion and X-ray photoelectron spectrometer (XPS) test results. The wear resistance of the coatings was evaluated through friction and wear experiments, and the wear mechanisms were investigated. The repeated annealing effects and the cyclic thermal activation effect of LP-DED resulted in the formation of a large number of small sub-grains. Molybdenum, with its larger atomic size, formed solid solutions and intermetallic precipitates with Co, Cr, Fe, and Ni elements in HEAs, leading to unique microstructures and corrosion resistance properties.

Direct Laser Writing of Laser-Induced Graphene Electronics for Advanced Healthcare Applications

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KAIST (Korea Advanced Institute of Science and Technology)

Abstract

In recent years, we have witnessed a tremendous demand of electronic devices that leads to a massive amount of e-waste and rapid exhaustion of non-renewable resources. Consequently, green electronics become a promising area to produce eco-friendly devices from natural materials using sustainable fabrication methods. Graphene, a two-dimensional material, exhibits exceptional electrical, mechanical, physical, and thermal properties which make graphene highly attractive for numerous applications. Up to now, graphene can be synthesized via several routes such as liquid-phase exfoliation, mechanical exfoliation, chemical vapor deposition, and reduction of graphene oxide. However, to realize the full potential of graphene, there is an urgent need to develop a cost-effective, scalable, and green fabrication pathway. In this work, we have developed a one-step approach to the preparation of arbitrary graphene patterns on fallen leaves using femtosecond laser pulses in ambient conditions. The formation of laser-induced graphene (LIG) has been confirmed and characterized using scanning electron microscopy (SEM), transmission electron microscopy (TEM), Raman spectroscopy, and electrical measurement. Owing to excellent electrical conductivity and highly porous structures, this LIG can be utilized in diverse applications such as supercapacitors, pseudo capacitors, and various types of sensors.

Purely-dissolutive wetting behaviours in metallic systems: a combined experimental and numerical approach

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Abstract

Despite its importance in numerous high-temperature processes e.g. soldering, liquid metal infiltration, and laser powder bed fusion, the understanding of high-temperature wetting remains heavily fragmented due to complicated physicochemical phenomena. They develop at the different interfaces leading to a plethora of wetting behaviors being described as inert, dissolutive, or product-forming. Moreover, the challenges are exacerbated by the difficulties in executing experiments under perfectly controlled environments. For instance, the presence of oxygen in the vapor phase, even at extremely low concentrations can trigger the formation of oxides influencing the formation of intermetallic compounds and finally wetting.

In this study, using a combination of a versatile high temperature optical wetting apparatus and a confocal scanning laser microscope [1], we investigated the spreading of metallic droplets on solid metals. 8 systems (liquid/solid) were tested, 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. They can be categorized into three groups based on the solubility of the solid element in the liquid (CS) and the solidification temperature range (CR) of the solid solution formed. We observed a slow stepwise spreading in systems with a relatively low CS and narrow CR. For systems with high CS, the spreading begins relatively fast and transitions to a step-wise progression when CS is reached [2]. Systems with a large CR, conversely, exhibit consistently fast spreading (Figure 1). Quantum-based simulations provided deeper insights into the underlying mechanisms affecting the solid solution formation while computational fluid dynamics confirmed the importance of a Marangoni flow involved in the step-flow spreading process.

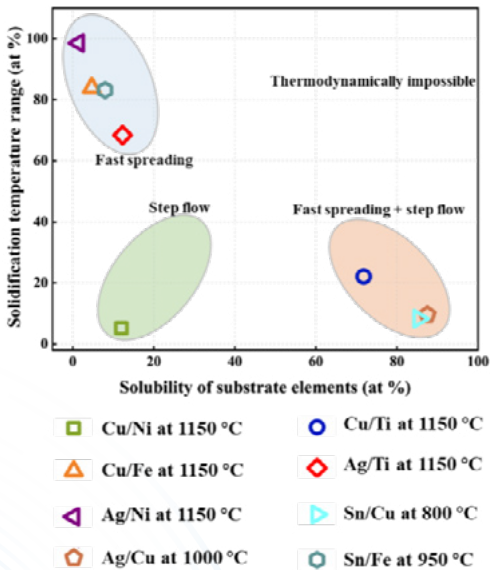


Figure 1: Purely-dissolutive wetting map in metallic systems

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Heterostructured AlCoCrFeNi_{2.1} high entropy alloy with simultaneously improved strength and ductility via laser powder bed fusion

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Abstract

Heterostructure has been evidenced to generate back stress-induced strengthening during deformation and can overcome the strength-ductility trade-off of the material. However, the advantage of additive manufacturing (AM) technology in freely tailoring local material properties has not been fully exploited in the preparation of heterostructured (HS) materials. In this work, we demonstrate changing the scanning mode of laser powder bed fusion (LPBF) to create heterogeneous regions, thereby successfully preparing AlCoCrFeNi_{2.1} eutectic high entropy alloy (EHEA) with a layered heterostructure. The results show that by controlling the laser scanning mode, the phase distribution and grain size can be regulated, enabling the fabrication of soft and hard regions. The layered HS material, formed by combining the soft and hard regions, exhibits superior mechanical properties (the yield strength, ultimate tensile strength, and elongation are 1032±22.6 MPa, 1310±26.3 MPa, and 18.7±0.8%, respectively), representing improvements of 13.9%, 5.9%, and 8.7% compared to the non-HS samples. The simultaneous enhancement in strength and ductility of this layered HS material is mainly due to the back stress-induced strengthening from the high-density interfaces of the heterogeneous regions during deformation. These results promote the development of high-performance materials with free-designed heterostructures fabricated by LPBF.

Selective Laser Melting Ultra-High Strength Maraging Steel: Process Optimization, Performance Enhancement and Precision Post-processing

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Abstract

Maraging steel is a precipitation-strengthened ultra-high-strength steel with high toughness, low hardening index, good formability, simple heat treatment process and little deformation during aging heat treatment. The ultimate tensile strength can reach more than 2000MPa. Therefore, it is widely used in aerospace, national defense, military industry and precision molds. Selective laser melting is a powder-bed-melting additive manufacturing technology with a laser as the heat source, which has high manufacturing density and high manufacturing resolution. It is particularly suitable for high-performance rapid manufacturing of metal components with complex geometric structures. To promote the application of additive manufacturing maraging steel in the preparation of high-end components, a systematic study on the laser selective melting additive manufacturing process of 18Ni300 maraging steel was carried out, including the formation mechanism of defects, process optimization, microstructure evolution regulation, performance enhancement and precision post-processing. The formation of surface and internal defects was suppressed by optimizing the laser power, scanning speed, scanning spacing and powder layer thickness, thereby reducing the surface roughness value to less than 10 μm and increasing the relative density to more than 99%. In addition, the heat treatment process was also optimized to precipitate a large number of nano-strengthening phase particles to improve the tensile strength to above 2100MPa. Furthermore, to improve the surface manufacturing of parts, an efficient machining process based on mechanochemical effect is proposed, which reduces the cutting force of laser selective melting maraging steel by more than 50% and improves the surface quality by more than 80%. These research results will provide a theoretical basis and technical support for the precision manufacturing of high-performance complex components made of ultra-high-strength maraging steel.

Characterisation of Hidden Dimensional Structure using Non-destructive X-ray Computed Tomography

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Abstract

Additive Manufacturing (AM) has a unique advantage due to its layer-by-layer process, which can produce complex geometrical structures in line with AutoCAD designs. It is important to identify and measure defects hidden inside AM parts to assess their mechanical strength during AM quality control. X-ray computed tomography (XCT) is a valuable tool for conducting non-destructive testing of hidden structures, including internal dimensional structures and defects resulting from selective laser melting (SLM) as one of the AM processes. In this paper, a series of calibrated step height standard artifacts with nominal step heights ranging from 50 μm to 200 μm have been designed and fabricated to quantitatively verify the dimensional measurement accuracy of XCT. Compared to the certified step heights measured by a high-precision laser confocal microscope (resolution: 20 nm), the step height measurements obtained using a calibrated XCT show a maximum deviation of about 2 μm across a range of up to 200 μm . This demonstrates that the proposed XCT can achieve micro-scale accuracy when measuring hidden dimensional structures. Furthermore, the proposed XCT was also applied to test the hidden defects (pore size and porosity) of AM mini dog bone samples (six AM samples made from CoCrMo alloy after heat treatment). The evaluation results indicate that the internal defective pores and porosity of the samples are clearly identified by the proposed XCT. The minimum and maximum defect diameters among these samples are approximately $\varnothing 40\text{ }\mu\text{m}$ and $\varnothing 220\text{ }\mu\text{m}$, respectively. The corresponding porosity values are 0.051%, 0.005%, 0.003%, 0.008%, 1.446%, and 0.704%. The results and findings suggest that the proposed XCT can serve as an accurate measurement tool in AM quality control, providing feedback data that can optimize AM parameter settings for a better printing performance.

Predictive Finite Element Analysis of TPMS PCL Scaffolds for Biomedical Applications

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Abstract

Background: Three-dimensional (3D) printed scaffolds have emerged as a transformative tool in tissue engineering, enabling precise replication of complex bone architectures. Among various designs, Triply Periodic Minimal Surface (TPMS) structures have gained attention due to their morphological similarity to natural trabecular bone. Their continuous, smooth surface geometry offers potential benefits for both mechanical performance and cellular integration.

Methods: We designed a series of TPMS scaffolds with varying unit cell sizes (UCS) and porosities. Finite Element Analysis (FEA) was conducted to simulate the mechanical behavior of these scaffolds, and the outcomes were validated through experimental mechanical testing. A predictive FEA model was developed to assess structural performance and identify optimal design parameters for further investigation.

Results: The results revealed a strong correlation between FEA predictions and experimental data, confirming the model's reliability. Specifically, the Young's modulus of diamond-type TPMS scaffolds exhibited a linear relationship with porosity, whereas changes in UCS and structural configuration had minimal effect. These findings suggest that porosity is the primary factor influencing the mechanical properties of TPMS-based scaffolds.

Conclusion: Our findings support the potential of FEA prediction in TPMS-based architectures for bone tissue engineering, particularly in mechanical properties prediction.

Ultrastrong nanotwinned titanium alloys through additive manufacturing

Yuman Zhu, Kun Zhang, Zhichao Meng, Kai Zhang, Peter Hodgson, Nick Birbilis, Hamish L. Frase, Samuel Lim, Huizhi Peng, Rui Yang, Hao Wang, Aijun Huang

Monash Centre for Additive Manufacturing, Monash University

Abstract

Additive manufacturing is leading a new era in metal fabrication across aerospace, automotive, biomedical and energy sectors due to its design freedom that can fabricate almost any geometrical part. Titanium alloys are presently the leading additively-manufactured metal components for the aerospace industry. However, most commercially available titanium alloys made by additive manufacturing do not have satisfactory properties for many structural applications. In this talk, we will present our recent breakthrough that ultrastrong and thermally stable titanium alloys can be produced by additive manufacturing, which may be directly implemented in service. As demonstrated in a commercial titanium alloy, after simple post heat treatment, adequate elongation and tensile strengths over 1600 MPa are achieved - resulting in the highest strength-to-weight among all AM alloys to date. The excellent properties are attributed to the unusual formation of dense, stable and internally-twinned nanoprecipitates, that are rarely observed in the traditionally processed titanium alloy. These nano-twinned precipitates are shown to originate from a high density of dislocations with a dominant screw character and formed from the AM process. The work herein paves a way to fabricate structural materials with unique microstructures and excellent properties for broad applications.

Bridge Design and Manufacturing for Additive Manufacturing: An AI-Driven Approach

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Abstract

Additive manufacturing (AM) has unlocked new possibilities for structural design, particularly in complex and lightweight bridge structures. This presentation introduces recent advancements at the Monash Centre for Additive Manufacturing, focusing on AI-driven methodologies for design and manufacturing. A service-oriented digital twin framework has been developed to enhance real-time monitoring and optimization of AM processes, improving manufacturing efficiency and quality control. Additionally, a data-driven design approach for stochastic cellular structures is explored, leveraging AI for design space exploration to identify optimal configurations for lightweight, high-performance structures. Finally, the talk will provide insights into future trends, discussing how artificial general intelligence (AGI) could further revolutionize AM design by enabling autonomous, adaptive, and highly efficient exploration of vast design spaces. This presentation will offer valuable perspectives on the intersection of AI, AM, and digital manufacturing for next-generation structural applications.

Acoustic-based dripping anomaly detection in wire laser-directed energy deposition

Xie Yuxuan, Chen Lequn, Cheng Xin Wei, Chew Youxiang, Senthil A Kumar

Abstract

Wire laser-directed energy deposition (WL-DED) is an emerging additive manufacturing technology for fabricating large, complex metal components with near-zero material waste, offering a more efficient alternative to powder-based L-DED. However, ensuring process stability remains a significant challenge, particularly due to anomalies such as wire-tip dripping. This phenomenon occurs when laser becomes defocused due to an uneven substrate or variations in printing speed, leading to premature melting of the wire above the substrate. If not properly controlled, wire-tip dripping can cause defects and printing failures, potentially resulting in high repair costs in severe cases. This underscores the critical need for effective process monitoring. Traditional monitoring methods used in powder-based processes may not be directly applicable to WL-DED due to differences in material feed mechanisms and heat distribution. To address this challenge, this study proposes a novel acoustic-based monitoring strategy for detecting wire-tip dripping with machine learning (ML). An off-axis short-wavelength infrared (SWIR) thermal camera is used to capture wire feedstock conditions, providing ground truth annotations, while a microphone captures laser-wire interaction sound. The key contribution of this work lies in the integration of acoustic sensing with ML-driven anomaly detection, enabling real-time identification of wire-tip dripping. A convolutional neural network (CNN) is trained on labelled acoustic data to classify process states and identify dripping instability. Furthermore, the underlying mechanisms of acoustic emissions in WL-DED are analysed with acoustic signal processing, offering critical insights into the feasibility of low-cost acoustic monitoring for closed-loop feedback control.

Experimental validation is conducted using Aluminium 7075 alloy deposition, demonstrating the system's effectiveness in detecting wire-tip dripping with high accuracy (93%). This study set the foundation for predictive ML modelling to forecast and mitigate the wire-tip dripping anomalies, enhancing the robustness of the WL-DED process.

Process, microstructure and properties of zinc fabricated by laser powder bed fusion additive manufacturing

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Abstract

Laser powder bed fusion (LPBF) of biodegradable zinc (Zn) combines tailorable microstructure and attractive performance, which is expected to be widely used in biomedical applications. The effect of process parameters on the quality of Zn was explored. An optimized processing window of LPBF was established for fabricating Zn samples with relative densities greater than 99%. The Zn sample with exceptional strength-ductility synergy was fabricated. The corresponding multiple deformation mechanisms were revealed. Furthermore, the effect of microstructure on the comprehensive properties of LPBF-fabricated Zn were also investigated, including its mechanical anisotropy, corrosion anisotropy, biological response. Particularly, the anisotropy of mechanical properties in LPBF-printed Zn (i.e., horizontal and vertical samples) was systematically evaluated and discussed to establish a correlation between anisotropic microstructure and mechanical response. With these foundations, a method for the modulation of grain characteristics in Zn during the LPBF process by leveraging the thermoelectric magnetic effect induced by a static magnetic field (SMF) for the first time was proposed, aiming to reduce the mechanical anisotropy of the printed Zn material while retaining its excellent ductility at specified strength levels. The solidification behavior in the Zn molten pool during the LPBF process under the influence of thermoelectric magnetic effects was simulated using a physical model that integrated SMF. The results indicated that the thermal electromagnetic force induced by SMF reached up to 106 N/m³, effectively fragmenting regular Zn columnar dendrites and enhancing heterogeneous nucleation efficiency, thus promoting the columnar-to-equiaxed transition and grain refinement. Consequently, compared to samples printed without SMF assistance, the mechanical anisotropy index of yield strength and elongation in the SMF-assisted LPBF-printed Zn sample was significantly reduced from 18.63% and 16.49% to 2.46% and 2.58%, respectively, while maintaining superior strength-ductility synergy. This study highlighted the promising prospects of LPBF-fabricated Zn scaffolds in the treatment of load-bearing bone defects.

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An innovative liquid-induced healing process for defect elimination and performance enhancement in additively manufactured nickel-based superalloy

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Abstract

Metal additive manufacturing (AM) confronts critical challenges from process-induced defects, particularly lack-of-fusion (LoF) defects, which significantly degrade the mechanical properties and structural integrity of components. Previous research has established that LoF defects in metal AM act as preferential stress concentrators, reducing tensile elongation and accelerating fatigue crack initiation. This study introduces a breakthrough liquid-induced healing (LIH) technique, which remelts grain boundaries in components containing LoF defects, generating liquid-phase flow to fill the defects and creating pathways for internal gas escape. By applying LIH to laser powder bed fusion (LPBF)-fabricated IN718, the research systematically evaluates defect elimination, microstructural evolution, and mechanical performance enhancement. Results show that LIH increases relative density from 97.99% to 99.97%, improves tensile elongation by 1.8 times, and extends creep life by 6.5 times at 650°C/650 MPa, attributed to concurrent defect healing and optimized γ' phase distribution. This integrated approach establishes a new paradigm for defect management in AM, enabling reliable high-temperature applications of nickel-based superalloys in aerospace.

Keywords: Additive manufacturing, Laser powder bed fusion, Lack-of-fusion defects, IN718, Defect healing

Enhanced hydrogen embrittlement resistance through microstructure tailoring by metal additive manufacturing

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Abstract

As global efforts accelerate toward net-zero carbon emissions, the development of safe, efficient, and durable infrastructure for hydrogen storage and transportation has become a strategic imperative. However, the existing pipelines used in the transmission network are prone to hydrogen corrosion which increases brittleness and, thus, reduces service life [1-3]. It is of importance to understand the hydrogen and pipeline steel interaction and to fabricate corrosion resistant barriers. Our research makes use of the laser metal deposition to fabricate coating with desired grain size, morphology, texture and dislocation cell structures. Our experimental results indicated that interlayer cooling led to uniform directional columnar grain growths with finer columnar grains in the interface to large and coarse grains with increase in deposition. It was also found that optimised interlayer cooling had a finer columnar grain structure than typically print approach. Laser shock peening processing led to a uniform generation of dislocations, significantly increasing overall dislocation density. Tailoring the grain morphology by controlling the interlayer temperature is particularly essential for the desired microstructure, leading to improved resistance to hydrogen embrittlement.

Acknowledgements

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The role of oxygen in additively manufactured titanium alloys

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Abstract

Additively manufactured titanium alloys have been extensively studied and are widely utilized across various industries. Historically, oxygen has been regarded as a detrimental element to titanium, often referred to as its 'kryptonite,' due to its ability to induce significant hardening while causing severe embrittlement.

Here we integrate alloy design with additive manufacturing process design to demonstrate a series of titanium–oxygen–iron compositions that exhibit outstanding tensile properties. We explain the atomic-scale origins of these properties using various characterization techniques. The abundance of oxygen and iron and the process simplicity for net-shape or near-net-shape manufacturing by additive manufacturing make these α – β titanium–oxygen–iron alloys attractive for a diverse range of applications. Furthermore, they offer promise for industrial-scale use of off-grade sponge titanium or sponge titanium–oxygen–iron, an industrial waste product at present. The economic and environmental potential to reduce the carbon footprint of the energy-intensive sponge titanium production is substantial.

Evolution of Standards in Additive Manufacturing with Emphasis on ASTM Standards

Andy Lu

Abstract

This presentation provides an in-depth exploration of the latest advancements and the evolving international standards landscape in Additive Manufacturing (AM). It places particular focus on the role of ISO/ASTM standards in shaping the future of AM, offering a clear overview of the most recent and relevant global standards that support the adoption, validation, and scaling of AM technologies across various industries.

Attendees will gain valuable insights into how international standards are driving consistency, reliability, and quality in AM production processes, and why conformance to these standards is essential for organizations aiming to achieve operational excellence and global competitiveness. The presentation highlights the growing importance of formal qualifications and certification frameworks in AM, particularly in highly regulated sectors.

A key part of the discussion delves into real-world industrial applications of AM in the aerospace, medical, and energy sectors—showcasing how standards and structured qualification processes are being applied to ensure product integrity and performance. In addition, the presentation offers practical guidance on navigating and implementing IQ (Installation Qualification), OQ (Operational Qualification), and PQ (Performance Qualification), which are critical to validating AM systems and ensuring process control.

The session also addresses emerging trends and future directions in the AM industry, supported by data and analysis from the Wohlers Report 2025. This includes insights into market growth, technology evolution, material innovation, and strategic challenges faced by manufacturers, making it a comprehensive overview for professionals looking to stay ahead in the rapidly advancing AM landscape.

Improved Strength and Ductility in Novel Metamaterials Additively Manufactured using Laser Sheet Fusion

Changquan Lai

Abstract

The advent of metal additive manufacturing has revolutionized metalworking and enabled the rapid prototyping of metal parts. However, market penetration of metal additive manufacturing techniques remains bogged down by high equipment and operating costs, as well as the brittleness of prints, which typically rely on powder-based precursors. To circumvent these limitations, my team and I have turned to the use of metal foil precursors, which are self-supporting and have inherent mechanical integrity in the in-plane directions. By adjusting the laser parameters used to weld the metal foils, we show how distinct sets of mechanical properties can be generated from the same metallic composition. Synthesizing these different properties side-by-side in an isostrain arrangement, we further demonstrate that these novel "metamaterials" can exhibit enhanced strength and ductility beyond those achieved with other manufacturing techniques.

3D printed dual network cross linked hydrogel electrolyte for wearable strain sensors and supercapacitors

Lei Chen, Dongfeng Qi, Hongyu Zheng

Center for Advanced Laser Manufacturing (CALM), Shandong University of Technology

Abstract

With the rapid advancement of flexible and portable electronics, conductive polymer hydrogels have been widely employed in flexible electronics. However, the design and fabrication of high-performance hydrogel electrolytes that integrate multiple desirable properties—such as mechanical adaptability, conductive sensitivity, and self-adhesion—remain a significant challenge. To address this, we report a rapid and convenient 3D-printable hydrogel developed via the incorporation of organic lithium salts. The introduction of lithium ions not only markedly enhances the ionic conductivity of the hydrogel but also serves as dynamic physical crosslinkers for polymer chains, thereby improving mechanical robustness. Furthermore, the use of lithium ions ensures excellent water-retention capacity. The hydrogel is synthesized via a facile one-pot copolymerization method comprising lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) and acrylamide (AM), endowing the material with multifunctional properties. The innovation of this hydrogel lies in its robust mechanical properties, outstanding ionic conductivity, and effective water retention, collectively enabling superior performance in wearable strain sensors and symmetric supercapacitors.

High-resolution integrated photonic devices realized using additive processes.

Dawn Tan, Gao Hongwei, George Chen and Ju Won Choi

Singapore University of Technology and Design

Abstract

Advances in two-photon polymerization technology and resins have greatly facilitated the development of 3D printed photonic devices. Operating in a paradigm distinct from conventional subtractive, lithographic processes typical in semiconductor manufacturing. 3D printing unlocks the third dimension, allowing more degrees of freedom for the design and realization of photonic devices. In this talk, we discuss high-resolution 3D printed photonic devices realized using two-photon polymerization. Nanostructured suspended air-bridge couplers circumvent the need for edge cleaving for light coupling from optical fibers while maintaining a low coupling loss of 1.6dB. Single and nested spiral waveguides showcase the three-dimensional optical path availed by 3D printing. High-speed measurements of 30Gbps non-return-to-zero data yield low bit error rates of 10⁻¹², indicating their high transmissivity and suitability for data transmission. We further demonstrate 3D printed Er-doped waveguide amplifiers where 1.3dB gain is achieved in 2.7cm waveguides. Resonant devices such as microring resonators and microtoroid resonators which have critical gaps as small as 150nm are achieved. Importantly, the ability to precisely 3D print the coupling waveguide next to the microtoroid circumvents the need for difficult alignment of a tapered fiber next to the microtoroid for excitation of resonant modes. High-resolution 3D printing is an important technology for the development of novel photonic devices toward diverse applications such as in high-speed communications, imaging and medicine.

Personalized AI-Driven Design and Precision Manufacturing of 3D Bio-Implants

Feng Chen

Abstract

The progress of tissue engineering and regenerative medicine hinges on the development of three-dimensional (3D) scaffolds that not only support cellular activities but also exhibit the requisite mechanical stability for implantation. Conventional strategies have been constrained by oversimplified architectural designs and limited manufacturing capabilities, resulting in engineered constructs with insufficient mechanical robustness, poor structural integrity, inadequate vascularisation, and suboptimal biofunctionality. In this study, we present innovative design and 3D bioprinting strategies aimed at addressing these limitations. At the core of our approach is the construction of complex biomimetic scaffolds through the assembly of Triply Periodic Minimal Surface (TPMS) units, which concurrently provide enhanced permeability, mechanical strength, and cellular support. To facilitate high-resolution, light-based bioprinting, we introduce a novel photoinhibiting method that mitigates cell-induced light scattering, thereby enabling the fabrication of the designed constructs with high fidelity. The resulting cell-laden architectures demonstrate improved oxygen diffusion, elevated cell viability, and efficient nutrient transport, underscoring their applicability in liver tumour modelling and other complex tissue systems. This work represents a significant step towards the long-term objective of whole-organ fabrication and offers a promising resolution to current challenges in soft tissue engineering.

Energy Absorption and Mechanics of Origami Metamaterials

Guoxing Lu

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Abstract

Additive manufacturing has offered new opportunities for designing and manufacturing metamaterials. This presentation introduces energy absorption and mechanics of origami inspired metamaterial which we have recently studied. Several examples of incorporating the concepts of origami will be presented. Additive manufacturing was employed in producing the test specimens. They include Miura metamaterials and its variations under quasi-static and dynamic compression and origami sandwich panels under quasi-static loading and ballistic impact.

Responses of such materials and structures involve large plastic deformation as well as dynamic effects. For metamaterials, analytical models have been developed to describe the strength and energy absorption capacity. It is assumed that the base material is ductile and can be approximated as a perfectly-plastic material. The analytical model is verified by the numerical simulations as well as quasi-static compression test of a four-sheet origami specimen. Response of such material under impact loading is also investigated and a shock model is proposed for high velocity impact. An issue of brittle fracture of additively manufactured materials is highlighted.

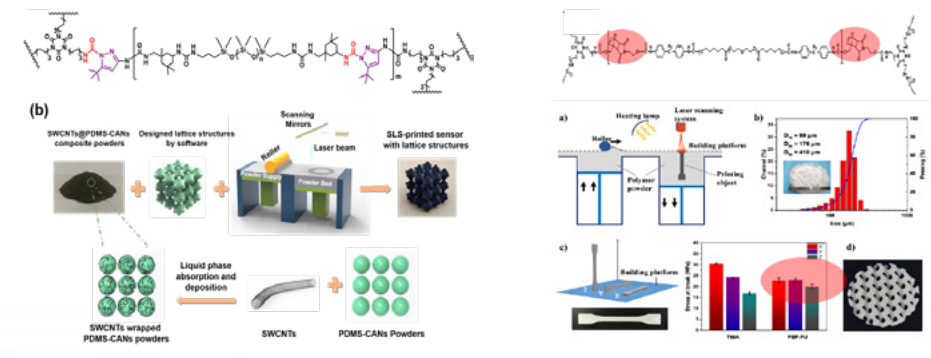
Polymer Powder Bed Fusion: Challenges and Opportunities

Hesheng Xia*

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Abstract

Powder Bed Fusion (PBF) including selective laser sintering (SLS), high speed sintering (HSS), multi-jet fusion (MJF) is one of the mainstream 3D printing technologies, which use the laser or IR energy to melt and fuse the powders and then stack layer by layer to form a printed part based on 3D model data. The major challenges for PBF technology is incomplete fusion, as well as the easily breaking in low-dimensional area. Herein, polymer covalent adaptable networks (CANs) were utilized to solve the challenge of PBF. PBF 3D printing of the self-made healable polymer PU-CANs and PDMS-CANs powders was successfully realized. The powder fusion can be significantly improved via dynamic chemical bond linking instead of traditional physical entanglement. The printed polymer CANs samples with lower porosity exhibited improved mechanical properties. On the other hand, PBF printing provide opportunities for functional printing. PBF is an excellent method to prepare the electrical conductive and electromagnetic EMI/EMWA materials. Using the carbon nanotubes coated polymer powder, or inkjet printed carbon powder, ingeniously utilizing the quasi-static processing characteristic of PBF printing, the conductive segregated carbon networks are in-situ formed in polymer matrix during the printing process, leading to an ultra-low percolation threshold of 0.007 wt %. The SLS-printed SWCNTs@PDMS-CANs strain sensors with TPMS Schwartz lattice structure possesses the high sensitivity. Also the materials possess excellent electromagnetic EMI shielding and wave absorption capabilities. At a SWCNTs loading of 2 wt%, the material's EMI shielding effectiveness reaches -22 dB. At 0.5 wt% SWCNTs, the printed specimen exhibits a minimum reflection loss of -24.03 dB at a thickness of 1.93 mm with an effective absorption bandwidth (EAB) of 5.75 GHz within the range of 12.25~18 GHz. The PBF printing can achieve electromagnetic shielding and absorption performance through controlling powder structure parameters and filler content. The sub-microscopic layered structures of the inkjet-printed carbon black particles used as infrared absorbers of HSS printing can be formed during the printing process, which can induce the multiple reflections and refractions of electromagnetic waves, significantly attenuating their intensity. At a specimen thickness of 28.3 mm, an effective absorption bandwidth (EAB) of 14 GHz (4~18 GHz) can be achieved.



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Acoustic levitation for omnidirectional and multi-material in situ printing

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Faculty of Dentistry, Oral & Craniofacial Sciences, King's College London;
Department of Mechanical Engineering, University College London*

Abstract

In situ 3D printing holds great promise for tissue engineering by enabling direct fabrication of biomaterials and constructs onto defect sites, minimizing surgical handling and enhancing integration. However, existing in situ bioprinters typically require print heads to be positioned very close to the target surface, risking damage or contamination to delicate surfaces, and restricting printing angles and multi-material integration. In this study, we present a contactless in situ printing platform that uses acoustic levitation to manipulate and deposit materials without physical contact. This system harnesses a phased array of transducers (PAT) to finely tune the ultrasonic field, generating acoustophoretic forces that levitate and transport objects in mid-air. It allows omnidirectional in situ printing of materials onto complex substrates with diverse orientations in a contactless and voxel-by-voxel manner. It is capable of manipulating a broad spectrum of materials, including liquids with zero-shear viscosities from 1 to 5,000,000 mPa·s, as well as solids. It has successfully printed structural, conductive, and biological materials in varying directions on complex substrates. Additionally, the contactless approach enables in situ printing safely on a delicate surface, as demonstrated by printing on a human hand. The flexibility and versatility of this approach demonstrate promising applications in areas ranging from biomedical engineering to industrial manufacturing.

AI Gastronomic Design: 3D Food Printing for Aesthetic Experience

Immanuel Koh

Abstract

The talk will discuss the creative affordances and opportunities of artificial intelligence in the generative design of 3D-printed food. Using the award-winning design project 'Neural Palate Kueh' which is currently on display as part of the Singapore Pavilion at the Venice Architecture Biennale 2025, the presentation will elaborate on the generative AI design process in the creation of the synaesthetic 3D-printed food project.

Moving Bioprinting Towards Clinical Application

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Abstract

Bioprinting, the ability to 3D print cells, has opened up many new possibilities in drug development, disease modelling and tissue engineering. However, despite the new technological developments and the availability of a range of materials, there remains many challenges which limit the ability to translate bioprinting towards clinical application. These challenges come from a variety of sources which includes the printers, the cells used, the materials used to encapsulate the cells, demonstration of safety and efficacy as well as the regulatory environment. The net result is that bioprinting remains very much in the realm of research. For example, most printers use extrusion of cells encapsulated in shear thinning gels, which limits scaffold design and has rather low resolution. On the cell front, most researchers use animal cells which can behave differently to human cells. Many of the materials in current use are biologically derived, are expensive in some cases and need chemical modification. Despite the challenges highlighted, there are ways to overcome some of these barriers which will be discussed during this talk. Importantly, the need for tissue engineered approaches to disease, repair and regeneration remains, both in an in vitro and in vivo context.

Reverse Engineering of Meat Structures Using 3D Printing of Plant Based Materials

TAN Lay Poh, Nicole CHEAM

Nanyang Technological University, Singapore

Abstract

Replicating the fibrous architecture of animal meat remains a key challenge in developing realistic plant-based alternatives. High moisture extrusion is one of the closest conventional techniques, producing aligned protein fibres. However, it often results in too uniform anisotropy across the entire product, which creates an overly stiff texture unlike real meat. To address this, we first used a syringe-based extrusion setup to mimic key parameters of high moisture extrusion, such as alignment through a die and heat induced structuring. This allowed us to demonstrate the potential to induce fibrous structures in plant-based formulations. Building on these findings, we transitioned to the 3D printer where spatial control allows for more precise structuring. We optimized formulation properties and printing conditions, including nozzle length, temperature, and mixing methods, to promote alignment within the printed fibres. This work aims to achieve more realistic meat like textures by controlling localized fibre orientation, where the viscosity and flow behaviour of the material play a crucial role.

Durable Immunomodulatory Hierarchical Patch for Rotator Cuff Repairing

Liren Wang

Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine

Abstract

Introduction/Objectives

High re-tear rates exceeding 50% in degradable shoulder cuff patches, observed over a five-year follow-up, are attributed to the failure of degradable polymers alone to restore the inflammatory niche post-rotator cuff injury, hindering tendon-bone interface healing. Theoretically, a degradable polymer with durable immunomodulatory functions throughout its degradation procedure might address this issue.

Methods

Ferulic acid (FA) was introduced into the repeating unit fragments of polyurethane by skeletal copolymerization to construct a biodegradable polymer (poly(ester- ferulic acid-urethane) urea, PEFUU) with long-lasting anti-inflammatory effects. After verifying the anti-inflammatory function of PEFUU in vitro, hierarchical composite nanofiber patch (HCNP) with sustained anti-inflammatory niche was constructed by electrospinning and lyophilization of decellularized Wharton jelly tissue. The HCNP was used for rotator cuff repairing in rat model. The effectiveness of promoting iRCT repairing by the HCNP was also validated by imaging, histology, and molecular biology methods.

Results

Via employing the paradigm of polymer backbone functionalization, a hierarchical composite nanofiber patch (HCNP) distinguished by its enduring immunomodulatory properties, was fabricated, adept at sustaining a protracted anti-inflammatory microenvironment conducive to fostering tissue regeneration (Scheme 1). The synthesis process by fabricating (PEFUU) was initiated, wherein FA was incorporated as a bioactive constituent. PEFUU stably releases FA in vitro, reversing the inflammatory niche produced by M1 macrophages and restoring the directed differentiation of stem cells. Subsequently, PEFUU was subjected to the electrospinning process, yielding a bipolar fiber patch characterized by an organized, yet partially random, stratified architecture. Within this stratified architecture, the random layer was strategically imbued with the enzymatic hydrolysate derived from decellularized Wharton jelly tissue (HDWJT). In vitro experimentation demonstrated the propensity of FA to undergo a gradual release profile concomitant with the progressive degradation of the HCNP. In a compelling demonstration of the HCNP's therapeutic prowess, this study extended to an in vivo milieu, employing a rat model of tendon-to-bone injury, manifesting as the restoration of the microstructural continuity inherent to the tendon-to-bone interface, coupled with the establishment of a trinomial distribution of collagen ordering.

Conclusions

This study provides an idea for the use of an electrospun nanofiber mat in tissue regeneration. By introducing anti-inflammatory small molecules through copolymerization, the inflammatory niche of the damaged tissue can be altered persistently, effectively inducing tissue regeneration.

Durable Immunomodulatory Hierarchical Patch for Rotator Cuff Repairing

Liren Wang, Jia Jiang, Xin Ma

Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine

Abstract

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Surface-Aware Robotic 3D Printing via real-time RGB-D Mapping and Semantic Segmentation

Mirnalini Selvarajan Sivakumar, Hirusha Maduwantha, Naresh Kumar Thanigaivel, Thileepan Stalin, Pablo Valdivia y Alvarado

Singapore University of Technology and Design

Abstract

3D printing directly onto non-planar and irregular surfaces presents a transformative opportunity for personalized fabrication, adaptive wearables, and real-time repair of soft systems. However, conventional 3D printing techniques are predominantly limited to planar surfaces and controlled environments, relying on pre-scanned models for tool path generation, restricting their applicability in dynamic, real-world settings. To overcome this, In-situ scanning of the print bed is necessary for understanding the surface and generating adaptive tool paths based on surface topologies.

The system integrates a 7-axis robotic arm, a wrist-mounted RGB-D-based vision system for 3D mapping, semantic surface segmentation, and surface-aware toolpath planning to enable printing on non-planar surfaces. The vision-based colour and depth information along with user-guided object selection helps in understanding the surface. Based on the user selected region of interest on the camera feed, the Segment Anything Model (SAM) outlines the desired object from the RGB data. The corresponding depth coordinates of the segmented contour were mapped for 3D point cloud visualization and surface-aware tool path generation. This real-time, modular pipeline enables the robotic arm to scan the print bed and print on any non-planar surface quickly.

We demonstrate this approach through printing decorative patterns on face masks and printing custom textures on real-world objects, such as a computer mouse. Furthermore, on-site repair of soft robots, such as printing missing skin segments for a stingray-inspired robot was also demonstrated. This study expands the possibilities of surface-aware printing by using vision-based systems in additive manufacturing and creates new opportunities for personalized manufacturing, on-site repairs, and flexible customization.

No More Guesswork: Predictive Control for Silicone Printing via Vision and Machine Learning

Akhila Prabodha, Hirusha Madhuwantha, Kaëlig Plantard, Rajesh Kumar Balaraman, Naresh Kumar Thanigaivel, Thileepan Stalin, Pablo Valdivia y Alvarado

Singapore University of Technology and Design

Abstract

3D printing RTV Silicones is challenging due to their unpredictable change in viscosity over time and dynamic flow behaviour, hindering the print quality and results in print failure. Manual tuning of print parameters is inefficient and inconsistent. This work presents a method combining in-situ vision-based line width monitoring and flow rate data collection with offline machine learning to predict optimal settings, enabling reliable RTV silicone printing with improved fidelity and reduced trial-and-error.

A fixed front camera was used to analyze the motion of extruded material. To estimate the flow rate, a contour tracking based time-distance analysis method was used. For data collection, various needle diameters, pressures, different combinations of material with thixotropic concentrations were used to study the extrusion dynamics in three distinct time zones with an interval of 30 minutes. The estimated flow rate results were cross validated by comparing the actual mass of the extruded material, showing agreement within a 10% margin of error.

Complementing this, a fixed top camera-based system uses image processing algorithms to measure the printed line widths for various print parameters. Measured widths for different process parameters were compiled into a dataset of 5,184 and utilized to train the predictive model. The camera-based width measurement was cross-validated against microscopebased line measurement with error margin of $\pm 100 \mu\text{m}$.

The predictive model accepts inputs such as desired needle diameters, material composition, and total print time to recommend optimal print settings that achieve the targeted quality. By learning from historical width measurements, the model generalizes the nonlinear relationship between extrusion behavior and print parameters.

An integrated monitoring system leveraging machine learning and vision-based sensing enables real-time data collection and dynamic adjustment of 3D printing parameters, transitioning from trial-and-error to a data-driven approach, thereby enhancing print quality and reducing failures.

4D Printing of Versatile Shape Memory Polymers with Digital Light Processing

Ng Chin Siang, Taehyub Lee, and Pei-Chen SU

School of Mechanical and Aerospace Engineering and Singapore Centre for 3D Printing, Nanyang Technological University, Singapore

Abstract

Vat photopolymerization has been used in a wide variety of applications from early-stage prototyping to industrial manufacturing of products. It allows easy fabrication of complex geometries that is usually costly for conventional manufacturing methods to fabricate. digital light processing (DLP) belongs to a family of additive manufacturing class known as vat photopolymerization, where a pool of photopolymer resin is solidified by UV light in a layer-by-layer fashion. In this talk, we introduce our resin formulation with nanoparticle additive to add the additional functionalities for targeted mechanical properties of printed parts. In particular, the dimensional accuracy of 3D printed parts in DLP by achieving a controlled UV penetration through the photopolymer resin is achieved to avoid excessive unwanted curing caused by overexposure while maintaining the superior mechanical properties of the printed part. Significant improvement in preventing unwanted curing was also observed in resin with zinc oxide nanoparticles, as evident by our printing tests on open channels and overhanging structures. Unlike the typical dye additive, Sudan I, which deteriorated the mechanical properties of printed parts, zinc oxide additives have rendered more effective curing that resulted in improved tensile strength, fracture strain and Young's modulus. Our recent progress on development of 4D printing of shape memory polymers will be presented in the aspect of improved printability, control process and post-process parameters on the impact of shape memory effects, and potential applications in medical devices.

Keywords: 4D Printing, Digital Light Processing; Dimensional Accuracy; Recovery forces

Biography: Professor Pei-Chen SU is a faculty member and Assistant Chair (Academic) at the School of Mechanical and Aerospace Engineering, Nanyang Technological University. She also serves as the Cluster Director at the Energy Research Institute and the Singapore Centre for 3D Printing, and currently holds the position of Vice President of the Thin Films Society. Her expertise lies in advanced manufacturing technologies, with a particular emphasis on 4D printing, micro/nanofabrication, thin films and coatings, and fuel cells.

A central aspect of Professor Su's research in 4D printing involves the development of photopolymers that are not only 4D printable but also capable of delivering substantial recovery forces for practical applications. Her team investigates the interplay between resin composition, programming and recovery temperatures, and output recovery force, leveraging these parameters to engineer precise force responses for innovative applications in energy conversion, medical devices, and beyond.

Additively manufactured biodegradable metal implants for repairing bone defects

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2. School of Materials Science and Engineering, Peking University, China;

Abstract

To address the critical demands of implants with customized structures and biodegradable performance for bone defect repair, this work has focused on the development of magnesium (Mg) and zinc (Zn)-based metal bone implants including powder materials, digital design as well as additive manufacturing technologies. WE43, Zn-Mg, Zn-Li, Zn-Cu powders were prepared and fabricated into porous scaffolds by laser powder bed fusion (L-PBF). The formation quality, mechanical properties, biocompatibility and biodegradability were characterized. The effect of chemical compositions, porous structure and surface conditions were investigated and optimized. The relative densities of L-PBF solid samples were greater than 99.5%. The tensile strength of WE43, Zn-1Mg and Zn-0.8Li solid samples reached to 300, 381 and 417 MPa. The Young's modulus and strength can be precisely adjusted by porous design. Machine learning-optimized porous scaffolds efficiently matched bone structure and modulus, and simultaneously enhanced compressive strength. Meta-materials scaffolds were designed to enhance mechanical stimulation to bone regeneration. High temperature oxidation resolved rapid degradation issues in Mg scaffolds WE43 alloy, enabling reliable load-bearing and controllable degradation. The released metal ions from degradation demonstrated critical influence on cell viability and osteogenesis, and was effectively modulated by alloying composition, porous structure and surface treatment. Additively manufactured biodegradable metal implants have been successfully applied to animal models with complicated bone defects including critical size, infection, and tumor. Customized Mg alloy implants have accomplished clinical application and successfully treating over 40 patients of periarticular bone defects. The inspiring outcome indicates significant clinical values of biodegradable metal bone implants.

Keywords:

Additive Manufacturing, Biodegradable Metal, Bone Implant, Bone Defect

Laser powder bed fusion of overhang structures using donut-shaped laser beam.

Quanquan Han
Shandong University

Abstract

Laser Powder Bed Fusion (LPBF) offers significant advantages in the fabrication of complex metal structures and the enhancement of material utilization. However, conventional Gaussian laser sources are limited by their uneven energy distribution and small spot size, resulting in narrow processing windows and low forming efficiency. This study utilizes a donut beam laser with a more uniform energy distribution to fabricate nickel-based superalloys and low-angle overhang structures, the micro-structure evolution will also be explored in the talk.

3D printing applications in craniomaxillofacial surgery

Raymond Wong

Abstract

The advent of 3D diagnosis, 3D simulation and 3D printing has allowed craniomaxillofacial surgeons to better treat patients in a more holistic and accurate manner. Personalized implants or guides allows a safer, more functional rehabilitation of patients and involves a high degree of accuracy, moving beyond just 3D models for diagnosis. The ability to 3D print resorbable implants allow regeneration of lost tissues. The speaker will focus on the advances and clinical applications of these technologies.

Effect of Topological Characteristics on the Manufacturability and Mechanical Performance of Multiscale Graded Structures Fabricated by Laser Powder Bed Fusion

Ruiqi Wang

Abstract

The abstract is as follows: Complex graded lattice structures emerge as a current focal point due to the controllability of physical, mechanical and geometrical properties spatially. However, the increasingly complex relationship between topological characteristics, manufacturability, and mechanical performance presents challenges for the application of graded structures. In this study, we designed and fabricated performance-driven multiscale graded Gyroid structures using laser powder bed fusion (LPBF) technology. The influence of unit cell size and induced grading of Gyroid structures was explored, revealing the mechanism of construction-process-performance response. The manufacturability and mechanical properties of uniform structures exhibited a significant scale effect. As the unit cell size decreased, the structural thickness increased and dross defects diminished, while the relative density deviation was insensitive to unit cell size. The correspondence between mechanical properties and relative density of uniform structures conforms to the Gibson-Ashby model. Structural distortion caused by unit cell size grading influenced manufacturability and mechanical properties. As the graded magnitude increased, the mean structure thickness and relative density of graded structures increased, and the mechanical properties decreased. The mechanism by how unit cell distortion affects manufacturability and mechanical performances was revealed. Notably, although the mechanical properties of the graded structures were inferior to that of uniform structure, the topology-optimized three-point bending beam composed of graded structures exhibited superior bending performance, showing a ~9.6% increase in bending strength and a ~46.8% improvement in bending displacement compared to uniform beam. This is attributed to the graded structure's ability to redistribute stress and inhibit crack propagation.

Platelet-Rich Plasma-Exosomes Therapy Overcoming Pro-Inflammatory and Catabolic Effects for Temporomandibular Joint Osteoarthritis

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- 2.Department of Orthopedics, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China
- 3.Shanghai Key Laboratory of Orthopedic Implants, Department of Orthopedics, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China.
- 4.Shanghai Engineering Research Center of Innovative Orthopaedic Instruments and Personalized Medicine, Clinical and Translational Research Center for 3D Printing Technology, Shanghai, China.

Abstract

Background: Temporomandibular joint osteoarthritis (TMJ-OA), a common subtype of temporomandibular joint disorder, is characterized by synovial inflammation and progressive articular cartilage degradation. Platelet-rich plasma (PRP) has shown clinical efficacy in osteoarthritis; however, its potential pro-inflammatory and catabolic effects limit its application. This study aimed to investigate whether PRP-derived exosomes (PRP-Exos) could retain the reparative properties of PRP while mitigating its unfavorable pro-inflammatory and catabolic side effects, and explore their potential as a novel bioink for 3D bioprinting. Methods: PRP-Exos were extracted and identified. In vitro experiments used IL-1 β -induced condylar chondrocytes to simulate TMJ-OA, evaluating the effects of PRP and PRP-Exos on chondrocyte proliferation, apoptosis, migration, and the expression of inflammation- and catabolism-related genes. Simultaneously, the effects of PRP and PRP-Exos on macrophage polarization were detected using immunofluorescence and flow cytometry. The protein composition of PRP-Exos was analyzed, and the mechanism of action was predicted. In vivo, a rat TMJ-OA model evaluated the therapeutic effects of PRP and PRP-Exos on condylar cartilage repair and synovial inflammation. Results: PRP-Exos retained the effects of PRP by promoting chondrocyte proliferation, inhibiting apoptosis, and promoting migration. Compared with PRP, PRP-Exos could better avoid pro-inflammatory and catabolic side effects and promote M2 macrophage polarization. Quantitative proteomic analysis indicated that PRP-Exos may regulate the cell cycle, lipid metabolism, and antioxidative stress pathways. TMJ-OA rat experiments further confirmed that PRP-Exos could effectively repair condylar cartilage and alleviate synovial inflammation, and that plasma-free PRP-Exos showed even better effects. Conclusion: PRP-Exos represent a promising novel bioink for TMJ-OA treatment. The enhanced therapeutic efficacy observed with plasma-free PRP-Exos compared to traditional PRP formulations suggests their strong potential for applications in 3D bioprinting to construct scaffolds for cartilage repair.

High-temperature high-entropy alloys: Targeted composition and microstructural design for synergistic multi-property enhancement

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Abstract

High-entropy alloys (HEAs), known for their unique compositional flexibility and tunable mechanical properties, have attracted significant attention for applications across a broad temperature range, from cryogenic to elevated-temperature environments. However, their deformation behavior and properties under high-temperature conditions exceeding 1000 °C remain inadequately understood. This presentation introduces our recent progress in the alloy design of a novel multi-component, Ni-rich high-temperature high-entropy alloy (MNiHEA), engineered for reliable operation at temperatures above 1000 °C [1–3]. I will highlight targeted composition and microstructural design aimed at enhancing mechanical strength, microstructural stability, oxidation/corrosion resistance, and manufacturability by laser-powder bed fusion. Case studies will demonstrate how specific compositional and microstructural couplings contribute to improved phase stability, coarsening resistance, and strength-ductility synergy across a wide temperature range of –196 °C to 1000 °C. The presentation will also cover formability optimizations achieved through thermo-mechanical processing and laser powder bed fusion additive manufacturing. Key topics include elemental selection, phase configuration, thermodynamic and mechanical properties, and microstructural modifications, as well as the synergistic mechanisms driving the achieved multi-property optimization. These findings offer valuable insights for the development of next-generation heat-resistant materials with enhanced performance, particularly for use in extreme environments such as aerospace and energy systems.

Keywords: High-temperature high-entropy alloys; Composition and microstructural design; Multi-property optimization; Synergistic mechanisms; Extreme environments

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The innovative laser sources applications in metal 3D printing (Invited)

Shuai Li

FastForm

Abstract

This report discusses the innovative applications of laser sources in metal 3D printing technology. It focuses on the breakthrough applications of ring-point laser, green laser, and beam shaping technology, addressing industry challenges such as the formation of high-reflectivity materials, control of printing defects, and efficiency enhancement. The ring-point laser utilizes a multi-beam collaborative system, combining central and annular beams, which significantly reduces spatter and achieves ultra-dense forming, thereby improving printing efficiency. The green laser markedly enhances the absorption rate of high-reflectivity materials, increasing printing efficiency and overcoming challenges in printing high thermal conductivity and electrical conductivity metals. Additionally, it expands the application of new high-temperature cooling channels. Beam shaping technology minimizes the heat-affected zone while enhancing interlayer bonding strength, leading to improved printing precision. In conclusion, this report serves as a reference for advancing industrial upgrades, realizing closed-loop value in technology, and further expanding the widespread application of metal 3D printing across various fields.

Real-time defect detection in Wire Arc Additive Manufacturing (WAAM) using microphone and emission spectroscopy

Kevin Angga Gunawan, Joselito Yam Il Alcaraz, Tegoeh Tjahjowidodo

KU Leuven

Abstract

Wire Arc Additive Manufacturing (WAAM) is an emerging technology that leverages the fundamental principles of arc welding. WAAM employs a layer-by-layer deposition process to produce components or objects. Various challenges arise during the technology development process, particularly in ensuring product quality. In this study, a real-time in-process nondestructive monitoring system employing a microphone and emission spectroscopy is proposed to detect product defects and identify the root causes. Experiments were designed to simulate defects caused by lack of shielding gas. The defect detection processes were performed using a model works based on wavelet scattering network. Following the detection of defects, the spectrometer analysis was initiated to identify the root cause. The selection of atomic spectra lines was determined by implementing a forward stepwise regression algorithm on the spectrometer data. Furthermore, to support the analysis, the analytical results were benchmarked against images obtained from radiographic testing (X-ray inspection), enhancing the robustness of the research findings. The experimental results demonstrated that the ratio of hydrogen and argon spectrum emerged as a pivotal indicator for detecting the absence of shielding gas.

3D Bioprinted scaffolds for joints regeneration

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Abstract

Tissue engineering is theoretically thought to be a promising method for the reconstruction of biological joints, and thus, offers a potential treatment alternative for advanced osteoarthritis. However, to date, no significant progress is made in the regeneration of large biological joints. In the current study, a biomimetic scaffold for rabbit humeral head regeneration consisting of heterogeneous porous architecture, various bioinks, and different hard supporting materials in the cartilage and bone regions is designed and fabricated in one step using 3D bioprinting technology. Furthermore, orchestrated dynamic mechanical stimulus combined with different biochemical cues (parathyroid hormone [PTH] and chemical component hydroxyapatite [HA] in the outer and inner region, respectively) are used for dual regulation of endochondral ossification. Specifically, dynamic mechanical stimulus combined with growth factor PTH in the outer region inhibits endochondral ossification and results in cartilage regeneration, whereas dynamic mechanical stimulus combined with HA in the inner region promotes endochondral ossification and results in efficient subchondral bone regeneration. The strategy established in this study with the dual modulation of endochondral ossification for 3D bioprinted anisotropic scaffolds represents a versatile and scalable approach for repairing large joints.

Upscaling of 3D Printing

U Xuan

Abstract

There has been a growing interest in the role of 3D printing in modern manufacturing. However, to fully realize its potential in large-scale operations, significant upscaling of current 3D printing technologies is required. Fused Filament Fabrication (FFF), one of the most widely adopted additive manufacturing methods due to its low cost, has attracted attention for fleet-based deployment. Such fleets of affordable printers hold great promise for high-volume, on-demand production of customized parts. A key limitation of FFF printing, however, is the need for manual removal of printed parts before a new print can begin as the print bed remains occupied. In addition, time is often lost when erroneous prints are not detected and stopped early. These issues contribute to increased machine downtime, reducing overall utilization and profitability. Since continuous round-the-clock printing is desired to increase profit, we are presenting a system designed by us to enable continuous operation of FFF printers, incorporating vision-based failure detection and robotic part removal. Another example of application is in 3D food printing, which is increasingly relevant in the context of a rapidly aging global population. 3D-printed food offers a potential solution for elderly individuals with dysphagia, helping to address nutritional challenges. However, current 3D food printing technologies are not yet scalable for use in hospitals and eldercare facilities, as they are labor-intensive and time-consuming. To address this, we have designed a novel 3D food printer to significantly reduce the time required.

Nanoscale TiC reinforced titanium matrix composites fabricated via gas-liquid reaction additive manufacturing

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Abstract

This study presents a novel laser additive manufacturing method for fabricating agglomeration-free nanoscale TiC-reinforced titanium matrix composites (TMCs) through in-situ nanophase reinforcement synthesis. We term this novel approach in-situ Laser Additive Manufacturing (isLAM), which innovatively integrates laser-induced gas-phase pyrolysis with selective laser melting (SLM) technology. TiC-reinforced TMCs are finally built in a layer-by-layer manner through SLM additive manufacturing. We successfully achieved agglomeration-free nanoscale TiC reinforced TMCs by the proposed isLAM method via a gas-liquid reaction. Remarkably, the TMCs exhibit a good combination of simultaneously high strength and high plasticity. More importantly, the isLAM technology shows promise not only for application in additive manufacturing of functionally graded TiC reinforced TMCs parts with continuously varying microstructures and properties through precise modulation of hydrocarbon gas concentration gradients, but also has potential for extension to in-situ additive manufacturing of high-performance components for a very wide range of nanocomposites. This advancement may substantially accelerate the development and application of additive manufacturing technologies.

Model-Based Additive Manufacturing Verification and Validation for the Maritime Industry

Michalis Benakis¹, Wenjin Yu², Xinying Liang³, Lequn Chen¹, Liu Tong¹, Alvin Tan Kuang Shuan¹, Cheng Xin Wei¹, Choy Chee Kit¹, Yuxuan Xie¹, Youxiang Chew¹

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2.American Bureau of Shipping (ABS)
3.Mencast Marine Pte Ltd

Abstract

Laser Directed Energy Deposition (L-DED) is an additive manufacturing technology used for the fabrication of large, high-value metal components of complex geometries. Varying process conditions and perturbations of the nominal printing environment may introduce defects in the manufactured parts, often leading to catastrophic failure. For the manufacturing of critical components, the maritime industry has set a series of standards and testing guidelines to ensure defect-free components are deployed on seaborne vessels.

In the present work, the approach of using process monitoring methodologies and technologies for rapid qualification is explored. Acoustic sensors are employed to acquire sound signals during the printing process. Analysis of extracted features in both time and frequency domains act as process status indicators correlated with defects such as crack and porosity obtained through non-destructive X-ray quality assessments. By means of machine learning algorithms, virtual quality maps are then reconstructed with potentially defected areas marked, generating a form of a digital twin representing the parts quality.

The outcome of the above procedure is subsequently used to propose a qualification framework to evaluate and implement data-driven models on actual industry provided maritime use cases. The presentation discusses the development of a standard method to evaluate the performance of a model, and guidelines to implement the evaluated model in traditional additive manufacturing verification and validation process.

This study leverages combination of advanced X-ray CT technology and process monitoring to enable more efficient, rapid, and reliable classification of propellers and marine components produced using metal additive manufacturing. The findings of this study have the potential to streamline qualification processes, reduce testing requirements, accelerate production cycles, and enhance performance optimization for future marine applications.

Influence of in-situ rolling strategies of Ti-6Al-4V in directed energy deposition

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Abstract

This study examines the influence of in-situ rolling process parameters on the microstructure and mechanical properties of Ti-6Al-4V alloy fabricated via Directed Energy Deposition (DED). The research investigates the effects of rolling reduction rate and rolling speed on the size of prior-β grains, texture intensity, and mechanical performance. The key findings are as follows: (1) Increased rolling reduction rate significantly reduces the average grain size of prior-β grains, enhances yield strength and ultimate tensile strength, and diminishes texture intensity, thereby achieving isotropic mechanical properties. (2) Rolling speeds ranging from 500mm/min to 1100mm/min effectively refine grain size and improve strength, with no sensitivity observed at lower or higher speeds. (3) The combined effect of higher rolling reduction rates and speeds further enhances grain refinement and mechanical properties, with optimal results observed at a 40% reduction rate and a speed of 1100mm/min. (4) The in-situ rolling process induces dynamic recrystallization, transforming columnar grains into equiaxed grains, which enhances isotropy and strength. This research offers a comprehensive understanding of optimizing in-situ rolling parameters to improve the performance of DED-manufactured Ti-6Al-4V components.

Coupling Physics-Informed Neural Networks with CFD for Multi-Physics Modeling of Metallic Glass Formation in Laser Powder Bed Fusion

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Abstract

The formation of metallic glass in Laser Powder Bed Fusion (LPBF) is governed by tightly coupled thermal-fluid-mechanical phenomena, including rapid heat transfer, melt pool convection, and stress-induced crystallization. Traditional computational fluid dynamics (CFD) approaches, while accurate, are computationally expensive and often limited in flexibility for real-time applications or inverse design. In this work, we propose a hybrid modeling framework that integrates multi-physics Physics-Informed Neural Networks (PINNs) with CFD simulations to efficiently capture the process dynamics of metallic glass formation. By embedding governing equations—such as heat conduction, Navier–Stokes fluid flow, thermo-mechanical stress evolution, and phase transformation kinetics—into the neural network’s loss function, the PINN model learns physically consistent solutions from sparse data while maintaining generalizability across process parameters. CFD simulations provide high-fidelity reference data to guide training and validation, enabling accurate prediction of melt pool morphology, cooling rates, residual stress fields, and amorphous-to-crystalline transitions. This coupled PINN-CFD approach offers a mesh-free, data-efficient, and computationally scalable solution for LPBF process modeling and optimization, paving the way for intelligent manufacturing of high-performance amorphous alloys.

3D-printed Intelligent magnetic soft millirobots for biomedical applications

Yi Zhang

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Abstract

Vat photopolymerization (VP) is a promising technique for fabricating magnetic soft millirobots (MSMRs) with precise and miniature 3D structures. However, the incorporation of magnetic filler materials into resin often causes challenges, the most common ones are the interference with the photon energy source and rapid sedimentation, leading to nonuniform filler distribution or failed prints. These issues limit the further application of VP in creating high-performance MSMRs. To address this, a novel circulating vat photopolymerization (CVP) platform is introduced, enabling the successful fabrication of MSMRs with high uniformity, high particle loading, and strong magnetic response. Through extensive material and printing characterization, $\text{SrFe}_{12}\text{O}_{19}$ is identified as an ideal magnetic filler for CVP, demonstrating the ability to print parts with 30% particle loading and good filler uniformity. Various tethered and untethered MSMRs are also fabricated monolithically and exhibit the capabilities of reversible 3D-to-3D transformation and precise manipulation of liquid droplets in 3D space. These robots show significant potential in biological and medical applications, particularly in environments that are difficult to access with traditional methods, such as congested or confined spaces. The ability to navigate such challenging environments opens up new possibilities for medical interventions and other applications requiring high manoeuvrability and precision.

Short Bio

Dr. Yi Zhang is currently a Professor at the University of Electronic Science and Technology of China. Previously he served as an assistant professor at the School of Mechanical and Aerospace Engineering at Nanyang Technological University, Singapore. He was also an affiliated faculty of China Singapore Joint International Research Institute, Singapore Center for 3D Printing, NTU-HP Digital Manufacturing Corp Lab, and Nanyang Quantum Science and Engineering Center. He received his Ph.D in Biomedical Engineering from Johns Hopkins University School of Medicine, USA, in 2013 and B.Eng in Bioengineering from Nanyang Technological University, Singapore, in 2007. He received his postdoc training in the Institute of Bioengineering and Nanotechnology, the Agency of Science Technology and Research (A*STAR), Singapore from 2013–2015, and subsequently worked there as a Research Scientist from 2015–2016. His research aims to develop micro and nano systems to bridge the gap between engineering advancement and current medicine practice. His achievement is recognized by a series of awards including Nanyang Young Alumni Award, Outstanding Self-Financed Student Overseas, Hodson Fellowship, Siebel Scholar, and various Young Scientist Awards, Best Conference Awards and Art in Science Awards.

Recent Developments in Laser Processing for Enhancing Metallic Surfaces

Ying Chun Guan

Abstract

Laser processing has been considered a promising technique to enhance surface performance of metallic materials in various applications, including aerospace, energy, and biomedical engineering. This talk presents our recent work on various metallic surfaces in our group, How the surfaces could be manipulated at various scales to improve interfacial bonding strength and enhance corrosion resistance while maintaining mechanical integrity will also be elaborated on. Additionally, fundamental mechanism of laser hybrid techniques will be discussed to explore their capabilities for practical applications.

Volumetric 3D Printing of Functional Devices: Process Control and Measurements

Gemin Chen, Shuai Peng, Mingdao Li, Jinya Sun, Yu Liu

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Abstract

Volumetric 3D printing can implement fast building of full – body bypassing layer – by – layer construction, therefore providing very high potential in fabrication of complex electronics and optics without support design. In this presentation, we will report our progress in development of automated, high precision volumetric 3D printing technique with focus on process control and measurement, which are demonstrating its competence in manufacturing superlens, flexible gel electronics, and bionic structures. This presentation is organized in detail with the new process design, smart process monitoring, feedback control. Several attracting application demons will be given and strategics behind will be shared.

Evolution and cracking inhibition of liquid film in laser cladding of non-weldable nickel-based superalloy

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Abstract

Liquation cracking is a defect based on the liquid film in the grain boundaries. In this study, the liquation cracking in the laser cladding of a non-weldable nickel-based K447A superalloy is researched, including the liquid film evolution behavior in the base metal, the liquation cracking criterion, and the control of liquation cracking. The results show that the liquid film originates from the Ni₂₁Hf₈ phase with an incipient temperature of ~1120°C. The liquid film is produced with successively γ /Ni₂₁Hf₈ eutectic liquation, Cr₅B₃ dissolution, and γ / γ' eutectic liquation. The criterion of liquid film cracking is established and the liquid film is satisfied with the condition of will result in cracking. Shot peening has a significant effect on inhibiting liquation cracking and recrystallization appears in the heat-affected zone during the heating process of laser cladding, and finally liquid network forms. The liquid network and thinner liquid film make the driving strain on the liquid film smaller and the critical strain of liquid film cracking bigger, as a result, liquation cracking is inhibited completely.

Keywords

Additive Manufacturing; Liquation cracking; Non-weldable alloy; Liquid film evolution; Recrystallization.

Design of shape memory alloy and maraging steel for additive manufacturing via in-situ alloying

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Abstract

In-situ alloying apporach was sucessfully employed for new alloy developepment for additive manufacturing (AM). A novel high entropy shape memory alloy (HESMA) was developed using laser powder bed fusion (LPBF) by introducing a moderate amount of silicon (10 % atomic percent) to a metastable high entropy alloy matrix. Multi-remelting strategy was employed to improve the chemical homogeneity of the printed HESMA with enhanced diffusion occurring during the remelt scan. The 3-remelting HESMA exhibited a near uniform chemical distribution, showcasing an excellent combination of shape memory performance and mechanical properties, with an admirable recoverable strain of 5.2 % and a high yield strength of about 500 MPa. In addition, a novel maraging steel was designed through in-situ alloying during laser-directed energy deposition (LDED), combined with processing parameters adjustment, to improve the intrinsic heat treatment (IHT) effect of AM. Based on the initial 18Ni300 maraging steel, an interlayer dwell time of 120 s was introduced to cool the deposited sample into a martensitic state, thereby facilitating subsequent ageing reaction in the martensitic matrix during the following LDED process. Thereafter, titanium was added to 18Ni300 to accelerate the precipitation kinetics of the nano-Ni Ti precipitates during IHT. Consequently, the ultimate strength of the IHTed maraging steel was improved from 1201 MPa (18Ni300) to 1546 MPa (18Ni–4Ni), rising by 28.7% and without sacrificing ductility.

Keywords: Additive manufacturing; 4D printing; High entropy shape memory alloy; Maraging steel; Intrinsic heat treatment.

Fabrication and Characterization of Microelectrode Arrays via Aerosol Jet Printed Gold Micro-Pillars

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Abstract

Aerosol Jet Printing (AJP) technology has emerged as a revolutionary additive manufacturing technique, demonstrating significant advantages in electronics and biosensor fabrication. This technology overcomes limitations of conventional printing processes, achieving submicron-scale resolution (10-20 μm) for precise patterning and enabling direct printing on flexible, curved, and three-dimensional substrates, providing crucial technical support for innovative biomedical device design. Our study employed non-toxic, biocompatible gold nanoparticle inks to achieve a paradigm shift from traditional 2D circuitry to 3D pillar structures in biosensor manufacturing via AJP technology. Through systematic optimization of critical process parameters including ink formulation, the ratio of the sheath gas flow rate to the carrier gas flow rate, printing speed, and substrate temperature, we successfully fabricated micropillar arrays with excellent morphology and electrical properties. The research comprehensively investigated the formation of gold micropillars under various process parameters, ink dilution, and print parameters. The experimental results revealed that optimized process parameters significantly enhanced pillar height consistency and material deposition quality, with minimal overspray which helps in achieving high density pillar array. Biosensor samples fabricated using the optimized process were validated through electrochemical characterization, demonstrating excellent electrochemical response characteristics and detection sensitivity. Collectively, this study provides important theoretical foundation and technical reference for the industrialization of AJP technology in biosensor applications, advancing innovative development of additive manufacturing in biomedical engineering.

Development of a 3D-Printable Compact Static Mixer for In-Situ Silicone 3D Printing and Validation via Mechanical Testing

Hirusha Madhuwantha Loku Hettige, Thileepan Stalin, Pablo Valdivia y Alvarado

Singapore University of Technology and Design (SUTD)

Abstract

Silicone, a widely used polymer in healthcare, soft robotics, and flexible electronics due to biocompatibility, temperature resistance, and mechanical resilience. However, 3D printing Silicone is hindered by practical challenges, including the need for large mixing equipment, multi-part pre-mixing, dynamic viscosity changes, and risk of curing. This study presents a compact, 3D-printable static mixer designed for in-situ mixing of two-part silicone formulations immediately prior to extrusion. The device is optimized for integration with syringe-based silicone extrusion systems, with the aim of minimizing pre-processing time, reducing material waste, and conserving build volume. To evaluate the mixer's mixing performance, tensile characterization of dog-bone specimens using both in-situ mixed and thinky-mixed sample silicones was tested. Mechanical properties—including ultimate tensile strength, elongation modulus, and toughness—were compared across sample sets. Results indicated that in-situ mixed specimens cured fully and achieved mechanical properties comparable to pre-mixed controls. Specifically, ultimate tensile strength increased by 9%; elongation modulus increased by 21.8%; and toughness increased by 54.8% relative to high-speed, thinky-mixed samples. No visual signs of phase separation or incomplete curing were observed, supporting the mixer's efficacy in achieving sufficient homogeneity for mechanical reliability. These findings demonstrate that in-situ mixing via a compact static mixer is a viable approach for applications where maximal homogeneity is not critical. This enables a simplified, low-cost 3D-printable mixer suitable for prototyping, academic labs, and constrained manufacturing environments, thereby expanding accessibility to silicone-based 3D printing.

Improved Strength and Ductility in Novel Metamaterials Additively Manufactured using Laser Sheet Fusion

Changquang Lai

Abstract

The advent of metal additive manufacturing has revolutionized metalworking and enabled the rapid prototyping of metal parts. However, market penetration of metal additive manufacturing techniques remains bogged down by high equipment and operating costs, as well as the brittleness of prints, which typically rely on powder-based precursors. To circumvent these limitations, my team and I have turned to the use of metal foil precursors, which are self-supporting and have inherent mechanical integrity in the in-plane directions. By adjusting the laser parameters used to weld the metal foils, we show how distinct sets of mechanical properties can be generated from the same metallic composition. Synthesizing these different properties side-by-side in an isostrain arrangement, we further demonstrate that these novel "metamaterials" can exhibit enhanced strength and ductility beyond those achieved with other manufacturing techniques.

Alveolar bone repair of rhesus monkeys by using BMP-2 gene and MSCs loaded three-dimensional printed bioglass scaffold

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Abstract

Background and purpose: Over the past years, the study of bone tissue engineering in the field of regenerative medicine has been the main research topic. Using a three-dimensional (3D) porous degradable scaffold complexed with mesenchymal stem cells (MSCs) and growth factor genes to improve bone tissue repair and regeneration has raised much interest. This study mainly evaluated the osteogenesis of alveolar bone defects of animals in the following experimental groups: sham-operated (SO), 3D printed bioglass (3D-BG), 3D-BG with BMP-2 gene loaded CS (3D-BG+BMP/CS), and 3D-BG with rhesus marrow bone MSCs and BMP/CS (3D-BG+BMP/CS+rBMSCs).

Methods: Simulated human bone defects with the critical size of 10×10×5mm were established in primates - rhesus monkeys, and in vivo osteogenesis was characterized by X-ray, micro-Computed Tomography, and histology.

Conclusions: Our results revealed that 3D-BG+rBMSCs+BMP/CS scaffold could improve bone healing best by showing its promote osteogenic properties in vivo. Considering the great bone repair capacity of 3D-BG+BMP/CS+rBMSCs in humanoid primate rhesus monkeys, it could be a promising therapeutic strategy for surgery trauma or accidents, especially for alveolar bones defects.

Electrospinning Mass Production of Functional Flexible Nanofibrous Membranes

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University of Technology

Abstract

Nanoparticles and membrane technologies have been extensively developed for applications in fields such as sensing interface enhancement, photoelectric interface optimization, pollution purification, and antibacterial surfaces. In response to the growing demand for advanced manufacturing in these areas, electrospinning direct writing (EDW) offers a promising route for the scalable fabrication of functional nanofibrous membranes. This presentation provides a comprehensive overview of recent research focused on the jet dynamics and electrical characteristics in EDW, the development of control systems, precise positioning strategies for micro/nanostructure deposition, modulation using external fields, formation of three-dimensional architectures, and the integration of functional devices. Special emphasis is placed on the control strategies and scalable implementation of high-precision EDW techniques for the mass production of flexible nanofibrous membranes with enhanced performance across diverse application domains.

Key words: Electrospinning Direct Writing (EDW), Flexible Nanofibrous Membranes, Mass Production

Additively Manufactured Architected Materials with Unprecedented Mechanical Performance and Functional Integration

Zhendong Li, Zichao Guo

Central South University

Abstract

Additive manufacturing (AM) enables architected materials with exceptional mechanical performance and tailored multi-functionality. This study designs and fabricates lattice structures that are mechanically robust while exhibiting tunable acousto-mechanical coupling—serving both structural and acoustic roles. Topology-driven design optimizes strut geometry, connectivity, and material distribution using AM techniques (DLP, LPBF) for strong mechanical integrity. Within this backbone, resonant features like Helmholtz cavities and quarter-wave channels embed acoustic functionality for sound absorption without weakening the structure. Acousto-mechanical coupling strategies are classified as weak or strong. Weak coupling integrates sound absorbers (e.g., MPPs) 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 exhibiting synergistic behaviors under load or excitation. Beyond acousto-mechanics, the AM framework accommodates other functions like vibration damping and thermal regulation. Using hierarchical architectures, biomimetics, and material-efficient layouts, AM facilitates truly multifunctional materials. These systems mark a step-change where mechanical excellence coexists with functional adaptability.

POSTERS

PRESENTERS

Abstract ID	Author Names	Abstract Title
0023	Mr Koya Ogura	Data-driven design for additive manufacturing of cellular-structured heat sinks with mirror symmetry
0032	Mr Kairi Aoyama	Machine learning aided importance analysis of material properties and laser conditions on solidification conditions during laser powder bed fusion
0033	Mr Hiroki Oka	Development of hierarchical porous Cu through annealing and selective etching of laser additively manufactured Cu-Al alloys
0034	Ms Jiayi Zhang	Exploring Time-Series Foundation Models for In Situ Monitoring in Metal Additive Manufacturing
0035	Mr Kazuki Nakamura	Controlling retention/decomposition of carbon fibers in Al toward local control of thermal conductivity through laser powder bed fusion
0043	Ms Yurino Osaki	Joint Strength of Resin/Al-Si Alloy Joints via Periodic and Graded 3D Interface Structures Controlled by Additive Manufacturing
0048	Ms Nguyen Bao Lam	3D printing of membrane support: Effect of support properties on the membrane characteristics and its implications on the wetting resistance during vacuum membrane distillation
0061	Mr Cherq Chua	Influence of Thermal History on Grain Structure in LPBF-Processed Scalmalloy: A Numerical Simulation Study
0065	Mr Zihan Zhang	Fatigue Life Assessment of Additively Manufactured Alloys: A Probabilistic Approach Using Weibull Distribution
0068	Wu Zicheng	Fatigue Characterization and XCT Defect Analysis of PBF Inconel 718 Specimens
0074	Dr Jingjing Wang	A brief review of fatigue behavior of metal binder jet processed metals
0078	Zhengnan Sun	Leaf-Inspired Hierarchical Structures for Enhanced Droplet-Based Energy Harvesting via Additive Manufacturing
0086	Dr Nathaniel Hendrik	Sustainable food structuring through additive manufacturing: Reintegrating soy fiber into high-protein soy products
0087	Mr Che-Wei Chang	Effects of adding different elements on Al-Cu alloy

0091	Dr Noel Quah Tan Kai	The Evolving Landscape of Wire Arc Additive Manufacturing – Fatigue Performance, Sustainability, Automation, and Hybrid Manufacturing.
0096	Mr Minjong Kim	Improvement of density using Subpressure-Driven Soft Deformation method for Material Extrusion based additively manufactured High-Entropy Alloys
0102	Dr Viraj Muthugala	Development of a Docking Mechanism for Reconfigurable Modular Robots Using Additive Manufacturing
0103	Dr S. M. Bhagya P. Samarakoon	Additive Manufacturing for False Ceiling Inspection Robot: FalconX
0156	Bozhi Hou	Biomechanical Evaluation of 3D-Printed Mandible Model by Using Polyurethane
234	Xuanlai Chen	In-Situ Alloying of Titanium Nitride Nanoparticles via Laser Powder Bed Fusion for Fabricating High-Strength, Ductile Titanium Alloys
235	Mr Yanpei Dang	Printed SiBCN microstructures for harsh environments
0260	Mr Desheng Liu	Slippery Hydrogel Bionic Soft Tissue and Organ Phantoms
0265	Dr Bangheng Liu	Innovative Biomaterials for Immune Organ Reconstruction and In Vitro Tertiary Lymphatic Structures Modeling
0270	Mr Chen Yang	Mitigating microstructural heterogeneity in laser directed energy deposition Ni-based superalloys by heat accumulation in-situ heat treatment
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POSTER ABSTRACTS

Data-driven design for additive manufacturing of cellular-structured heat sinks with mirror symmetry

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Abstract

Heat sinks dissipate heat generated by electric devices, extending their life. Conventional manufacturing processes of heat sinks have limited the manufacturable shapes to fins or pins. Additive manufacturing (AM) has expanded the freedom of manufacturable shapes. For example, lattice or cellular structures have a high specific surface area, enhancing the heat transfer at the solid/fluid interface. However, a high specific surface area increases pressure loss, hindering efficient fluid supply to heat sinks. Cellular structures that balance high heat transfer rates and low-pressure loss need to be designed. Recently, we have proposed a design methodology based on the Voronoi tessellation and machine learning. The Voronoi tessellation designs cellular structures by drawing perpendicular bisecting planes between arbitrarily arranged seed points in a design space and replacing the plane edges with solid struts. A neural network model predicts the heat transfer rate and pressure loss from the coordinates of seed points and strut radius. A genetic algorithm inversely analyzes the neural network model to optimize the coordinates of seed points and strut radius. As a result, reliable optimized structures were obtained. However, all the optimized structures have irregular shapes due to a low probability of regularly arranging seed points. In this study, cellular structures with a mirror-symmetrical plane were designed by the Voronoi tessellation, and their heat transfer rate and pressure loss were evaluated by computational fluid dynamics (CFD). Some mirror-symmetrical structures exhibited a good balance of high heat transfer rate and low-pressure loss compared to irregular structures. To clarify the reason, the cellular structures were described by eleven structural features, followed by dimensional reduction using principal component analysis. Although introducing mirror symmetry limits the design freedom, the diversity of structures in the structural feature space was expanded, presumably leading to a good balance of high-heat transfer rate and low-pressure loss.

Machine learning aided importance analysis of material properties and laser conditions on solidification conditions during laser powder bed fusion

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Abstract

Laser powder bed fusion (L-PBF) is a process of fabricating complex-shaped components by repeating metal powder bedding and laser irradiation. Recently, thermal conduction and fluid dynamics simulations during laser irradiation have been developed to understand the temperature fields and solidification conditions during the L-PBF process. To achieve realistic simulations, multi-physics models treating various phenomena including thermal conduction, melting/solidification, fluid flow, and evaporation have been established. As a result, it is difficult to understand the effect of material properties and laser conditions on the thermal fields and solidification conditions. To solve this problem, a data-driven approach is proposed in this study. Simulated data is used to train a machine learning model to correlate the material properties and laser conditions with temperature fields and solidification conditions. Importance analysis methods are applied to the machine learning model to clarify the effect of material properties and laser conditions on temperature fields and solidification conditions. To verify this approach, we performed simulations assuming a moving heat source model with a Gaussian energy distribution. Material properties (thermal conductivity, specific heat, melting point) and heat source conditions (power, scanning speed, spot diameter) were randomly varied in five 500 combinations to obtain solidification conditions (cooling rate, solidification rate, temperature gradient). The data was trained to a neural network to correlate the material properties and heat source conditions with the solidification conditions. Then, Shapley additive explanation (SHAP) analyses were applied to the neural network model to interpret the effect of material properties and heat source conditions on the solidification conditions. As a result, it was clarified that thermal conductivity, melting temperature, and scan speed significantly affected the cooling rate, melting temperature, scan speed, and power affected the thermal gradient, and thermal conductivity, scan speed, and power significantly affected the solidification rate.

Development of hierarchical porous Cu through annealing and selective etching of laser additively manufactured Cu-Al alloys

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Abstract

Additive manufacturing enables the fabrication of complex-shaped metallic parts (e.g., lattice structures) with a high specific surface area. The surface can be utilized for various functionalities including catalytic performance or hydrophilicity by introducing nanoscale structures such as pores on the surfaces. In this study, we aim to fabricate hierarchical porous Cu with millimeter-, micrometer-, and nanometer-scale pores through laser powder bed fusion (L-PBF) of lattice-structured Cu-Al alloys and subsequent selective etching (annealing/etching). Annealing controls the morphology of α -Al/CuAl₂ two-phase microstructure, and etching removes Al from α -Al and CuAl₂ to form micro- and nano-scale pores. The objective of this study is to clarify suitable Al compositions for fabricating hierarchical porous Cu.

Cu-70 mol%Al alloys were fabricated by L-PBF method under 25 laser conditions. In addition, to efficiently clarify the suitable Al compositions, Cu-X mol%Al (X=70, 75, 78, 80) alloys were made by casting, and subsequent single laser scan to simulate rapid solidification of L-PBF method. These samples were then annealed to investigate changes in microstructure as a function of annealing temperature and time. Al was removed by etching the annealed samples using an HCl solution. L-PBF-built Cu-70 mol%Al alloys had submicron-order fine lamellar structures. In addition, a lattice structure could be fabricated, demonstrating the L-PBF formability of Cu-Al alloys. When the L-PBF-built and single-laser scanned Cu-70 mol%Al alloys were annealed, the lamellar structure changed to a morphology in which the α -Al phase was spherically isolated in the CuAl₂ phase. In contrast, Cu-80 mol%Al alloys showed continuous CuAl₂ and α -Al phases, after annealing. Chemical etching of an annealed Cu-80 mol%Al alloy imparted micro-scale connecting pores formed by the removal of the α -Al phase and nanoscale pores formed on the inner walls. These results indicate that Cu-80 mol%Al is a suitable composition to form a hierarchical structure with open pores.

Exploring Time-Series Foundation Models for In Situ Monitoring in Metal Additive Manufacturing

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Abstract

Metal additive manufacturing (MAM) offers advantages such as material efficiency, customization, rapid prototyping, and the ability to produce complex geometries. However, challenges in reliability and consistent quality hinder its broader industrial adoption, highlighting the need for robust quality assurance mechanisms. Traditional machine learning (ML)-based in situ monitoring (ISM) essentially detects existing defects but is hindered by inadequate generalization ability and low training efficiency. Motivated by recent advancements in time-series foundation models for general time-series analysis, this study novelly explores time-series foundation models for ISM in MAM to address these issues. Three representative time-series foundation models are employed across two ISM datasets with different sensor data and processes. Through fine-tuning, we demonstrated strong generalizability and competitive performance with minimal training and compact input data. Compared to state-of-the-art models, our approach offers efficient training and enhanced generalizability. Our contributions include leveraging time-series foundation models in MAM ISM, addressing key challenges in traditional ML-based ISM, and demonstrating efficient results across tasks and datasets. This work paves the way for adopting time-series foundation models for ISM in MAM, making a significant contribution to advance innovative ML applications in the domain.

Controlling retention/decomposition of carbon fibers in Al toward local control of thermal conductivity through laser powder bed fusion

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Abstract

It is expected that selective heat transfer can be achieved by creating Al/carbon fiber (CF) composites with high thermal conductivity at heat transfer parts and creating Al/Al₄C₃ composites with low thermal conductivity around Al/CF composite parts to prevent heat dissipation. Laser powder bed fusion, which is one of the common additive manufacturing processes, is a promising process for locally controlling the microstructure by tailoring laser conditions. However, the high reactivity of Al and CFs hinders the fabrication of Al/CF composites by tailoring laser conditions. In this study, we coated TiC with various thicknesses on CFs to control the interfacial reaction between Al and CFs during laser irradiation. Al/CF and Al/CF-TiC powder mixtures were irradiated with a single laser scan to demonstrate the controllability of Al/CF and Al/Al₄C₃ composite microstructure through laser conditions. CF was coated with TiC by heating mixtures of CF, Ti, and chlorides at 850 to 1050°C for 3.6 ks. Al powder was mixed with CF or TiC-coated CF (CF-TiC). The powder mixture was laid on a compact made from the same powder mixture and irradiated with a laser. Laser power was varied from 100 to 500 W while laser scan speed was fixed at 50 mm/s. The TiC coating thickness was controlled in the range of 0.18 to 2.5 μm by changing the ratio of CF to Ti. When the Al/CF powder mixture was irradiated with a laser, the powder mixture was not melted, or the CF was transformed into Al₄C₃, demonstrating the difficulty in fabricating an Al/CF composite. When the Al/CF-TiC powder mixture was irradiated with 200 W laser, CFs were mostly retained. When the laser power was increased to 400 W, the CF was transformed into Al₄C₃. Thus, TiC coating enabled the fabrication of both Al/CF and Al/Al₄C₃ composites through laser conditions.

Joint Strength of Resin/Al-Si Alloy Joints via Periodic and Graded 3D Interface Structures Controlled by Additive Manufacturing

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Abstract

In recent years, the reduction of CO2 emissions has become a global issue, and in the field of transportation vehicles, weight reduction is essential. To address this, multi-material structures are being developed, in which various lightweight materials are placed in optimal locations. Consequently, the development of dissimilar material joining technology with long-term reliability and joint strength is crucial for these applications. Our research group has been working on joining metals and resins based on mechanical interlocking via three-dimensional (3D) interface structures. This structure provides 3D mechanical interlocking between metals and resins, reducing the load on individual interlocking points and enhancing resistance to external forces. In this study, to clarify the desirable 3D structure for improving joint strength, the designed 3D lattice structures were fabricated on a metal substrate using Al-12% Si (mass%) alloy powder by laser powder bed fusion, followed by the fabrication of a joint with an ultraviolet curable resin. The basic 3D structure was cubic and body-centered cubic (BCC) lattices, with the number of lattice layers and lattice porosity as structural parameters. Furthermore, a few models with three layers of graded porosity from the substrate were also prepared. The joint strength and fracture behavior of the joints were then evaluated and observed. In addition, the finite element method (FEM) was used to analyze stress distributions in the joints. The simulation results were compared with experiments to clarify the dominant factors influencing joint strength. As a result, the joint strength increased as the number of layers increased from 0 to 3, but remained constant beyond 3 layers. The FEM simulation showed that maximum principal stress was relaxed with increasing the number of layers, presumably enhancing the joint strength. Additionally, the strength of joints with a graded porosity was higher than that with a uniform porosity.

3D printing of membrane support: Effect of support properties on the membrane characteristics and its implications on the wetting resistance during vacuum membrane distillation

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Abstract

Vacuum membrane distillation (VMD) technology is a promising membrane separation process for seawater desalination, wastewater treatment, and resource recovery due to its compatibility to renewable energy, commercial viability and thermal efficiency. However, a major limitation of VMD is the liability to membrane wetting. One strategy to improve the wetting resistance is through reducing the pore diameter of the membrane, which helps to increase the liquid entry pressure (LEP). Most of the research into VMD membranes centres around tailoring and fabricating the membrane active layer. The optimized properties of the support layer have yet been thoroughly explored. The support layer helps reduce membrane compaction, conserves the pore structures and deter the shrinkage of the active layer. However, there is a lack of research into how varying the pore size and porosity of the support influences the resulting membrane characteristics and VMD performance, as the conventional non-woven support presents limited case for support structural variation. Thus, this research applies 3D printing to create support layer with tuneable pore size and porosity for subsequent fabrication of a PVDF-co-HFP membrane. A material extrusion 3D printer is used to print the polyamide supports of pore size from 60 to 180um. The result showed that as the support pore size decreases, the active layer pore size decreases and the contact angle slightly increases, leading to higher LEP. As the support porosity decreases, the flux decreases due to higher resistance. The rejection is greater than 99.99% for all membranes. The highest flux achieved by the 3D printed support is 4.71 l/m2h, over 65.8% improvement from the PET support. The membrane remains wetting resistant for during 35 hours tested.

Influence of Thermal History on Grain Structure in LPBF-Processed Scalmalloy: A Numerical Simulation Study.

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Abstract

The laser powder bed fusion (LPBF) of Scalmalloy, an Al-Mg-Sc-Zr alloy, has attracted significant interest in the aerospace and automotive industries due to its excellent printability and high-strength performance. These properties are primarily attributed to its unique bimodal grain structure, which comprises both fine equiaxed and coarse columnar grains. Previous studies have shown that the formation of this bimodal grain structure is governed by the precipitation of primary $Al_3(Sc,Zr)$ phases and the local thermal history during processing. In this work, a finite element method (FEM) numerical simulation model was developed to establish the relationship between thermal history and grain structure in LPBF-processed Scalmalloy. Single track samples were first fabricated using various laser power and scan speed combinations. The microstructural features, such as grain morphology and size, at different locations within each melt pools were then characterized and linked to the local thermal history predicted by the FEM simulation. This work provides insights into the thermal effects on microstructural evolution in LPBF-processed Scalmalloy, which could facilitate the development of novel scanning strategies for achieving enhanced microstructure control.

Fatigue Life Assessment of Additively Manufactured Alloys: A Probabilistic Approach Using Weibull Distribution

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Abstract

This study investigates the fatigue life variability of additively manufactured (AM) alloys, including IN718, IN625, Ti-6Al-4V, 316L, and AlSi10Mg, by analyzing the effects of surface roughness and internal defects through a Weibull statistical framework. X-ray computed tomography (XCT) and optical microscopy (OM) are employed to characterize defect morphology, including porosity, lack of fusion, and surface roughness parameters. Axial fatigue tests are conducted under controlled loading conditions to evaluate the fatigue performance of each material. The obtained fatigue life data are analyzed using a Weibull distribution model to quantify the reliability of fatigue behavior across different stress conditions. Furthermore, probabilistic stress-life (P-S-N) curves are constructed to estimate fatigue life distribution and provide a probabilistic assessment of failure risk under varying loading scenarios. By correlating Weibull parameters with defect characteristics and surface roughness, this study aims to establish a data-driven approach for assessing fatigue reliability in AM alloys. The analysis provides insights into how defect size, distribution, and surface features influence fatigue performance, which may guide the optimization of AM processing and post-processing techniques. The study also examines the influence of material composition on fatigue behavior, contributing to a broader understanding of fatigue performance in AM alloys. This research provides a quantitative framework for assessing fatigue reliability in AM components, with potential applications in aerospace, biomedical, and energy sectors where fatigue life prediction is critical.

Fatigue Characterization and XCT Defect Analysis of PBF Inconel 718 Specimens

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Abstract

Inconel 718 (IN718) is a high strength and thermal resistant Nickel-based alloy that is widely utilized in high-tech applications, such as aerospace, automotive and energy fields. Its good mechanical properties and high-temperature resistance make it a potential material in additive manufacturing (AM). Due to its short tool life and low productivity in machine operations, selective laser melting (SLM) has emerged as an effective method for complex parts. Even though SLM IN718 parts can reach a density exceeding 99%, defects such as lack of fusion (LoF) or gas pores still play a significant role in fatigue fracture. This piece of work investigates the tensile properties and fatigue behaviour of as-built SLM Inconel 718 specimens. A set of tensile specimens is prepared for tensile properties measurements while a batch of fatigue specimens is cut from building plate and is subjected for fatigue tests under uniaxial fatigue loading conditions. Additionally, the correlation between fatigue properties and fracture defect detected via laser microscopy is also explored. Results from the tensile tests indicate that SLM IN718 exhibits a yield strength of ~650 MPa and an ultimate tensile strength of ~950 MPa in the as-built condition, with an elongation of ~28%. Fatigue testing reveals a fatigue limit of ~350 MPa at about 10^7 cycles. Furthermore, defect detection and fracture surfaces combined with fatigue data are performed. The results suggest that with an increase in number of cycles to failure and a decrease in stress amplitude, the dominant fracture mechanism gradually shifts from internal defect-induced failure to sub surface- or surface roughness-induced failure due to reduced stress concentration at lower amplitudes. These key findings provide critical insights into mechanical performance and fracture mechanisms of IN718. This research contributes to optimizing the SLM IN718 design and reveals the potential of its application in high-tech fields.

Critical review of metal binder jet fatigue behavior and test results

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Abstract

The fatigue behavior of metal binder jet (MBJ) processed metals is critically reviewed. Majority of the fatigue failure is led by inherent pores within MBJ parts for different metals including 316L, 17-4PH, Inconel 625 and Ti6Al4V. Most of the existed pores shortened their fatigue life by escaping fatigue crack initiation stage more or less while short crack propagation stage becomes dominant. With higher work hardenability like 316L, fatigue strength however is less affected and even higher than selective laser melting (SLM) counterpart that holds higher tensile and yield strength. Post-process techniques such as hot isostatic pressing (HIP) removes majority of the pores while improvement of the fatigue behavior is dependent on individual materials and the microstructure after HIP as well. It was concluded that suitable post-processing technique such as HIP, heat treatment, etc. is usually necessary (with optimized processing condition) for improving fatigue property targeting for combined strength and ductility, but is material dependant, similarly as fatigue crack propagation rate, that is da/dN .

Keywords: metal binder jet, metals, fatigue behavior, post-processing

Leaf-Inspired Hierarchical Structures for Enhanced Droplet-Based Energy Harvesting via Additive Manufacturing

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Abstract

Inspired by the intricate structural motifs of natural leaves, a bioinspired droplet-based energy harvester is developed to achieve high-efficiency energy conversion from water droplets. Fabricated via fused deposition modeling (FDM) additive manufacturing, the device integrates a fluorinated ethylene propylene (FEP) film with a 3D-printed polycarbonate (PC) substrate functionalized with conductive silver paint. The hierarchical, leaf-like architecture, incorporating strategically designed air layers, enhances droplet spreading dynamics and interfacial interactions, significantly improving energy conversion efficiency. A highly efficient charge generation mechanism is triggered upon droplet bridging, while the optimized 3D framework facilitates seamless charge transfer and storage, minimizing energy dissipation. By synergizing biomimetic design principles with the precision of FDM 3D printing, this work demonstrates a scalable and sustainable approach to harvesting energy from water droplets. The results highlight the potential for applications such as raindrop energy conversion, offering a promising pathway toward advancing renewable energy technologies and addressing global energy sustainability challenges.

Sustainable food structuring through additive manufacturing: Reintegrating soy fiber into high-protein soy products

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Abstract

Advancements in three-dimensional printing (3DP) enable personalized nutrition with tailored textures and flavors, aligning with the demand for plant-based protein products. Soy protein isolate (SPI) offers strong nutritional and functional properties; however, its use as a sole bulking material often results in undesirable structural integrity and textural properties, necessitating the use of structuring additives. Hydrocolloids, are typically incorporated into formulations as flow modifier or binding agent, which are critical for achieving printability and shape fidelity in 3DP. This study explores 3DP as a rapid prototyping tool to evaluate soy fiber—a by-product derived from SPI processing and further refinement of soymilk sidestream of okara—as a natural structuring agent. Various ink formulations incorporating soy protein derivatives as bulk material, including milled soy extrudate and SPI, were tested alongside soy fiber and microcrystalline cellulose (MCC) as a model structuring agent to benchmark the structuring performance of soy fiber due to high purity of insoluble fibers. High shear achieved with a high-speed disperser facilitated interactions between proteins and fibers, enhancing ink stability. Rheological characterization using flow curves and viscoelastic parameters guided the selection of optimal 3DP parameters for an auger-based printhead, achieving shape fidelity exceeding 90%. Both formulations with MCC and soy fiber further improved shape fidelity to over 95% with increased compression force as measured by texture analysis, emphasizing the potential of soy fiber as natural ingredient substitute for structuring additives for 3D-printed soy-based products. This study highlights potential of 3DP in food processing as a tool to efficiently test different constituents using model systems, showcasing its capability to transform low-value byproducts like soy fiber into functional ingredients. The dual functionality of soy fiber as both a natural structuring agent and a nutritional enhancer in high-protein plant-based products further emphasizes its value in sustainable food innovation.

Effects of adding different elements on Al-Cu alloy

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Abstract

This study was divided into two main parts. The first part focuses on the relative density and mechanical properties of basic aluminum-copper alloy, while the second part discusses the mechanical properties and microstructure of the modified aluminum-copper alloy. Aluminum alloys are widely used in various industrial fields due to their high specific strength and high workability. Different alloy systems have been developed for different working environments in various industries by adding different elements to enhance alloy properties. Among them, aluminum-copper alloys, with their low cost, high specific strength, and high-temperature resistance, are currently being explored for applications in the automotive and aerospace industries. Additive Manufacturing is an emerging process that enables the production of fine and complex-shaped workpieces layer by layer. Compared with traditional casting processes, it allows for a reduction in post-processing. However, aluminum alloys in additive manufacturing often encounter issues such as hot cracking due to solidification shrinkage. These problems can be mitigated by adding impurity atoms, which act as heterogeneous nucleation sites in the molting pool, helping to reduce shrinkage and hot cracking during solidification. This experiment attempts to print aluminum-copper alloys using additive manufacturing. However, due to the low laser absorption rate of aluminum-copper alloys, severe hot cracking and porosity issues arise during solidification. To address these issues, different metal elements are added to the aluminum-copper alloy to form heterogeneous nucleation sites through metal particles, promoting grain refinement. Additionally, the formation of precipitates enhances the alloy through precipitation strengthening, further improving its strength. This study investigates the effects of adding different metal elements, compares the morphology and influence of different precipitates in the microstructure, and examines their relationship with the macroscopic mechanical properties.

The Evolving Landscape of Wire Arc Additive Manufacturing – Fatigue Performance, Sustainability, Automation, and Hybrid Manufacturing.

Quah Tan Kai Noel

Abstract

Wire Arc Additive Manufacturing (WAAM) has emerged as a cost-effective and scalable solution for Large-Format Additive Manufacturing (LFAM), with interests growing in sectors like aerospace, maritime, and energy. However, the widespread adoption of WAAM in structural and safety-critical applications remains hindered by several unresolved challenges, particularly in fatigue performance, process sustainability, automation limitations, and the need for hybrid manufacturing strategies to enhance final part quality. This review evaluates the recent advancements in these 4 key domains that highlights the importance of defect mitigation, surface engineering, real-time process monitoring, and lifecycle analysis. Recent studies have demonstrated that surface roughness from bead formation, combined with near-surface porosity and tensile residual stresses, accelerates crack initiation under cyclic loading. To mitigate this, researchers are exploring in-situ monitoring, defect classification using AI, and adaptive control strategies that dynamically adjust process parameters to enhance part quality in real-time. As a result, special emphasis is placed on fatigue-life prediction and crack propagation mechanisms in WAAM-produced materials, where surface roughness, residual stress fields, microstructural anisotropy, and volumetric defects collectively influence long-term performance. The paper also covers hybrid manufacturing approaches that combine WAAM with complementary processes, such as in-situ rolling for grain refinement, subtractive finishing for surface quality, and hybrid repair strategies that utilize WAAM for large-scale deposition followed by precision machining to maximize sustainability efforts to reduce carbon emissions. Collectively, these advancements form a roadmap towards reliable, first-time-right (FTR) manufacturing, envisioning WAAM to encompass a broad industrial adaptation for critical applications.

Improvement of density using Subpressure-Driven Soft Deformation method for Material Extrusion based additively manufactured High-Entropy Alloys

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Abstract

High-entropy alloys (HEAs) are alloys formed by mixing multiple elements in similar proportions, exhibiting superior strength and ductility compared to conventional alloys, along with excellent wear resistance and corrosion resistance. Due to these outstanding properties, HEAs have high potential for application in various high-performance industries such as aerospace, defense, and marine engineering. In this study, feedstock was prepared by mixing a polymer binder with CoCrFeNi HEA powder produced via gas atomization and in particular, CoCrFeNi HEA powder manufactured through a mechanical alloying process based on oxide powder (bead milling–spray drying–hydrogen reduction). The prepared feedstock was used for the material extrusion (MEX) based additive manufacturing method, followed by debinding and sintering.

Although the MEX process offers excellent geometric freedom, porosity formation and weak interlayer bonding can be major challenges during additive manufacturing process. To address these issues, we have applied subpressure-driven soft deformation technique to reduce porosity to improve its density in metal 3D printing. Through this approach, we aim to explore the potential changes in the microstructure and mechanical properties of the sintered structures fabricated via additive manufacturing.

This study investigates the applicability of the subpressure-driven soft deformation technique in HEA-based additive manufacturing and explores its potential for reducing porosity and improving mechanical properties. Furthermore, the mechanical alloying process based on oxide powder is considered to be low-carbon process with lower CO₂ emissions compared to gas atomization, making it a promising eco-friendly manufacturing approach. Through this research, we aim to enhance the quality of HEA-based additive manufacturing processes and expand their applications to industries.

Development of a Docking Mechanism for Reconfigurable Modular Robots Using Additive Manufacturing

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Abstract

Reconfigurable modular robots have gained significant scientific attention for their adaptability to various tasks. Assembling and disassembling are fundamental functions in reconfigurable modular robots, facilitated by a docking mechanism between robots. This work presents a novel genderless pin-hole docking mechanism manufactured using additive manufacturing. This docking mechanism consists of two pins, two holes, and a locking mechanism driven by a servo motor. During the docking process between two robots, the two pins of one robot align with the holes of another, and the locking mechanism secures the connection, ensuring a stable yet reconfigurable link.

The pin-hole mechanism and servo motor were securely fastened to the base plate, providing structural integrity and ease of integration. All three components were fabricated using fused deposition modeling (FDM) with Polylactic Acid (PLA) on a Prusa MK4 3D printer. The nozzle temperature was maintained at approximately 220°C, while the heated bed was kept at 60°C to prevent initial print failures. Both Polylactic Acid (PLA) and Polyethylene Terephthalate Glycol-Modified (PETG) were tested for fabrication. PLA produced optimal results, while PETG exhibited fine threading on the pin-hole interface, increasing friction and reducing fault tolerance. The PLA-printed docking mechanism demonstrated a smooth surface finish, enhancing fault tolerance and overall performance.

Mechanical properties of the PLA-printed mechanism, such as maximum displacement and strength, were analyzed using Finite Element Analysis (FEA) until a converging solution was obtained. The mechanism withstood up to 15 MPa of stress and exhibited a displacement of 0.0038 mm at maximum stress during the analysis. These results were further validated through real-world experiments using two robots. Overall, fused deposition modeling proved to be an effective method for developing an accurate and reliable docking mechanism for modular robots.

Additive Manufacturing for False Ceiling Inspection Robot: FalconX

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Abstract

The FalconX robot is a mobile false ceiling inspection robot that is used for inspecting interiors of concealed false ceilings often found in office buildings. FalconX is equipped with a camera for visual inspections, and rotary arms for leverage and self-righting in case it gets stuck or flipped over in the false ceiling. The robot's function thus minimizes fall risks for trained workers, while providing enhanced observation and accessibility to the interior of false ceilings. The FalconX robot has been successfully deployed in various settings such as presentation rooms, lift lobbies and hospital offices. The top casing for FalconX, along with the camera holder and the support wheels of the self-righting mechanism were produced using 3D-printing technologies. Wheel caps for the FalconX that prevent it from toppling to its side were also made using 3D-printing. Additive manufacturing enabled fast yet structurally stable (albeit non-load bearing) mechanical elements, allowing for rapid iterations of the top half of FalconX's casing. PLA plastic was used as the main material for 3D-printing the various covers for FalconX, given that it is a cheap and easy material for quick prototyping. The PLA plastic material also has minimal warping capability and is easy to use. Variations of the casing parts could be printed within a day for testing and iterating by use of a Prusa 3D-printer available inhouse for prototyping in the lab. The Prusa 3D-printer can print objects of up to 25 cm (W) x 21 cm (L) x 22cm (H), which is ideal for small prototyping creation such as the parts for FalconX. The rapid prototyping allowed the development team to effectively test out various camera and sensor types daily with quick printing for housing the various components snugly in their corresponding receptacle designs.

Biomechanical Evaluation of 3D-Printed Mandible Model by Using Polyurethane

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Abstract

Introduction:

Additive manufacturing has gained significant traction in the medical field, with applications in 3D-printed prosthetics, implants, and biological models. This study investigates the feasibility of a 3D-printed mandible model that mimics the biomechanical properties of the human mandible. By leveraging 3D printing technology, it is possible to fine-tune the anisotropy of polymers to align with the mechanical properties of cancellous bone.

Method:

Polyurethane (PU) was used as the material for the mandible elements, with a Gyroid infill pattern designed to achieve a tuneable porosity. Cube samples and a complete mandible model were printed using Stereolithography (SLA) technology. The anisotropic elastic modulus was evaluated through compression tests on the cube samples. The biomechanical response of the mandible model under biting forces was also assessed and compared to a finite element model with properties representative of the human mandible.

Results:

The compressive elastic modulus of the 3D-printed cube samples ranged from 80-250 MPa along the layer direction and 50-150 MPa along the printing direction. A comparison between the physical mandible model and the finite element model showed that the mechanical strain error in the marked regions was less than 15%.

Conclusion:

This study demonstrates that a tuneable 3D-printed PU mandibular model can effectively replicate the biomechanical properties of the human mandible, particularly its compressive elastic modulus anisotropy. In the future, this 3D-printed biological model holds potential as a fundamental biomechanical experimental platform for the development and study of mandibular implants and prosthetics.

In-Situ Alloying of Titanium Nitride Nanoparticles via Laser Powder Bed Fusion for Fabricating High-Strength, Ductile Titanium Alloys

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Abstract

Alpha-titanium is renowned for its exceptional ductility but has been overlooked due to its limited strength. Alloying with other elements is a common strategy to enhance its strength. Nitrogen, the most potent hardening element in titanium, has been neglected because its hardening effect typically results in a significant sacrifice of ductility. In this study, we integrate alloy design with additive manufacturing processes to demonstrate the utilization of nitrogen for achieving outstanding tensile properties. We employed two scales of TiN powder as a nitrogen source during in-situ alloying via laser powder bed fusion and discovered that the addition of micron-sized TiN (15-53 microns) resulted in leftover TiN particles in as-printed samples, which adversely affect ductility. Nonetheless, with the incorporation of nano-sized TiN powder (<100 nm), all nitrogen constituents manifest as interstitial nitrogen and distributed evenly. By incorporating compositional and process design, we achieved over a 60% improvement in yield strength with almost no loss of elongation in the titanium-nitrogen alloy. A systematic exploration of deformation mechanisms suggests that the incorporation of nitrogen significantly refines grains, inhibits variant selection, and activates more <c+a> dislocations, thereby synergistically strengthening the titanium-nitrogen alloys. These findings advance the development of solid solution-strengthened titanium alloys and provide novel insights for the exploration and creation of cost-effective, high-performance titanium alloy.

Printed SiBCN microstructures for harsh environments

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Abstract

Man-made microstructures have earned significant interest from researchers due to their various applications, including microlenses, microelectromechanical systems (MEMS), biochips, and photonic crystals. Many of these applications demand materials that offer excellent processability, mechanical strength, as well as thermal and chemical stability. While polymers are commonly used for fabricating microstructures, they often fall short in providing the necessary mechanical strength and stability in extreme environments characterized by high temperatures or corrosive substances. In such cases, polymer-derived ceramics (PDCs) present a promising solution. PDCs combine the ease of processing found in polymers with the robust mechanical strength and stability of ceramics, making them a superior choice for fabricating microstructures designed to withstand harsh conditions. This study presents a photosensitive precursor for SiBCN ceramics, notable for its high photosensitivity and ceramic yield of 76 wt.%. This is achieved through a nucleophilic addition reaction between polyborosilazane and 2-isocyanatoethyl acrylate. The composition and chemical structure of both the precursors and the resulting ceramics have been thoroughly characterized. Utilizing two-photon lithography followed by pyrolysis, this photosensitive precursor enables the direct fabrication of SiBCN microstructures with intricate geometries and submicron features, approximately 700 nm, marking the smallest SiBCN structures reported to date. On a microscopic scale, it has been observed that shrinkage during pyrolysis is anisotropic and dependent on surface area. The study also explores potential applications for these printed SiBCN microstructures, such as high-temperature embossing stamps for microlens production and structural-color fabrication. The finding can inspire the exploration of preceramic chemistries and open up opportunities for future development of lithography and additive manufacturing technologies in the field of PDCs.

Slippery Hydrogel Bionic Soft Tissue and Organ Phantoms

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Abstract

Compared with living organs, animals and clinical trials, tissue and organ phantoms with biomimetic three-dimensional structures have the advantages of low cost, ethics, and easy operation, yet still remains hither to unmet challenges in their fabrication such as vivid biological structures and the closed physicochemical characterizations. Hydrogels have been extensively adopted in tissue engineering, medical devices, and biological lubrication because of their well physical and chemical properties such as flexibility, viscoelasticity, and slipperiness with biological soft tissues. However, there are still some scientific and technical issues in slippery structured hydrogels, such as the difficulty in regulating mechanical properties and constructing biomimetic structures. Here to address, we develop vat photopolymerization three-dimensional (3D) printable slippery hydrogels with the tailorable modulus that can widely match the mechanical properties of different biological soft tissues by harnessing micro-scale molecular regulation strategies such as dual network structure and hydrogen bond network. And meanwhile, a variety of slippery hydrogel-based bionic soft tissue and organ phantoms with similar structures and morphologies as well as suitable mechanical properties to biological soft tissues were constructed, such as heart, liver, kidney, intestine, lung, brain tissue, and vascular networks. Proof-of-concept 3D printed slippery hydrogel organ phantoms, a 3D printed human brain phantom with the tortuous cerebral arteries and lubricating characters was used to serve as an effective neurosurgical training platform for realistic simulation of endovascular interventions. These biomechanically adapted biomimetic high-precision slippery hydrogel soft tissue and organ phantoms have potential applications in the fields of surgical training, medical device testing, and organ-on-a-chip.

Mitigating microstructural heterogeneity in laser-directed energy deposition Ni-based superalloys by heat accumulation in-situ heat treatment

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Abstract

The microstructure and mechanical properties of additively manufactured (AM) components often exhibit inherent heterogeneity due to their complex thermal histories. Building on conventional heat treatment strategies to mitigate microstructural heterogeneity, this study employed a continuous laser forming method coupled with enhanced heat accumulation and the resulting in-situ heat treatment (IHT) to homogenize AM DD98m samples. Results demonstrate that heat accumulation stabilizes cooling rates at ~65 K/s and maintains primary dendrite arm spacing (PDAS) at ~55 μm. By promoting solid-state elemental diffusion, IHT significantly reduces elemental segregation, leading to extensive dissolution of γ-γ' eutectic phases. Due to the IHT, the γ' phase exhibits consistent volume fractions and comparable precipitate size distribution across specimens, yielding relatively homogeneous microhardness throughout the samples. Notably, the layered γ' phase, previously underexplored in literature, is attributed to IHT-induced local Ostwald ripening, driven by aluminum (Al) diffusion gradients. This work successfully utilizes IHT to control solid-state phase transformations, thereby reducing AM component heterogeneity. The findings advance strategies for tailoring microstructural uniformity in additive manufacturing, offering a novel pathway to mitigate microstructural heterogeneity in superalloys.

The optimization of Processing and Post - treatment for Laser Powder Bed Fusion of Zirconium - Niobium Alloy

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State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences

Abstract

Owing to its excellent biocompatibility and low magnetism, the Zr-2.5Nb alloy has been widely used in the medical field. Additive manufacturing (AM), as a layer-by-layer manufacturing method, is capable of fabricating complex structures to meet individual requirements that traditional manufacturing methods fail to achieve. This study investigates the effects of processing parameters and annealing temperature on the microstructure and properties of additively manufactured Zr-2.5Nb alloy. Under optimized parameters, the relative density reaches 99.22%, with the matrix mainly composed of fine acicular α' martensite. As laser power increases, α' martensite gradually transforms into α and β phases. The tensile strength decreases while elongation first increases and then decreases with rising laser power. The maximum tensile strength is 979.63 MPa and the maximum elongation is 14.18%. Heat treatment results show that from 550°C to 950°C, the microstructure undergoes an $\alpha' \rightarrow \alpha + \beta \rightarrow \alpha W$ transition. The formation of αW significantly reduces corrosion resistance, but annealing at 650°C–750°C can mitigate this reduction. Compared to the as-built samples, annealing increases the elongation of additively manufactured Zr-2.5Nb by over 100%, reaching 30%–32.64%, while maintaining a tensile strength of 670 MPa. The study shows that combining laser powder bed fusion and heat treatment can significantly enhance the mechanical properties of Zr-2.5Nb alloy, offering a new material processing technology for personalized implant device development in the medical field.

Optical Coherence Tomography Angiography Enhanced 3D Bioprinted Perfusion Platform for Vascularized Microtissue Dynamics

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Hangzhou Dianzi University

Abstract

In vascularized tissue engineering, the construction of functional tissues relies not only on the fabrication of complex biological structures, but also on the precise regulation and real-time monitoring of internal microfluidic environments. However, existing imaging approaches often fail to simultaneously achieve high spatial resolution, wide flow velocity range, and dynamic observation, posing a critical bottleneck to tissue maturation and functional reconstruction. To address this challenge, we developed a perfusion culture platform integrated with Optical Coherence Tomography Angiography (OCTA) and proposed a Complex Correlation Difference (CCd-OCTA) algorithm. By adaptively adjusting scan time intervals and scanning modes, the system can accurately measures flow velocities ranging from 0 to 600 mm/s. Using sacrificial-material-assisted multi-nozzle extrusion-based 3D bioprinter, vascular-mimicking scaffolds containing human hepatocellular carcinoma cell line C3A were fabricated in situ within PDMS-based microfluidic chips, forming perfusable and structurally complex microtissue constructs. The integrated OCT system enabled real-time 3D visualization of both tissue architecture and flow distribution within the chip. Flow measurements obtained via CCd-OCTA showed minor deviations from ideal CFD simulations, but matched closely with CFD results based on reconstructed geometries, demonstrating high measurement fidelity. Moreover, dynamic perfusion culture was assessed using OCT and confocal microscopy, revealing significantly increased viable cell number and volume under perfused conditions, particularly near flow channels. This work establishes a comprehensive workflow combining imaging, modeling, and bioprinting, offering a powerful tool for perfusion regulation and flow optimization in microfluidic tissue models. It holds significant potential for advancing long-term dynamic culture and the development of functional engineered tissues.

WAAM toolpath print geometry prediction based on trapezoidal bead model

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Abstract

Wire arc additive manufacturing (WAAM) relies on reliable and accurate layer by layer deposition to create a part. Toolpath strategies (contour, raster, zig-zag , etc..) and parameters (bead width, raster angle, etc...) are often chosen to ensure the printed layer can have a flat top surface while minimizing deviations from the desired layer's print geometry. These selections are influenced by feedback from experimental prints, simulation results or one's prior experience. However, experimental prints takes time and consume resources, while simulation techniques available for WAAM are physics based and take a long time to compute. Thus, we propose a low fidelity simulation approach through the use of trapezoidal bead model to predict the resulting printed geometry for a given toolpath. This provides a fast approach to evaluate the effectiveness of toolpath strategies and parameters in achieving the desired print geometry. To verify the effectiveness of the trapezoid bead model, experiments were conducted on a variety of print geometry and their error compared to the model prediction which shows reasonable accuracy.

Rapid Design and Manufacture of Low-Frequency Acoustic Absorption Metamaterials with Enhanced Coupling Characteristic

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Abstract

The current designs of low-frequency acoustic absorption metamaterials suffer from inadequate prediction accuracy and low efficiency. Herein, by integrating impedance theory with artificial neural networks, we propose an optimisation method of unit impedance correction (UIC). Meanwhile, a mutated honeycomb structure with teardrop-shaped apertures (MHSTA) fabricated by stereolithography is proposed, which can enhance the low-frequency coupling performance through rationally arranging the relative positions of the apertures. To verify prediction ability of the UIC method, the 50 mm-thickness typical structures of MHSTA are designed for two low-frequency ranges (220–500 Hz and 230–550 Hz). Compared with the simulation, the UIC result can reach the maximum relative error of 3.9% and the maximum absolute error of 0.033, which ensures the accurate prediction commendably. The experiment also demonstrates that the acoustic absorption coefficients are highly consist with the UIC result. This work provides a novel strategy of precise design for low-frequency acoustic absorption metamaterials.

Deformation mechanism of dislocation slip and kinking behavior in dynamic compression response of TiZrHfNb alloy fabricated by laser directed energy deposition

Chunjie Shen, Xu Cheng, Zhuo Li, Chen Yang, Yansong Zhang, Ruiqi Li

Beihang University

Abstract

In this study, the dynamic response and deformation mechanism of TiZrHfNb RHEA fabricated by laser directed energy deposition (L-DED) were researched under a dynamic compression test at a nominal strain rate of 3500s⁻¹. The L-DED TiZrHfNb alloy with columnar grains exhibits exceptional mechanical properties with a uniform dynamic flow stress of 1670±10 MPa and a maximum plastic strain of 0.28±0.03. The dislocation slipping and kinking behavior dominate uniform plastic deformation. Firstly, the dislocations are primarily confined within dislocation channels due to coplanar slip, and the evolution of them in dynamic compressive deformation process has undergone spacing refinement and crossing. Furthermore, the kinking behavior induced by the lattice rotation with the T=<011> axis denotes the work hardening effect. Particularly, the second kinking behavior effectively relieves local stress concentration and delays fracture before the formation of adiabatic shear band (ASB).

A Meta-Adapted Mixture of Experts Framework for Predicting Tensile Properties of Additively Manufactured Aluminum Alloys

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Abstract

Conventional models for predicting the tensile properties of additively manufactured (AM) aluminum alloys often struggle to capture the intricate cross-dependencies among alloy compositions, process parameters, and microstructural descriptors, resulting in limited generalization and interpretability. To overcome these challenges, we propose a novel predictive framework that integrates a meta-adapted mixture of experts (MoE) architecture with a multi-task self-attention decoder. In this approach, specialized expert subnetworks process chemical compositions, thermal histories, and elemental physicochemical attributes, while a meta-gating mechanism dynamically learns to allocate contributions, enabling adaptive tailoring to diverse alloy-process regimes. The unified decoder employs self-attention to jointly predict yield strength (YS), ultimate tensile strength (UTS), and elongation (El), effectively leveraging correlations among these mechanical properties. We evaluated the proposed model on a comprehensive dataset. Experimental results indicate the framework achieves superior accuracy with R² exceeding 0.93 for YS and UTS, alongside stable performance across different alloy families and processing methods. This hybrid architecture not only surpasses traditional ensemble and deep learning approaches but also offers interpretable insights via meta-gate analysis, facilitating targeted alloy optimization. Overall, our framework provides an advanced data-driven pathway to accelerate AM-specific alloy design while substantially reducing experimental costs.

Immunomodulation and promotion of bone regeneration by 3D printed HA/PCL scaffolds with different fiber orientation and HA content

Jiaxiang Song

Abstract

With the rise of bone tissue engineering (BET), 3D-printed HA/PCL scaffolds for bone defect repair have been extensively studied. However, little research has been conducted on the differences in osteogenic induction and regulation of macrophage (MPs) polarisation properties of HA/PCL scaffolds with different fibre orientations and HA content. Here, we applied 3D printing technology to prepare three sets of HA/PCL scaffolds with different fiber orientations (0-90, 0-90-135, and 0-90-45) and different HA contents (0, 20%, and 30%) to investigate the differences in physicochemical properties and to explore the effects of MPs and bone marrow mesenchymal stem cells (BMSCs) on the response of the scaffolds. The results showed that the multi-angle interlaced fibers affected the overall porosity and compressive strength of the scaffolds. The best compressive properties of the scaffolds were obtained when the HA content was 20%. Compared with others, the scaffolds in the 0-90-45 group and the 20% HA content group induced the osteogenic differentiation of BMSCs more significantly and promoted the polarization of MPs toward the M2 phenotype, forming an immune microenvironment favorable for osteogenesis. Unexpectedly, 0-90-45 scaffolds significantly upregulated the expression of angiogenic genes (PDGF, VEGF). Animal bone defect experiments demonstrated that the 3D printed HA/PCL scaffolds had the best immunomodulatory effects and promoted regeneration of bone and vascular tissues compared to other groups. In conclusion, this study is a step forward in exploring BET scaffolds and provides a very promising bone-filling material.

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