MetFoam2019

11th International Conference on Porous Metals and Metallic Foams

August 20–23, 2019

DoubleTree by Hilton Hotel • Dearborn, Michigan, USA

FINAL PROGRAM

SPONSORED BY: TMS

TMS Structural Materials Division, TMS Composite Materials Committee and, TMS Additive Manufacturing Committee.

www.tms.org/MetFoam2019

SCHEDULE OF EVENTS

Tuesday, August 20	Time	Location
Registration	6:00 PM - 8:30 PM	Great Room
Welcome Reception	7:00 PM - 8:30 PM	Dearborn/Southfield/Allen Park
Wednesday, August 21	**Time**	**Location**
Registration	7:00 AM - 5:30 PM	Great Room
Welcome	8:00 AM - 8:20 AM	Michigan
Exhibition Installation	8:00 AM - 10:00 AM	Great Room
Plenary Session	8:20 AM - 8:50 AM	Michigan
Technical Sessions	8:50 AM - 11:55 AM	See Technical Program
Break & Exhibit Viewing	10:10 AM - 10:35 AM	Great Room
Poster Installation	10:15 AM - 1:30 PM	Great Room
Lunch	11:55 AM - 1:30 PM	Superior
Technical Sessions	1:30 PM - 5:05 PM	See Technical Program
Break & Exhibit Viewing	3:10 PM - 3:30 PM	Great Room
Poster Session & Reception	5:30 PM - 7:00 PM	Great Room
MetFoam Committee Meeting	7:00 PM - 8:00 PM	Private
Thursday, August 22	**Time**	**Location**
Registration	7:00 AM - 5:30 PM	Great Room
Plenary Session	8:00 AM - 8:30 AM	Michigan
Technical Sessions	8:30 AM - 11:55 AM	See Technical Program
Break & Exhibit Viewing	10:10 AM - 10:35 AM	Great Room
Lunch	11:55 AM - 1:30 PM	Superior
Poster Dismantle	11:55 AM - 3:30 PM	Great Room
Technical Sessions	1:30 PM - 5:05 PM	See Technical Program
Break & Exhibit Viewing	3:10 PM - 3:30 PM	Great Room
Conference Dinner	5:30 PM - 7:00 PM	Superior
Friday, August 23	**Time**	**Location**
Registration	7:00 AM - 12:00 PM	Great Room
Plenary Session	8:00 AM - 8:30 AM	Michigan
Technical Sessions	8:30 AM - 11:15 AM	See Technical Program
Break & Exhibit Viewing	10:10 AM - 10:30 AM	Great Room
Exhibition Dismantle	10:30 AM - 11:55 AM	Great Room
Plenary Session	11:20 AM - 11:50 AM	Michigan
Concluding Comments	11:50 AM - 11:55 AM	Michigan
Lunch	11:55 AM - 1:30 PM	Superior

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* *Full abstracts included.*

On behalf of the MetFoam conference Steering Committee, the International Scientific Advisory Board, and the Minerals, Metals, & Materials Society (TMS) we are pleased to welcome you to the 11th International Conference on Porous Metals and Metallic Foams (MetFoam 2019).

These multifunctional materials continue to promise innovative solutions in key critical sectors including biomedical engineering, energy, nanotechnology, ground transportation, space and defense. Cutting-edge manufacturing techniques such as freeze casting, selective laser melting and 3D printing have recently been used in producing porous metals and metallic foams. This development is very likely to open new areas in terms of design and applications of these materials; it may also lead to reducing their cost. The study of the physics of making them as well as the effect of their manufacturing processes and structure on their properties has been on going over the past years. New mother metals such as magnesium have been investigated. Researchers have given considerable attention to combining metal foams with other materials to obtain salient properties and performance gain. We are very hopeful that we will witness mass production and serial applications of metal foams in the near future.

Building on the great success of the first ten International Conferences on Porous Metals and Metallic Foams, MetFoam 2019 will convene stakeholders—including researchers, educators, and engineers—to discuss the latest advances in the production methods, properties, and applications of these lightweight porous/cellular materials.

We look forward to an exciting meeting of outstanding speakers, interactive poster sessions, and dynamic discussions. Thank you for your participation in MetFoam 2019

Warmest Regards,

GENERAL CHAIR:

- **Nihad Dukhan**, University of Detroit Mercy, USA

STEERING COMMITTEE:

- **Olaf Andersen**, IFAM Dresden, Germany
- **John Banhart**, Institute of Applied Materials, Germany
- **David Dunand**, Northwestern University, USA
- **Bo-Young Hur**, Gyeongsang National University, South Korea
- **Louis-Philippe Lefebvre**, National Research Council, Canada
- **Hideo Nakajima**, The Wakasa Wan Energy Research Center, Japan
- **Afsaneh Rabiei**, North Carolina State University, USA
- **Franticek Simancík**, Institute of Materials & Machine Mechanics SAS, Slovakia
- **Hui-ping Tang**, State Key Laboratory of Porous Metal Materials, Northwest Institute for Nonferrous Metal Research, China
- **Dong-hui Yang**, Hohai University, China

INTERNATIONAL SCIENTIFIC ADVISORY BOARD:

- **Norbert Babcsán**, Aluinvent, Hungary
- **Joachim Baumeister**, Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung, Germany
- **Peng Cao**, The University of Auckland, New Zealand
- **Karen Chen-Wiegart**, Stony Brook University, USA
- **Dinc Erdeniz**, Northwestern University, USA
- **Francisco García-Moreno**, Helmholtz Zentrum Berlin, Germany
- **Thomas Hipke**, Fraunhofer IWU Chemnitz, Germany
- **Kamel Hooman**, The University of Queensland, Australia
- **Andrew Kennedy**, Lancaster University, United Kingdom
- **Carolin Körner**, Friedrich Alexander Universität Erlangen-Nürnberg, Germany
- **Yong Liu**, Central South University, China
- **Eric Maire**, Laboratory MATEIS - INSA LYON - Université de Lyon, France
- **Simone Mancin**, University of Padova, Italy
- **Manas Mukherjee**, Indian Institute of Technology Madras, India
- **Ashley Paz y Puente**, University of Cincinnati, USA
- **René Poss**, Evonik Resource Efficiency GmbH, Germany
- **Vladimir I. Shapovalov**, Materials and Electrochemical Research (MER) Corporation, USA
- **Shinsuke Suzuki**, Waseda University, Japan
- **Frederic Topin**, Polytech'Marseille Technopôle de Chateau Gombert, France
- **Lorenzo Valdevit**, University of California, Irvine, USA
- **Haydn Wadley**, University of Virginia, USA
- **Cuie Wen**, Royal Melbourne Institute of Technology University, Australia
- **Donghui Yang**, Hohai University, China
- **Yuyuan Zhao**, University of Liverpool, United Kingdom

ABOUT THE CONFERENCE & EXHIBITION

REGISTRATION

Your registration badge ensures admission to each of these events:

- Technical and Poster Sessions
- Tuesday Welcome Reception
- Wednesday Poster Reception
- Refreshment Breaks during session intermission coordinated with exhibit viewing
- Thursday Conference Dinner*

**Please note that while one ticket for the conference dinner is included, registration was required for this event through the conference registration form.*

REGISTRATION HOURS

The registration desk will be located in the Great Room.

Tuesday	6:00 p.m. to 8:30 p.m.
Wednesday	7:00 a.m. to 5:30 p.m.
Thursday	7:00 a.m. to 5:30 p.m.
Friday	7:00 a.m. to 12:00 p.m.

INTERNET ACCESS

Complimentary wireless internet access is available in the conference areas of the DoubleTree by Hilton Hotel. To access the wireless network, choose the "Hilton Honors" network and enter "METFOAM2019" as the password. Complimentary high speed internet is available in all guest rooms

TECHNICAL SESSIONS

All oral presentations will be on the 1st level in the Michigan room or the Erie/Ontario/Huron room. See the Technical Program section on pages 15-38 for room locations.

PROCEEDINGS

The MetFoam 2019 proceedings publication will be produced by TMS in partnership with Springer. The publication and all individual contributions will be assigned DOI numbers, and the publication will be submitted to the major indexing services. The expected publication date is February 2020, at which time all meeting attendees will have complimentary access to the proceedings in eBook format.

EXHIBITION HOURS

The exhibition will be located on the 1st level in the Great Room.

Wednesday, August 21
10:10 a.m. to 10:35 a.m.
3:10 p.m. to 3:30 p.m.
5:30 p.m. to 7:00 p.m.

Thursday, August 22
10:10 a.m. to 10:35 a.m.
3:10 p.m. to 3:30 p.m.

Friday, August 23
10:10 a.m. to 10:30 a.m.

SPONSORS

TMS would like to thank the following Exhibitors and Corporate Sponsors for their generous support of the event:

SILVER SPONSOR

GRIMS® GROUPE
FONDEURS D'INNOVATION

The aim of the GRIMS Group is develop innovative product designs, using the high performance processes of our foundries. On the industrial side, the Gravitec foundry (permanent mold process) and the FTB one (sand mold process) contribute to the development of the NéoLATTICE® concept, focused on metallic foams innovative products. Over the last 8 years GRIMS Group has developed number of different types of metallic foams, especially in aluminum. Originally the foam used a Kelvin cell and this foam was produced under the Castfoam license (CTIF patent). Then various shapes of the repetitive cell have been designed, calculated and produced, function of the technical specification targeted. This significant methodic development is at the origin of the « lattice structures » whose applications have been validated in many industrial fields.

TMS would like to thank the following Exhibitors and Corporate Sponsors for their generous support of the event:

SPONSORS

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Bruker offers a broad range of analytical systems. Our systems include those for enhanced analytical Electron Microscopy: EDS and WDS X-ray spectrometry, EBSD, micro-X-ray fluorescence, micro-computed tomography and nanomechanical characterization in the electron microscope. www.bruker.com

Heat exchangers are core components of energy systems. Their optimization in terms of integration, weight and performances can enhance the performances of energy systems. Additive manufacturing is a solution for generating complex structures and creating a customize thermal solution. Specialized in thermal systems and in the use of AM, TEMISTh is providing engineering services such as feasibility study, thermal and fluid simulations, design integrating manufacturing process and its parametrization. Finally, we ensure 3D prototyping and the characterization of the heat exchanger. The company was founded in 2012 by a team of researchers in the field of thermal systems and is located in Marignane in the TEAM Henri-Fabre platform. This platform gives us access to 3D printer and experts and to ensure the fabricability of prototypes. In the next years, TEMISTh aims to become a leader of additive exchanger by developing numerical solution for generative design dedicated to thermal systems.

TESCAN is a global supplier of scientific instrumentation and microscopy solutions, headquartered in Brno, Czech Republic. The company is focused on research, development and manufacturing of scientific instruments and laboratory equipment including electron- and ion microscopy, micro-CT and more. TESCAN's subsidiary for micro-CT technology, TESCAN XRE, was formed via the acquisition of Belgium-based XRE NV in 2018. Today, TESCAN XRE acts as TESCAN's global micro-CT technology, R&D and applications center, based in Ghent, Belgium. TESCAN's leading-edge 3D X-ray micro-computed tomography (micro-CT) systems are designed to meet 3D and 4D application demands across a variety of fields. TESCAN's micro-CT product lines, UniTOM XL, CoreTOM and DynaTOM, combined with a suite of software solutions, are demonstrating leadership in dynamic CT (e.g. high-speed, high-throughput imaging), enabling the study of materials evolution under various sample environments (i.e. compression, tension, flow, etc). Such non-destructive imaging technologies have proven essential for academic research and industrial R&D in areas such as materials science, earth science, failure analysis, and more.

TABLETOP SPONSOR

nTopology is a software company creating design and engineering solutions to support advanced manufacturing and automation initiatives. In an environment driven by data and physics, using the latest 3D modeling technology, creative restraints are removed and engineers can fully realize the benefits of advanced manufacturing techniques like additive manufacturing. nTopology products enable engineers to better define, represent, and lock down various engineering processes, digitally. When engineers have robust tools that efficiently integrate important data, they can accurately capture all their knowledge and repurpose it for tomorrow's products.

SPONSOR

The United States National Science Foundation (NSF)

NSF is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense..." With an annual budget of $7.8 billion (FY 2018), NSF is the funding source for approximately 24 percent of all federally supported basic research conducted by America's colleges and universities. NSF's goals—discovery, learning, research infrastructure, and stewardship—provide an integrated strategy to advance the frontiers of knowledge, cultivate a world-class, broadly inclusive science and engineering workforce and expand the scientific literacy of all citizens, build the nation's research capability through investments in advanced instrumentation and facilities, and support excellence in science and engineering research and education through a capable and responsive organization. www.nsf.gov

NETWORKING & SOCIAL EVENTS

WELCOME RECEPTION

The Welcome Reception will be held on Tuesday, August 20, from 7:00 p.m. to 8:30 p.m. in the Great Room.

POSTER VIEWING/NETWORKING RECEPTION

A Poster Session/Networking Reception is planned for Wednesday, August 21, from 5:30 p.m. to 7:00 p.m. in the Great Room. Don't miss this great networking opportunity!

CONFERENCE DINNER

The dinner will be held on Thursday, August 22, from 5:30 p.m. to 7:00 p.m. in the Superior room.
Please note that while one ticket for the conference dinner is included, registration was required for this event through the conference registration form.

ABOUT THE VENUE

The newly renovated DoubleTree by Hilton Hotel Dearborn is just minutes to Dearborn or Detroit, Michigan. Guests will enjoy complimentary wireless internet in all guest rooms, the hotel lobby, and public areas, an indoor pool and hot tubs, and breakfast buffet. The hotel also features the Grille39 restaurant.

Visit the conference Housing & Travel page at **www.tms.org/MetFoam2019** for more information on things to do while you're in Dearborn.

PLENARY, KEYNOTE & INVITED SPEAKERS

PLENARY SPEAKERS

- **Kamel Hooman**, Associate Professor, The University of Queensland, Brisbane, Australia
  Presenting: "*Metal Foam Research Direction: Simplicity versus Accuracy*"
- **Haydn N.G. Wadley**, University Professor, Edgar Starke, Jr Professor of Materials Science and Engineering, University of Virginia, Charlottesville, VA, USA
  Presenting: "*Multifunctional Nano to Macro Metallic Lattice Materials and Structures*"
- **Christopher B. Williams**, Professor, John R. Jones III Faculty Fellow, Virginia Tech, Blacksburg, VA, USA
  Presenting: "*Additive Manufacturing of Porous Metallic Structures with Designed Mesostructure*"
- **Ulrike Wegst**, Associate Professor of Engineering, Dartmouth College, Hanover, NH, USA
  Presenting: "*Porous Metals by Freeze Casting: Challenges and Opportunities*"

KEYNOTE SPEAKERS

- **Kiju Kang**, Chonnam National University
- **Manas Mukherjee**, Indian Institute of Technology Madras
- **Peter Quadbeck**, Fraunhofer Institute for Manufacturing and Advanced Materials IFAM
- **Afsaneh Rabiei**, North Carolina State University

INVITED SPEAKERS

- **Norbert Babcsán**, Innobay Hungary Ltd.
- **Karen Chen-Wiegart**, Stony Brook University
- **Dinc Erdeniz**, Marquette University
- **Francisco Garcia-Moreno**, Helmholtz Zentrum Berlin Für Matl Und Energie
- **Thomas Hipke**, Fraunhofer-IWU
- **Louis-Philippe Lefebvre**, National Research Council Canada
- **Simone Mancin**, University of Padova
- **Ashley Paz y Puente**, University of Cincinnati
- **Frédéric Topin**, Aix-Marseille University-CNRS, Laboratory IUSTI
- **Lorenzo Valdevit**, University of California, Irvine
- **Donghui Yang**, Hohai University

CONFERENCE POLICIES

BADGES

All attendees must wear registration badges at all times during the conference to ensure admission to events included in the paid fee such as technical sessions, exhibition, and receptions.

REFUNDS

The deadline for all refunds was July 8, 2019. No refunds will be issued at the conference. Fees and tickets are nonrefundable.

AMERICANS WITH DISABILITIES ACT

The federal Americans with Disabilities Act (ADA) prohibits discrimination against, and promotes public accessibility for, those with disabilities. In support of, and in compliance with ADA, we ask those requiring specific equipment or services to contact TMS Meeting Services at mtgserv@tms.org in advance.

CELL PHONE USE

In consideration of attendees and presenters, we kindly request that you minimize disturbances by setting all cell phones and other devices on "silent" while in meeting rooms.

TMS MEETINGS CODE OF CONDUCT

TMS is committed to providing a safe, inclusive, and welcoming environment and an experience that embraces the richness of diversity where all participants may exchange ideas, learn, network, and socialize in the company of colleagues in an environment of mutual respect. TMS does not tolerate harassment in any form and requires all participants to abide by the TMS Anti Harassment Policy and Meetings Code of Conduct in all venues, including ancillary events and social gatherings. Participants include, but are not limited to, attendees, exhibitors, speakers, members, guests, contractors, and TMS staff. TMS will communicate its AntiHarassment Policy and Meetings Code of Conduct to all service providers and venue leadership. To review the Code of Conduct, which includes a list of both expected and unacceptable behaviors, consequences for violating the code, guidelines for reporting unacceptable behavior, and an outline of incident investigation procedures, please go to www.tms.org/CodeofConduct.

The TMS Anti-Harassment policy prohibits conduct that is disrespectful, unprofessional, or harassing as related to any number of factors including, but not limited to, religion, ethnicity, gender, national origin or ancestry, physical or mental disability, physical appearance, medical condition, partner status, age, sexual orientation, military and veteran status, or any other characteristic protected by relevant federal, state, or local law or ordinance or regulation. Failure to comply with this policy could lead to censure from the TMS Board of Directors, potential legal action, or other actions. Anyone who witnesses prohibited conduct or who is the target of prohibited verbal or physical conduct should notify TMS staff member as soon as possible following the incident. It is the duty of the individual reporting the prohibited conduct to make a timely and accurate complaint so that the issue can be resolved swiftly.

PHOTOGRAPHY AND RECORDING

TMS reserves the right to all audio and video reproduction of presentations at TMS-sponsored meetings. By registering for this meeting, all attendees acknowledge that they may be photographed by TMS personnel while at events and that those photos may be used for promotional purposes, in and on TMS publications and websites, and on social media sites.

Any recording of sessions (audio, video, still photography, etc.) intended for personal use, distribution, publication, or copyright without the express written consent of TMS and the individual authors is strictly prohibited. Attendees violating this policy may be asked to leave the session.

ANTITRUST COMPLIANCE

TMS complies with the antitrust laws of the United States. Attendees are encouraged to consult with their own corporate counsel for further guidance in complying with U.S. and foreign antitrust laws and regulations.

TMS DIVERSITY AND INCLUSION STATEMENT

The Minerals, Metals & Materials Society (TMS) is committed to advancing diversity in the minerals, metals, and materials professions, and to promoting an inclusive professional culture that welcomes and engages all who seek to contribute to the field. TMS recognizes that a diverse minerals, metals, and materials workforce is critical to ensuring that all viewpoints, perspectives, and talents are brought to bear in addressing complex science and engineering challenges. To build and nurture this diverse professional community, TMS welcomes and actively engages the participation of underrepresented groups in all of its initiatives and endeavors.

EMERGENCY PROCEDURES

The chances of an emergency situation occurring at MetFoam 2019 are quite small. However, being prepared to react effectively in case of an incident is the most critical step in ensuring the health and safety of yourself and those around you. Please take a few moments to review the maps of the DoubleTree Dearborn facility printed in this program (on the back cover). When you enter the building, familiarize yourself with the exits and the stairs leading to those exits. When you arrive at your session or event location, look for the emergency exits that are in closest proximity to you.

If there is a fire or other emergency, the alarm will be sounded and the hotel team will advise which exit to proceed to and ask guests to evacuate the hotel. There are exits behind the ballroom and to the left as you exit the ballroom.

If there is a tornado, the alarm will sound and the hotel team will direct all guests to shelter in the ballroom.

All of the hotel department managers are certified in CPR and trained in AED operation.

MetFoam2019

11th International Conference on Porous Metals and Metallic Foams

August 20–23, 2019

DoubleTree by Hilton Hotel • Dearborn, Michigan, USA

TECHNICAL PROGRAM

NOTICE:
The content in this technical program was generated on August 6. However, changes may still be implemented. Please refer to the online session sheets for the most up-to-date information.

SPONSORED BY: TMS — TMS Structural Materials Division, TMS Composite Materials Committee and, TMS Additive Manufacturing Committee.

SESSION OVERVIEW

Tuesday, August 20	Wednesday, August 21		Thursday, August 22		Friday, August 23	
Dearborn/ Southfield/ Allen Park	Erie/Ontario /Huron	Michigan	Erie/Ontario /Huron	Michigan	Erie/Ontario /Huron	Michigan
		8:00 AM Welcome & Wednesday Plenary Page 15		8:00 AM Thursday Plenary Page 22		8:00 AM Friday Plenary I Page 30
	8:55 AM Design of Porous Metals I Page 15	8:55 AM Nanoporous Metals Page 16	8:35 AM Characterization II Page 22	8:35 AM Freeze Casting Page 23	8:35 AM Nanoporous Metals & Fabrication Page 30	8:35 AM Freeze Casting, 3D Printing, & Fabrication Page 31
	10:10 AM Break		10:10 AM Break		10:10 AM Break	
	10:35 AM Industrial Applications Page 16	10:35 AM Properties Page 17	10:35 AM Design of Porous Metals & Fluid Flow Page 24	10:35 AM Fabrication & Fluid Flow Page 25	10:30 AM Composites & Design of Porous Metals Page 32	10:30 AM Shellular Materials Page 33
						11:20 AM Friday Plenary II & Concluding Comments Page 33
	11:55 AM Lunch		11:55 AM Lunch		11:55 AM Lunch	
	1:30 PM Characterization I Page 18	1:30 PM Porous Biomaterials Page 19	1:30 PM Characterization III Page 26	1:30 PM Fabrication of Composites, Syntactic Foams, & Metallic Metamaterials Page 27		
	3:10 PM Break		3:10 PM Break			
	3:30 PM Design of Porous Metals II Page 20	3:30 PM Fabrication Page 21	3:30 PM Design of Porous Metals & Fabrication Page 28	3:30 PM Heat Transfer & Fluid Flow Page 29		
7:00 PM Welcome Reception	Great Room 5:30 PM Poster Session & Reception Page 34		Superior 5:30 PM Conference Dinner			

SESSION GRID - WEDNESDAY

Erie/Ontario/Huron

Session	Design of Porous Metals I
Chair	Donghui Yang, Hohai University
8:55 AM	Design and Mechanical Performance of Metallic Sandwiches for Functional Lightweight Applications: Olaf Andersen, Fraunhofer Society
9:10 AM	TPMS Lattice Design for Additive Manufacturing: Ian Maskery, University of Nottingham
9:25 AM	Design of Energy Absorbing Materials for Space Crafts Based on Voronoi Diagrams: Koichi Kitazono, Tokyo Metropolitan University

Session	Industrial Applications
Chair	Thomas Hipke, Fraunhofer-IWU
10:35 AM	Metal Foams – From Research to Industrial Application: Thomas Hipke, Fraunhofer-IWU
10:55 AM	Effect of Spent Air Removal Scheme on Jet Impingement Heat Transfer onto Thin and High Porosity Metal Foams: Prashant Singh, North Carolina State University
11:10 AM	Stochastic Modeling of the Effects of Structural Randomness on the Mechanical Behavior of 3D Printed Metals: Skylar Mays, University of Kentucky
11:25 AM	Metal Foams with Ceramic Inserts for Security Applications: Rene Vogel, Fraunhofer Institute for Machine Tools and Forming Technology IWU
11:40 AM	Pore Size Effect on Oil/Water Separation Efficiency of Hydrophobic Surface in Aluminum Foams: Viviana Marcela Posada Pérez, Universidad Nacional de Colombia

Session	Characterization I
Chair	Manas Mukherjee, Indian Institute of Technology Madras
01:30 PM	A Novel Method to Produce Foams from Metallic Melts: Melt Injecting Technique: Manas Mukherjee, Indian Institute of Technology Madras
01:55 PM	Structural Control of Fe-based Porous Layer Fabricated through Combustion Synthesis for Joining with Resin Parts: Asuka Suzuki, Nagoya University
02:10 PM	Development of Rotational Incremental Hammering Process for Porous Metals: Han Cui, University of California, San Diego
02:25 PM	The Challenge of Open Cellular Metal Foam Production: Christian Hannemann, Fraunhofer Institute for Machine Tools and Forming Technology
02:40 PM	Deformation of Porous Structure during Bonding Porous Aluminum with an Al–Si-based Alloy Brazing Sheet: Tomohito Kurosaki, UACJ
02:55 PM	Liquid Metal Route Foaming of Mg Alloy and Mg Matrix Composite: Goarke Kumar, SRM Institute of Science and Technology

Michigan

Session	Wednesday Plenary
Chair	Nihad Dukhan, University of Detroit Mercy
8:20 AM	Multifunctional Nano to Macro Metallic Lattice Materials and Structures: Haydn Wadley, University of Virginia

Session	Nanoporous Metals
Chair	Yu-chen Karen Chen-Wiegart, Stony Brook University
8:55 AM	Studies of Bicontinuous Metallic Nano-structure by Dealloying with Synchrotron X-ray Methods: Yu-chen Karen Chen-Wiegart, Stony Brook University
9:15 AM	Fabrication of Nano Shellular: Kiju Kang, Chonnam National University
9:30 AM	Electro-mechanical Response of Porous Metals at the Small Length-scales: Sundeep Mukherjee, University of North Texas
9:45 AM	Hierarchically Structured Copper Nanofoam for Use as High-Performance Lithium-Ion Battery Anode: GiGap Han, Kookmin University

Session	Properties
Chair	David Dunand, Northwestern University
10:35 AM	Coupling Effect of Porosity and Cell Size on the Deformation Behavior of Close-cell AlCu5Mn Alloy Foam Fabricated by Melt-foaming Route in Quasi-static Compression: Donghui Yang, Hohai University
10:55 AM	Improvement in Energy Absorption Capacity of Al-SiCp-CNT Hybrid Composite Foam by Addition of SiCp and CNT: Bishnu Yadav, AMPRI
11:10 AM	Influence of Temperature on Deformation of Closed-cell Aluminum Foams in Solid-liquid-gas Coexisting State: Zhiyong Liu, Wayne State University
11:25 AM	Microstructure Design of Open-cell High Strength Steel Foams: Jan Frömert, Pforzheim University
11:40 AM	High-fidelity Numerical Simulation of Open-cell Aluminum Foams Using Crystal Plasticity Modeling: Dongfang Zhao, University of Utah

Session	Porous Biomaterials
Chair	Olaf Andersen, Fraunhofer Society
01:30 PM	Reticulated Titanium Foams for Intraoperative Manipulation of Customized CMF Implants : Peter Quadbeck, Fraunhofer Institute for Manufacturing Technologies IFAM, Branch Lab Dresden
01:55 PM	Effect of Interlamellar Spacing and Eutectoid Phase Content on the Mechanical Properties of TixAlyCo Foam: Amit Abhash, CSIR AMPRI Bhopal
02:10 PM	Mechanical and Biocorrosive Properties of Magnesium-aluminum Alloy Scaffold for Biomedical Applications: Kicheol Hong, Kookmin University
02:25 PM	Fabrication of Antireflective Ni-Cu Films in the Broadband: Baorong Ji, Southeast University
02:40 PM	Biological Response to Magnesium-based Foams Modified by Directed Plasma Nanosynthesis: Viviana Marcela Posada Pérez, Universidad Nacional de Colombia
02:55 PM	Influence of the Composition and Deposition Process on the Properties of Bioactive Coatings in Porous Titanium: Ernesto Chicardi Augusto, University of Seville

SESSION GRID - WEDNESDAY

Erie/Ontario/Huron

Session	Design of Porous Metals II
Chair	Norbert Babcsán, Innobay Hungary Ltd.
03:30 PM	Hybrid Aluminium: Composites, Foams, Sandwiches – 3 to the 5th Power Industry Overview: Norbert Babcsán, Innobay Hungary Ltd.
03:50 PM	Viscoplastic Behavior of Additively-manufactured Polymeric Lattices with Triply Periodic Minimal Surfaces: Aliaa Abu Ali, Khalifa University of Science and Technology
04:05 PM	An Auxetic Sandwich Panel for Mobile Devices: Eun Byeol Park, Chonnam National University
04:20 PM	Use of Metalic Foam to Solve Shock Absorption Issies: Cyrille Grimaud, NEOLATTICE
04:35 PM	Fabrication and Properties of Protective Coatings on Pore Walls for Lotus-type Porous Copper: Hao Du, Institute of Metal Research, Chinese Academy of Sciences
04:50 PM	Microstructure Characterization and Investigation on Energy Absorption Properties of LM 9 Foam by Optimization Techniques: Dipen Rajak, Sandip Institute of Technology & Research Centre (SITRC) Nashik

Michigan

Session	Fabrication
Chair	Ashley Paz y Puente, University of Cincinnati
03:30 PM	Fabrication of Metallic Lattice Structures via a Decoupled Printing and Alloying Approach: Ashley Paz y Puente, University of Cincinnati
03:50 PM	Production of Metal Foam with Sub-mm Bubbles Using a Rotating Gas Injector: M.A. Noack, Technische Universität Berlin
04:05 PM	Sonication for the Porosity Gradation of Foams Meets Replica Templating: A Hybrid Manufacturing Process for Lightweight Multifunctional Structures: Carmen Torres-Sánchez, Loughborough University
04:20 PM	Ultra-light and Nanostructured Metallic Foams Synthesized by Plasma Electrolysis: Ronan Botrel, CEA
04:35 PM	Numerical Simulations and Experimental Studies on the Microstructure and Properties of Nickel-based Lattice Materials: Yanpeng Wei, Shenyang Research Institute of Foundry
04:50 PM	Controllable Continuous Porosity via Powder Bed Fusion: Scott Roberts, Jet Propulsion Laboratory

SESSION GRID - THURSDAY

Erie/Ontario/Huron

Session	Characterization II
Chair	Francisco Garcia-Moreno, Helmholtz Zentrum Berlin Für Matl Und Energie
8:35 AM	Design and Fabrication of a Bronze Syntactic Foam by Low Pressure Injection Molding: Joseph W Newkirk, Missouri University of Science and Technology
8:50 AM	Corrosion Studies of Open Cell Aluminum Foam in Simulated Marine Environments: Ho Lun Chan, Cal Poly Pomona
9:05 AM	Effect of Gravity on Drainage and Liquid Imbibition in Evolving Metal Foams: Felix Bülk, Technische Universität Berlin
9:20 AM	3D Characterization of an Open-cell Aluminum Foam under Compression Test with Combined In-situ High-energy X-ray Computed Tomography and Diffraction Microscopy: Quinton Johnson, University of Utah
9:35 AM	Energy Absorption and Deformation Mechanisms of Porous Magnesium/Carbon Nanofiber Composites: Qizhen Li, Washington State University
9:50 AM	Dynamic Phenomena in Liquid Metal Foams Studied by X-ray Tomoscopy: Francisco Garcia-Moreno, Helmholtz Zentrum Berlin Für Matl Und Energie

Michigan

Session	Thursday Plenary
Chair	Nihad Dukhan, University of Detroit Mercy
8:00 AM	Porous Metals by Freeze Casting: Challenges and Opportunities: Ulrike G.K. Wegst, Thayer School of Engineering, Dartmouth

Session	Freeze Casting
Chair	Ranier Sepulveda Ferrer, Universidad de Sevilla
8:35 AM	Spaceborne In-situ Laboratory to Study the Solidification of Powder Suspensions during Freeze-casting in Microgravity: Robert Lundberg, Northwestern University
8:50 AM	Effects on the Process Condition on the Fabrication of Iron Oxide Porous Materials by Freezes Casting: Pedro Javier Lloreda-Jurado, Universidad de Sevilla
9:05 AM	Effect of Gravity during Solidification of Aqueous Particle Suspensions for Freeze-casting: Kristen Scotti, Northwestern University
9:20 AM	Sensorization for the Modelling and Simulation of the Freeze-casting Technique: Ana Beltran, University of Seville
9:35 AM	Fabrication of Fe-Ni Laminated Porous Material by Sequential Freezes Casting: Ranier Sepulveda Ferrer, Universidad de Sevilla

SESSION GRID - THURSDAY

Erie/Ontario/Huron

Session	Design of Porous Metals & Fluid Flow
Chair	Louis-Philippe Lefebvre, National Research Council Canada
10:35 AM	High-performance Micro/Nano-hybrid Porous Cobalt Oxide/Cobalt Anode for Use in Lithium-ion Batteries: Hyeji Park, Kookmin University
10:50 AM	Synthesis and Characterization of Metallic Syntactic Foams: João Roberto Moreno, Universidadade Tecnologica Federal do Paraná
11:05 AM	Analysis of Bubble Accumulation Mechanisms and Cell Structure Evolution in Aluminum Foam with Sub-mm Sized Cells: Ningzhen Wang, Technische Universität Berlin
11:20 AM	The Deformation of Expanded Clay Syntactic Foams during Compression Characterized by Acoustic Emission: Csilla Wiener, Budapest University of Technology and Economics
11:35 AM	Structure and Permeability of Porous Structures Deposed by Shock Wave Induced Spraying: Louis-Philippe Lefebvre, National Research Council Canada

Session	Characterization III
Chair	Dinc Erdeniz, Marquette University
01:30 PM	Performance of Composite Metal Foams against Various Threats, from Insect to Large Bullets: Afsaneh Rabiei, North Carolina State University
01:55 PM	Cenosphere/Aluminum Matrix Syntactic Foam via Stir Casting: Characteriastion and Deformation Behaviors: Jeki Jung, Korea Institute of Materials Science
02:10 PM	Microstructural Characterization of Porous Cu by Vapor Phase Dealloying: Qingkun Meng, China University of Mining and Technology
02:25 PM	Compressive Behavior of Porous Aluminum with Aligned Unidirectional Pores with Various Relative Cell Wall Thicknesses: Mahiro Sawada, Waseda University
02:40 PM	In-situ Observation of Bubble Coalescence in Metallic Foams: Paul Kamm, Helmholtz-Zentrum Berlin
02:55 PM	Compression Behavior of Low-pressure Casted AMC Syntactic Foams with High Porosity: Pierre Kubelka, Pforzheim University

Michigan

Session	Fabrication & Fluid Flow
Chair	Frédéric Topin, Aix-Marseille University-CNRS, Laboratory IUSTI
10:35 AM	Foaming of Al-Mg-X (X = Cu, Zn, Si) Alloys Using Mg as blowing Agents: Georgy Kurian Kaladimadathil, Indian Institute of Technology Madras
10:50 AM	Stabilization Mechanism of Cell Wall during Semi-solid Foaming of Al-Si Alloy: Takashi Kuwahara, Waseda University
11:05 AM	Shaping of Aluminum Foam by Press Forming during Precursor Foaming: Yoshihiko Hangai, Gunman University
11:20 AM	The Stabilization Mechanism of Semi-solid Foaming Method by Primary Crystals: Satomi Takamatsu, Waseda University
11:35 AM	Flow Laws and Heat Transfer in Metal Foams: State-of-the-art Correlations and Current Problems: Frédéric Topin, Aix-Marseille University-CNRS, Laboratory IUSTI

Session	Fabrication of Composites, Syntactic Foams, & Metallic Metamaterials
Chair	Simone Mancin, University of Padova
01:30 PM	A Novel Micro-architected Material, Shellular in a Minimal Surface: Kiju Kang, Chonnam National University
01:55 PM	study on the infiltration process and compressive behavior of steel matrix syntactic foams: Quanzhan Yang, Shenyang Research Institute of Foundry Co. Ltd.
02:10 PM	A Novel Integrated Preparation Method and Its Process Optimization of the In-situ Ordered Porous Aluminum Filled Tubes: Hai Hao, Dalian University of Technology
02:25 PM	Mechanical Properties of Periodic Interpenetrating Phase Composites Based on Triply Periodic Minimal Surfaces: Rashid Abu Al-Rub, Khalifa University of Science and Technology
02:40 PM	Topology-property of Metallic TPMS Metamaterials: Oraib Al-Ketan, Khalifa University

SESSION GRID - THURSDAY

Erie/Ontario/Huron

Session	Design of Porous Metals & Fabrication
Chair	Afsaneh Rabiei, North Carolina State University
03:30 PM	Fabrication and Mechanical Testing of Micro-architectured Shape Memory Alloys: Dinc Erdeniz, Marquette University
03:50 PM	Micro-architected TPMS Shell-based Lattices: Fabrication and Mechanical Testing: Oraib Al-Ketan, Khalifa University
04:05 PM	Study on the Technology of Manufacturing Foam Magnesium Alloy by Negative Pressure Penetration Casting Method: Yihan Liu, Northeastern University
04:20 PM	Effects of Pore Structure on the Cyclical Oxidation/Reduction of Iron Foams: Teakyung Um, Kookmin University
04:35 PM	Modeling of the Tape-cast Open-porous Microstructures: Samih Haj Ibrahim, Warsaw University of Technology
04:50 PM	Implicit Modeling for Functionally Tailored Engineering Cellular Materials and Spatially Varying Structures: Ryan O'Hara, nTopology inc.

Michigan

Session	Heat Transfer & Fluid Flow
Chair	Simone Mancin, University of Padova
03:30 PM	Metal Foam Applications: From Laboratory to Market: Simone Mancin, University of Padova
03:50 PM	Experimental and Numerical Investigation of Heat Transfer Performance on PCM/Copper Foam Composite Heat Exchanger for Electronic Device Thermal Management: Brahim Madani, FGMGP/USTHB
04:05 PM	Characterizing Interstitial Heat Transfer in Metal Foam Enhanced Phase Change Materials: Wim Beyne, Ghent University
04:20 PM	The Effect of Geometry on the Thermomechanical Behavior of Metal Foams for Use in Heat Exchangers: Mujan Seif, University of Kentucky
04:35 PM	Dynamic Response of Corrugated Sandwich Panels Subjected to a Composite Foam Projectile Impact: Xin Wang, Xi'an Jiaotong University
04:50 PM	Oxidation/Reduction Cycling of Freeze-cast Iron Foams: Stephen Wilke, Northwestern University

SESSION GRID - FRIDAY

Erie/Ontario/Huron

Session	Nanoporous Metals & Fabrication
Chair	Lorenzo Valdevit, University of California, Irvine
8:35 AM	Influence of Zinc on the Compaction and Foaming of AlSi8Mg4 Alloy: Tillmann Neu, Technische Universitität Berlin
8:50 AM	Thermal Decomposition of Transition Metal Dichalcogenides as a Route to Synthesize Nanoporous Metals: Swarnendu Chatterjee, Drexel University
9:05 AM	Hierarchical Bulk Nanoporous Aluminum for On-board Hydrogen and Heat Generation by Hydrolysis in Pure Water: John Corsi, University of Pennslyvania
9:20 AM	Real-time USAXS and WAXS Studies of Morphology Evolution in 3D Nanoporous Gold during Electrochemical Dealloying and Post-dealloying Coarsening: Samuel Welborn, University of Pennsylvania
9:35 AM	Influence of Heat Treated Calcium on the Stability of 6061 Aluminium Alloy Foam: Vinothkumar Sundharamoorthi, Indian Institute of Technology Madras
9:50 AM	Deformation and Damage Mechanisms in Nano-architected Metamaterials with Spinodal Topologies: Lorenzo Valdevit, University of California, Irvine

Michigan

Session	Friday Plenary I
Chair	Nihad Dukhan, University of Detroit Mercy
8:00 AM	Additive Manufacturing of Porous Metallic Structures with Designed Mesostructure: Christopher Williams, Virginia Tech

Session	Freeze Casting, 3D Printing, & Fabrication
Chair	Jean-Michel Hugo, TEMISTh SAS, Hôtel Technologique
8:35 AM	Ti-TiB Composite Micro-scaffolds by 3D Printing and Sintering of TiH2+TiB2 Powder-loaded Inks: Binna Song, Soochow University
8:50 AM	Iron and Nickel Micro-scaffolds with Porous Struts Created via 3D-extrusion-printing and Reduction of Oxide-particle Inks: Christoph Kenel, Northwestern University
9:05 AM	Influence of Sintering Temperature on Fabrication of Open-cell 6061Aluminum Alloy Foams: Tan Wan, Tsinghua University
9:20 AM	Thermohydraulic Characterization of Additive Manufactured Two-phase Heat Exchangers Using Lattice Structure: Jean-Michel Hugo, TEMISTh SAS, Hôtel Technologique

Erie/Ontario/Huron	
Session	Composites & Design of Porous Metals
Chair	John Banhart, Helmholtz-Centre Berlin
10:30 AM	Innovating Architected Self-healing Materials as Adaptive Plasma-facing Components Designed for Extreme Plasma-burning Fusion Environments: Jean Paul Allain, University of Illinois at Urbana-Champaign
10:45 AM	Open-cell Aluminum Foam Core Sandwich with Density-graded Foam Core and Multi-metal Sandwich: Vasanth Shunmugasamy, Texas A&M University at Qatar
11:00 AM	A Very Thin Sandwich Panel Reinforced with Diamond-like-carbon: Yoonchang Jeong, Chonnam national university

Michigan	
Session	Shellular Materials
Chair	Kiju Kang, Chonnam National University
10:30 AM	Mechanical Behavior of Shellular under Internal Pressure: Kiju Kang, Chonnam National University
10:45 AM	Mechanical Properties of Shellular with Minimal Surfaces: SeungChul Han, Chonnam National University
11:00 AM	A Novel Bioreactor System with a Shellular Scaffold: Jiafei Gu, Chonnam National University

Session	Friday Plenary II
Chair	Nihad Dukhan, University of Detroit Mercy
11:20 AM	Metal Foam Research Direction: Simplicity Versus Accuracy : Kamel Hooman, University of Queensland

POSTER SESSION GRID - WEDNESDAY

Great Room
Preparation and Properties of Porous Titanium with a Hierarchical Structure Porous by Fibers and Powders: Shifeng Liu, Xi'an University of Architecture and Technology
Cooling of PEM Fuel Cell Stacks Using Open-cell Metal Foam: Ali Hmad, UDM
Fabrication of an Ultrahigh Pressure Vessel Based on Shellular: Yoonchang Jeong, Chonnam National University
Fabrication of Shellulars with Various Minimal Surfaces Based on Beads Arranged in Regular Patterns: Anna Na, Chonnam National University
Influence of Metal Foam Morphology on Heat and Mass Transfers Inside Methanol Steam Reforming Reactor: Brahim Madani, USTHB/ALGIERS
Additively Manufactured Metallic Core for Sandwich Structures: Okanmisope Fashanu, Missouri University of Science & Technology
Research of Mechanical Characterization for Hypercube Models Created by Direct Metal Laser Sintering Method : Jeongho Choi, Kyungnam University
Foaming Behaviour and Evolution of Cell Structure of Aluminum Foam with Extrusion Forming Precursor on Condition of Restrictive Foaming: Lucai Wang, Taiyuan University of Science and Technology
Fluxless Soldering of Aluminium Foams: Amir Izadpanahi, Materials Research Group of (ACECR)
Effect of Process Parameters Manufacture on Aluminum Foams Acoustic Properties : Amir Izadpanahi, Materials Research Group of (ACECR)
Change in Compressive Properties of Lattice-structured Al-Si Alloy Fabricated by Selective Laser Melting under Various Heat Treatment Conditions: Takafumi Wada, Nagoya university
Fabrication of Porous Layer on Fe Substrate through Laser-induced Combustion Synthesis: Yuto Ueda, Nagoya University
Bonding Properties of Lotus-type Porous Cu/Sn-Ag-Cu/Cu Joint: Sang-Wook Kim, Inha University
Processing and Electrical Properties of Ni Foams Synthesized via Freeze Casting: Sukyung Lee, Kookmin University
Study on the Mechanical Properties of Composite Metal Foam Core Sandwich Panels: Jacob Marx, North Carolina State University
Compression Behavior of Low-pressure Casted AMC Syntactic Foams with High Porosity: Pierre Kubelka, Pforzheim University

POSTER SESSION GRID - WEDNESDAY

Great Room
Synthesis and Application of Porous NiO/Ni Anode for Use in Advanced Lithium-ion Batteries: Youngseok Song, Kookmin University
Microstructural Effects on Compressive Behavior and Deformation Band Propagation in Open-pore Metal Foams: Alexander Matz, Pforzheim University
Decomposition Behaviour of Ti and Zr Hydrides Studied by Neutron Diffraction: John Banhart, Helmholtz-Centre Berlin
Elastic Properties of Open Cell Aluminum Metallic Foam Transformed through Hydrostatic Loading: Mark Cops, Boston University
Barium Transport Mechanisms in Porous Scandate Cathodes: Mujan Seif, University of Kentucky
Finite Element Simulation of Compressive Behavior of Disordered Cellular Solids: Takuya Hamaguchi, Tokyo Metropolitan University
Impact Energy Absorption of Additively Manufactured Porous Aluminum Alloys with an Axisymmetric Acorn Shape: Yuta Fujimori, Tokyo Metropolitan University
Designing Nanostructured Porous Surfaces to Enhance in Vitro Osseointegration: Ana Fatima Civantos, University of illinois
Open Porous Metal Fiber Structures for the Next Generation of Sorption-driven Heat Pumps and Cooling Machines: Olaf Andersen, Fraunhofer Society
Manufacturing Process and Characterization of Bioactive Gelatins Coated Porous Titanium: Paloma Trueba, University of Seville
Manufacturing and Characterization of Ti, Mg and Mg-Ti Samples for Biomedical Applications: Julio J. Guzmán, Universidad de Sevilla
Characterization and of Metal-foam Flow Field for PEM Fuel Cells: Yussef Awin , University of Detroit Mercy
Cylinder-pack Modeling of Open-cell Metal Foam for Flow and Heat Transfer : Omer Saad, University of Detroit Mercy
The Study on the Usage of Foamed Magnesium and Its Alloy: Yihan Liu, Northeastern University
Enhanced Osteoblast Adhesion and Differentiation by Porous Ti Scaffolds Designed Using Space Holder Technique: Ana Maria Beltran, University of Seville

Wednesday Plenary

Wednesday AM
August 21, 2019

Room: Michigan
Location: Doubletree by Hilton Hotel

Session Chair: Nihad Dukhan, University of Detroit Mercy

8:00 AM Introductory Comments

8:20 AM Plenary
Multifunctional Nano to Macro Metallic Lattice Materials and Structures: *Haydn Wadley*[1]; [1]University of Virginia
Numerous applications are emerging for metallic cellular materials made from alloys whose compositions and microstructures have been tailored to provide compelling combinations of material properties. Structures that are required to support high bending loads are often optimized by sandwich panels. These are best made from high specific strength metals using open cell lattices with strut widths in the millimeter range; other applications such as multifunctional heat plate structures made from high temperature metals with high thermal conductivity also exploit open cell topologies, but with strut widths in the micrometer range to promote liquid permeation and maximize working fluid evaporation rates. Closed cell systems offer the opportunity to reach the theoretical limits of stiffness both, for anisotropic and isotropic systems, and are therefore best fabricated from high specific stiffness metals. These closed cell systems also offer thermal insulation, acoustic damping and impulsive load mitigation opportunities; expanding the types of metal that maximize their performance. As lattice strut or web thicknesses decrease into the nanometer regime, new functionalities may emerge including the opportunity to manipulate phonon transport, control chemical reaction rates, and, perhaps exploit defect starvation concepts to increase lattice strength. However, none of these applications can be realized without advances in scalable processes for the affordable manufacture of metallic cellular materials that retain critical properties of the solid metal from which they are made. This presentation will use emerging applications, such as those above, to motivate an assessment of 3D metal additive, new subtractive and metal forming methods for making millimeter to micrometer scale open and closed cell lattices. Preliminary results for a space-holding concept for making nickel nanolattices will also be presented and the challenges of its scale-up discussed.

8:50 AM Break

Design of Porous Metals I

Wednesday AM
August 21, 2019

Room: Erie/Ontario/Huron
Location: Doubletree by Hilton Hotel

Session Chair: Donghui Yang, Hohai University

8:55 AM
Design and Mechanical Performance of Metallic Sandwiches for Functional Lightweight Applications: *Olaf Andersen*[1]; Michael Franke[1]; Ulrike Jehring[1]; [1]Fraunhofer Society
Fully metallic sandwiches with an open porous core that allows for the through-flow of fluids for cooling purposes can be of use in functional lightweight applications. The design of optimized sandwich constructions with maximized weight-specific stiffness was carried out based on an extended linear sandwich theory. Different core materials such as sponges and sintered fiber structures were taken into account. Resonant frequency and damping analysis was used in order to determine the elastic properties of the sandwich cores. Sandwiches were manufactured with steel cover sheets and mechanically tested. The experimental results were compared with the theoretical results.

9:10 AM
TPMS Lattice Design for Additive Manufacturing: *Ian Maskery*[1]; [1]University of Nottingham
This presentation describes the development and operation of a bespoke design tool focussed on triply periodic minimal surface (TPMS) lattice structure research. Such structures are uniquely manufacturable with additive manufacturing (AM) processes and have recently been the subject of great scientific interest owing to their high specific mechanical properties. TPMS lattice structures have a range of other characteristics which may provide solutions to the challenges of impact protection, thermal management and vibration isolation. The design considerations relevant to AM TPMS lattice structures will be discussed, including the choice of cell type, cell size, orientation and volume fraction. Lastly, a novel proposal will be put forward relating to the design of cellular-graded TPMS lattices with predictable mechanical performance.

9:25 AM
Design of Energy Absorbing Materials for Space Crafts Based on Voronoi Diagrams: *Koichi Kitazono*[1]; Keiji Matsuo[1]; Takuya Hamaguchi[1]; Yuta Fujimori[1]; [1]Tokyo Metropolitan University
Open-cell porous aluminum and titanium alloys were manufactured through Powder Bed Fusion (PBF) process. Compressive properties of the porous metals depend on the cell structure as well as the porosity. The authors manufactured some ordered cell structures, truncated octahedron and rhombic dodecahedron, and disordered cell structure, based on Voronoi diagrams using a 3D-CAD software. Compression tests revealed the anisotropic deformation of the porous metals with ordered cell structure. On the other hand, the porous metals with disordered cell structure showed relatively isotropic and uniform deformation, which is suitable as energy absorbing materials for space crafts. Therefore, controlling the disordered cell structure designed by Voronoi diagram enables to develop the advanced porous metals having various mechanical properties.

9:40 AM Break

Nanoporous Metals

Wednesday AM
August 21, 2019

Room: Michigan
Location: Doubletree by Hilton Hotel

Session Chair: Yu-chen Karen Chen-Wiegart, Stony Brook University

8:55 AM Invited

Studies of Bicontinuous Metallic Nano-structure by Dealloying with Synchrotron X-ray Methods: Chonghang Zhao[1]; Lijie Zou[2]; Fei Chen[3]; *Yu-chen Karen Chen-Wiegart*[4]; [1]Stony Brook University; [2]Wuhan University of Technology; Stony Brook University; [3]Wuhan University of Technology; [4]Stony Brook University; Brookhaven National Laboratory

Dealloying, a selective etching process, can be used to fabricate a variety of nanoporous metals and nano-scale metallic composites with a characteristic bi-continuous structure. The bi-continuous patterns did not exist in the alloy prior to the dealloying process, but rather formed dynamically via an elegant self-organizing process while the dealloying progressed. The most widely studied dealloying method is aqueous solution dealloying. In addition, a molten metal in liquid state can also be used as a dealloying agent, so-called liquid metal dealloying. Alternatively this phase separation and transformation process can also be achieved by a solid-state interfacial dealloying, utilizing a solid-state metal as the dealloying agent to form bi-continuous structure. We study the nanoscale morphology in the three different dealloying systems, in particular utilizing advanced synchrotron-based X-ray imaging and microscopy methods. We will highlight the characterization methods to shed light on their underlying morphological evolution mechanisms.

9:15 AM

Fabrication of Nano Shellular: JongHyuck Jeong[1]; *Kiju Kang*[1]; [1]Chonnam National University

B-Shellular is a 3D shell architecture fabricated based on polymer beads arranged in a regular pattern. The fabrication method enables the architecture to have a form of a triply periodic minimal surface (TPMS), which results in excellent mechanical properties. As the first trial to prove the scalability of B-Shellular, this study reduces the unit cell size down to a micro-meter order, thereby expanding the fields of applications. Fabrication of the nano B-Shellular starts with a deposition of polymer beads in a regular pattern such as FCC or PC. Through annealing and sintering process, the polymer beads are swollen and connected. A TPMS-like architecture is then obtained through chemical treatment and O_2 plasma etching. A nano B-Shellular consisting of nickel foil is obtained by using electroless plating and etching out the polymer beads. Through observation by SEM and nano CT, the topology is proved to resemble a mathematical model of TPMSs.

9:30 AM

Electro-mechanical Response of Porous Metals at the Small Length-scales: *Sundeep Mukherjee*[1]; [1]University of North Texas

Understanding the mechanical and electrical response of porous metals at the small length-scales is critical for their use in energy applications. Nano-porous metallic film was obtained by electrochemical dealloying. Mechanical and electrical properties were measured as a function of depth for the nano-porous structure as well as the unaltered substrate. The ratio of moduli of the nano-porous film and substrate was found to scale with the square of the relative density in agreement with linear elasticity models for cellular materials.

9:45 AM

Hierarchically Structured Copper Nanofoam for Use as High-Performance Lithium-Ion Battery Anode: *GiGap Han*[1]; Um Ji Hyun[2]; Park Hyeji[1]; Hong Kicheol[1]; Yoon Won-Sub[2]; Choe Heeman[1]; [1]Kookmin University; [2]Sungkyunkwan University

Most previously proposed methods for the manufacture of dealloyed nanoporous copper (Cu) could not be realized for practical applications, due to their poor mechanical properties caused by the use of metal 'powders' to create a precursor alloy prior to dealloying. Therefore, a new facile synthesis is proposed based on a pack-cementation process using Cu foil instead of Cu powder. Depending on the pack-cementation time and the amount of Al, a hierarchical micro/nanoporous Cu was also created and coated with tin. The coin-cell test exhibited a four-fold higher areal capacity (7.4 mAh/cm2 without any performance degradation up to 20 cycles).

10:00 AM Break

Industrial Applications

Wednesday AM
August 21, 2019

Room: Erie/Ontario/Huron
Location: Doubletree by Hilton Hotel

Session Chair: Thomas Hipke, Fraunhofer-IWU

10:35 AM Invited

Metal Foams – From Research to Industrial Application: *Thomas Hipke*[1]; Friedrich Schuller[2]; [1]Fraunhofer-IWU; [2]Havel Metal Foam

The paper presents the development of metal foam history (1996 - 2018) form first research steps up to the founding and industrialisation with the Havel metal foam company. The overview will cover some highlights in research and development, in manufacturing and the application side. Compared to the worldwide activities in cellular metals it can be pointed out that Germany still has one of the leading positions. During the last years the main activities in R&D in cellular metals are focused in energy related applications, thermal insulation and combustion and all kind of lightweight design and crash protection. Havel metal foam is a new manufacturer of aluminium foam. A wide range of products are manufactured like panels, 3d net shape parts and sandwich structures. In the last years some new real applications coming up in the field of automotive, railway, ship building, machine tools and for design purposes.

10:55 AM

Effect of Spent Air Removal Scheme on Jet Impingement Heat Transfer onto Thin and High Porosity Metal Foams: Srivatsan Madhavan[1]; *Prashant Singh*[1]; Srinath Ekkad[1]; [1]Department of Mechanical and Aerospace Engineering, North Carolina State University

High porosity metal foams find application in removal of large heat loads such as in electronic cooling owing to their increased wetted surface area. In addition to this, metal foams can be subjected to array jet impingement to further enhance the heat transfer. Steady state heat transfer experiments have been conducted on high porosity (95%) thin metal foams under an array of orthogonal impinging jets for Reynolds number in the range of 3000 and 12000. The jets are arranged such that spanwise jet-to-jet spacing (X) is equal to 4D while streamwise jet-to-jet spacing (Y) is equal to 8D, where D is the diameter of the jet. Upon impingement, the fluid exits the channel under two different crossflow schemes (maximum and intermediate). Metal foams used in this study are 6.35 mm thick with a pore-density of 40 pores per inch (ppi). It is observed that in the case of smooth surface impingement, the maximum HTC is obtained in the center of the domain while for the foam impingement case, it is obtained around the channel exit. An average enhancement of about two times over baseline case of impingement without metal foam is observed in the flow range tested for intermediate crossflow orientation.

11:10 AM
Stochastic Modeling of the Effects of Structural Randomness on the Mechanical Behavior of 3D Printed Metals: *Skylar Mays*[1]; Katherine Moody[1]; Mujan Seif[1]; Matthew Beck[1]; [1]University of Kentucky
Additive manufacturing in the form of 3D printed metals allows for the production of complex metallic shapes; fabrication of parts on-demand; and opportunities to reduce cost and carbon footprint. Additive manufacturing of metals is a layer-by-layer process involving the laser sintering of a porous metallic powder precursor. Since laser sintering of powders induces a massive temperature gradient, it is crucial to understand the thermomechanical behavior of the porous precursor under those conditions. Furthermore, because sintered powders have an inherently random configuration, computational models of their behavior are difficult to construct. Here, we present a computational approach capable of generating representative volumes of spheroid-based porous powders. With finite element analysis, computation of thermomechanical properties reveals macroscopic sensitivity to reduced density, spheroid quantity, and relative sphere overlap. These results provide great insight into the continuum-scale behavior of porous metallic powder precursor during sintering and will catalyze other ongoing efforts in the field.

11:25 AM
Metal Foams with Ceramic Inserts for Security Applications: *Rene Vogel*[1]; Claudia Drebenstedt[1]; Stefan Szyniszewski[2]; Teresa Fras[3]; Ludovic Blanc[3]; Florian Bittner[4]; [1]Fraunhofer Institute for Machine Tools and Forming Technology IWU; [2]University of Surrey; [3]French-German Research Institute of Saint Louis ISL; [4]Fraunhofer Institute for Wood Research
Protective performance and a low weight of armor-plates is the most important objective in security applications. Metallic foams can provide a high level of protection without an extensive mass and are used as a part of various laminated armor systems in the past. Embedding ceramic spheres in metallic foam combines the hardness of ceramics with the flexibility of the lightweight cellular matrix. Interestingly, the material has also an extreme cutting resistance against mechanical tools such as angle grinder, drill bits or other cutting devices.In several testing campaigns aluminum foam was combined with an internal layout of stacked ceramic parts. The cellular core was foamed directly to steel cover sheets or was bonded to different steel alloy face plates. Blast wave propagation of the metallic foam ceramic composite (MFCC) panels was evaluated during the tests. Furthermore several ballistic tests were performed and compared to state of the art armor materials.

11:40 AM
Pore Size Effect on Oil/Water Separation Efficiency of Hydrophobic Surface in Aluminum Foams: Laura Álvarez[1]; Patricia Fernández-Morales[2]; Juan Ramírez[1]; *Viviana Marcela Posada Pérez*; [1]Universidad Nacional de Colombia; [2]Universidad Pontificia Bolivariana
Porous materials with modified surface have been presented as an alternative for the attention of oil spills in water sources, due to their applicability as a selective barrier. The selective barrier effect on the aluminum foams was achieved using a process of maximization of the surface area by pickling with sodium hydroxide and the formation of a low energy layer by immersion in lauric acid. This work focus on the definition of parameters of manufacture, functionalization and valuation of aluminum foams in pore sizes of 425, 850 and 1200 µm for separation of water / oil mixtures to static and dynamic conditions. The evaluation of the applied treatment was based on the volumetric efficiency of a pump coupled to the material manufactured and the quantification of the surface area before and aftertreatment, finding significant differences between the different pores used.

Properties

Wednesday AM	Room: Michigan
August 21, 2019	Location: Doubletree by Hilton Hotel

Session Chair: David Dunand, Northwestern University

10:35 AM Invited
Coupling Effect of Porosity and Cell Size on the Deformation Behavior of Close-cell AlCu5Mn Alloy Foam Fabricated by Melt-foaming Route in Quasi-static Compression: *Donghui Yang*[1]; [1]Hohai University
Closed-cell AlCu5Mn alloy foam with porosity range of ~45-90% were fabricated by the melt-foaming route. The pore structure of the fabricated Al alloy foam was analyzed and the coupling effect of porosity and cell size on the quasi-static compression behavior of the foam was investigated. The results show that the cell size of the foam decreases with the porosity decline and the hierarchical pore structure characteristics becomes obvious when the foam porosity is low. During the compression process, for the foam with high porosity (>74%), the stress-strain curve is serrated due to the large cell size being easy to deform and more strain needed to let the stress recover. Meanwhile, the compression curve of the foam with low porosity (<74%) is smooth without serration, which is attributed to the hierarchical pore structure and less strain needed to let the stress recover.

10:55 AM
Improvement in Energy Absorption Capacity of Al-SiCp-CNT Hybrid Composite Foam by Addition of SiCp and CNT: *Bishnu Yadav*[1]; Dehi Mondal[1]; S Sriram[1]; Dilip Muchhala[1]; Pradeep Singh[1]; Amit Abhash[1]; [1]AMPRI
Hybrid composite foam (HCFs) of varying relative densities were made by liquid metallurgy route through stir casting technique using AlSi12Cu1Mg1 aluminium alloy as the base metal and SiCp and CNT were used as strengthening as well as a thickening agent. The CaH2 was used as a foaming agent, varies between 0.5 to 0.8 wt.% to get varying densities in these foams. The deformation behavior of these HCFs were investigated at a strain rate of 0.01/s. The HCFs exhibit uniform distribution of CNT and SiCp particles within the matrix when these are added together in the alloy. But when CNTs are added separately in the alloy, it has the tendency of agglomeration. These have been confirmed with the FESEM micrograph, Raman mapping, and microhardness. It was examined that plateau stress, energy absorption, and Young's modulus of hybrid composites foams are much higher(40 to 50% higher energy absorption)than monolithic composite foams.

11:10 AM
Influence of Temperature on Deformation of Closed-cell Aluminum Foams in Solid-liquid-gas Coexisting State: *Zhiyong Liu*[1]; Yanxiang Li[2]; Ying Cheng[2]; Xu Zhou[2]; [1]Heze University; [2]Tsinghua University
The influence of temperature on deformation of the closed-cell aluminum foam(CAF) in solid-liquid-gas coexisting state was studied. The results showed that the suitable deformation temperature was 635°C, the maximum deformation of the CAF could be obtained, and its characteristic parameters were kept. When the CAF was deformed at 635°C, the solidification microstructure among dendrites, fine dendrites and part of dendritic arms were melted into liquid, resulting in the degenerate dendrites were ripened into the rose-like grains, the fraction of the liquid in the CAF reached 50%, and rose-like grains were distributed discretely in liquid, the results mentioned above made cell walls thixotropic deformed easily. At the same time, the gas pressure in cells increased near three times that at room temperature that approximated to the rheological stress of the cell walls. Therefore, the cells can be moved together with thixotropic deformation of cell walls.

11:25 AM
Microstructure Design of Open-cell High Strength Steel Foams: *Jan Frömert*[1]; Alexander Matz[1]; Norbert Jost[1]; [1]Pforzheim University
This study presents a novel manufacturing process for high strength open-cell steel foams using investment casting. The influence of microstructure on the compressive properties of a martensitic stainless steel foam (AISI 420) was investigated. To enhance ductility and strength, quenching and partitioning heat treatment was applied to the steel foams, resulting in a microstructure consisting of annealed martensite and fine metastable austenite. Through the adaption of heat treatment parameters, a defined volume fraction of austenite can be stabilized up to room temperature in this martensitic steel. The composition of the dual phase microstructure greatly affects the compressive properties. Especially, time and degree of martensitic transformation in metastable austenite defines whether the steel foams possess brittle or ductile behavior. Therefore, it is possible to tailor the properties of the foams to fit the needs of possible applications by using just one material.

11:40 AM
High-fidelity Numerical Simulation of Open-cell Aluminum Foams Using Crystal Plasticity Modeling: *Dongfang Zhao*[1]; Joseph Tucker[2]; Ashley Spear[1]; [1]University of Utah; [2]Exponent
The objective of this work is to investigate the dependence of bulk- and ligament-scale mechanical response on grain structure of open-cell aluminum foam using a high-fidelity numerical framework. The grain-to-continuum compressive response of foam is investigated using the Finite Element Method (FEM). To accurately predict the local, micromechanical deformations at the grain scale, a crystal-plasticity constitutive model has been incorporated into the FEM driver. Also, grain-boundary strengthening and free-surface softening mechanisms have been implemented into the CPFEM framework to simultaneously account for the Hall-Petch effect in polycrystalline materials. A parallel effort focuses on algorithmic development for generating representative synthetic, polycrystalline, 3D foam models to help populate and expand an aluminum-foam design space. The foam features, along with the simulated compressive responses, are used as training data in a multi-variate optimization algorithm to provide insight into the correlation of local and global mechanical properties with foam microstructural features.

Characterization I

Wednesday PM	Room: Erie/Ontario/Huron
August 21, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Manas Mukherjee, Indian Institute of Technology Madras

1:30 PM Keynote
A Novel Method to Produce Foams from Metallic Melts: Melt Injecting Technique: Venkat Pamidi[1]; *Manas Mukherjee*[1]; [1]Indian Institute of Technology Madras
We present a novel method to produce metal foams. In this method, bubbles are created inside melt buy injecting a metallic jet into a pool of molten metal. This melt injection causes air entrainment inside the melt, which in turn results in bubble formation. We refer this method as melt injection technique. Al and Al-TiB_2 foams were produced with about 90% and 80% porosity, respectively. Al foams were produced without any additional step to create or add stabilising particles. It was observed that during the foaming process alumina layer and alumina particles formed at the gas-liquid interface of foam. The stabilisation of these foams was attributed to the combined action of oxide layer and particles. Structural and mechanical properties of these foams are comparable to the foams produced by other existing techniques. We also studied the mechanism of bubble formation due to air entrainment using a water model.

1:55 PM
Structural Control of Fe-based Porous Layer Fabricated through Combustion Synthesis for Joining with Resin Parts: *Asuka Suzuki*[1]; Kazuki Noritake[1]; Naoki Takata[1]; Makoto Kobashi[1]; [1]Nagoya University
In order to reduce CO_2 emission, multi-material structure has been focused on, in which the most suitable material is used at each component of vehicles. Joining technologies between dissimilar materials like metals and resins are required. We have developed a mechanical interlocking via porous layer. A resin is infiltrated into porous layer synthesized on a metal substrate to form interpenetrating phase layer (IPL), in which the metal and resin interlock three-dimensionally. We demonstrated that Al/resin joints via IPL exhibited high bonding strength. In the present study, to achieve Fe/resin joint, Fe-based porous layer was fabricated on a Fe substrate through the combustion synthesis reactions among Fe-Ti-B powders. Effects of Fe particle size and blending ratio of raw powder mixture on the porous structure was investigated. In addition, the bonding strength of Fe/epoxy resin joints via the porous layer was evaluated. Concept to establish high-strength Fe/resin joints will be discussed.

2:10 PM
Development of Rotational Incremental Hammering Process for Porous Metals: *Han Cui*[1]; Ryo Matsumoto[2]; Hiroshi Utsunomiya[2]; [1]Stanford University; [2]Osaka University
Porous metals have huge potential in various engineering applications, but their applications have been limited due to the lacking of studies on plastic working and metal forming. In this study, a new forming process named rotational incremental hammering was developed. Inspired by the friction stir welding process, the forming punch was rotated at high speed while indenting the workpiece to introduce localized heating and more intense plastic deformations. Open-cell nickel foam plates were shaped into simple stair-shape components with different forming parameters to exam the effects of tool rotational speed and indentation speed with respect to forming accuracy. It was found that the tool rotation at a higher speed and indentation at a lower speed are beneficial. Moreover, the component with complicated 3D stepped-shape was successfully manufactured with the developed process, and the feasibility of the developed process to be implemented in industries as a fast-prototyping technique was justified.

2:25 PM
The Challenge of Open Cellular Metal Foam Production: *Christian Hannemann*[1]; Mandy Uhlig[1]; Thomas Hipke[1]; [1]Fraunhofer Institute for Machine Tools and Forming Technology
Five years ago Fraunhofer IWU started research in open cellular structures as the market is growing caused by their large surface. Heat exchangers, filters and battery electrodes are examples for potential applications. Casted Aluminum foams are in serial production and we cooperate with the manufacturer but for prototyping of individual foams especially in combination with solid regions for fixing, encasing or sub-division new parameters and technological processes were developed. Advantageous, limitations and potentials will be shown. Alternatively, galvanic coating of PUR foams with Copper, Nickel and other metals is common, again buyable and state of the art. R&D activities related to application development and adapted geometries not yet realizable by conventional mass production will be shown. Investigations for graded strut-structures and cylindrical tube-like parts were intensified to reach serial production level. The lecture represents investigations, results, dropped and new approaches of all routes.

2:40 PM

Deformation of Porous Structure during Bonding Porous Aluminum with an Al–Si-based Alloy Brazing Sheet: *Tomohito Kurosaki*[1]; Makoto Kobashi[2]; Naoki Takata[2]; Asuka Suzuki[2]; Hiroki Tanaka[1]; Tadashi Minoda[1]; [1]UACJ; [2]Nagoya University

Improving the thermal conductivity of phase change materials (PCMs) by combining with porous aluminum has been reported. Bonding technologies between porous aluminum and other aluminum components is required for a practical application. In the present study, porous aluminum fabricated by space holder method were attempted to braze with an Al–Si-based alloy brazing sheet. Cross-sectional observation after brazing showed that the porous aluminum was metallurgically bonded to the brazing sheet. However, the porous aluminum was deformed, and the amount of deformation increased with increasing brazing temperatures, resulting in the reduced porosity near the interface between the porous aluminum and the brazing sheet. Electron probe microanalysis revealed the presence of silicon in the cell walls after brazing. Therefore, the liquid phase containing silicon migrated to the cell walls from the brazing sheets. We have concluded that the liquid phase migration into the cell walls caused deformation of the porous aluminum.

2:55 PM

Liquid Metal Route Foaming of Mg Alloy and Mg Matrix Composite: *Goarke Kumar*[1]; Akshay Devikar[1]; Deepak Bhosale[1]; Francisco Moreno[2]; Manas Mukherjee[3]; John Banhart[2]; [1]SRM Institute of Science and Technology; [2]Helmholtz Centre Berlin for Materials and Energy; [3]Indian Institute of Technology Madras

We developed a novel liquid metal processing route for foaming Mg alloy with large pore volume, uniformly distributed pores, comparable with the Alporas foam. Mg alloy containing Al and Ca at different concentrations, with and without stabilizing particle (SiC) are used for foaming. MgCO3 and CaCO3 are used as blowing agents and the gas evolution kinetics is studied using thermo-gravimetric and colorimetric techniques. The foams obtained are characterised using X-ray computed tomography for pore size distribution and pore circularity. The foaming behaviour of the Mg, influenced by the modified surface tension and viscosity of the melt is studied systematically. Microstructural investigation is performed to understand the effect of Al and Ca on providing stable and continuous oxides layer over the discontinuous MgO, that delays gas out-diffusion and enables foaming. The quasi-static compressive strength and energy absorption behaviour of Mg foams produced are also investigated.

3:10 PM Break

Porous Biomaterials

Wednesday PM	Room: Michigan
August 21, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Olaf Andersen, Fraunhofer Society

1:30 PM Keynote

Reticulated Titanium Foams for Intraoperative Manipulation of Customized CMF Implants: *Peter Quadbeck*[1]; U. Jehring[1]; G. Standke[2]; B. Kieback[1]; [1]Fraunhofer Institute for Manufacturing and Advanced Materials IFAM, Branch Lab Dresden; [2]Fraunhofer Institute for Ceramic Technologies and Systems IKTS

The therapy of cranio-maxillofacial defects typically require patient specific concepts. However, high costs and the need for rapid availability of such implants affect the attractivity of such solutions. Therefore a new approach on the basis of cellular metals has been developed. The main idea of the concept is to use pre-assembled open cell titanium foams with high porosity and thin struts, and intraoperatively adapt their shape with the help of a 3D-printed defect pattern. After post processing by cutting and bending, these structures are infiltrated by a pasty-like resorbable CaP-cement, which hardens after contact with water and provides the needed stability of the CMF-implant. Commercial pure Titanium foams have been realized by means of PM slurry replication method. In order to allow for appropriate post processing, low carbon, oxygen and nitrogen contents are needed. Thus, further development has been done in each processing step. As a result, low carbon containing raw materials have been selected and chemically pretreated to improve their debinding properties. The thermal debinding has been optimized by FTIR process gas analysis, which allows the efficient adjustment of the heat treatment regime. Further improvement has been realized by implementing a new concept of integrated debinding and sintering. In this way implant materials with contamination levels close to ASTM standards and adequate ductile properties have been developed.

1:55 PM

Effect of Interlamellar Spacing and Eutectoid Phase Content on the Mechanical Properties of TixAlyCo Foam: *Amit Abhash*[1]; Pradeep Singh[1]; Bishnu Yadav[1]; D Mondal[1]; [1]CSIR AMPRI Bhopal

The mechanical properties of TixAlyCo foam have been examined as a function of the eutectoid phase (EP) between a-Ti and Ti2Co content and interlamellar spacing. The Ti alloy foam had been treated with Kroll's reagent in order to obtain the microstructure of the sintered pellets. It was observed that the increase in EP content and the decrease in interlamellar spacing, increases the microhardness and strength of the sintered foam. It was further observed that the eutectoid phase content and interlamellar spacing significantly depend on the Co wt%. Increase in Co wt% increased the EP content and decreased the interlamellar spacing. The Al present in the sample made the solid solution and has an insignificant effect on the EP content. The cell sizes are measured and found to be invariant while a small change in cell wall thickness of the foam is observed with the EP content.

2:10 PM

Mechanical and Biocorrosive Properties of Magnesium-aluminum Alloy Scaffold for Biomedical Applications: *Kicheol Hong*[1]; Hyeji Park[1]; Yunsung Kim[2]; Michal Knapek[3]; Kristián Máthis[3]; Akiko Yamamoto[4]; Heeman Choe[1]; [1]Kookmin University; [2]University of Michigan; [3]Charles University; [4]National Institute for Materials Science

Magnesium (Mg)-aluminum (Al) alloy (AE42) scaffolds were synthesized via a camphene-based freeze-casting process with precisely controlled heat treatment. The average porosity was ~52% and the median pore diameter was ~13 micrometers. Deformation mechanisms were identified using acoustic emission (AE) signals and adaptive sequential k-means (ASK) analysis. Twinning, dislocation slip, strut bending, and collapse were dominant during compressive deformation. The corrosion potential of the Mg alloy scaffold (-1.44 V) was higher than that of pure bulk Mg (-1.57 V) owing to the inherent benefits of alloying. However, the corrosion rate of the Mg alloy scaffold was faster than that of bulk pure Mg due to the enhanced surface area of the Mg alloy scaffold. As a result of cytocompatibility evaluation following ISO10993-5, the concentration of the Mg alloy scaffold extract reducing cell growth rate to50% (IC50) was 10.7%, which is higher than 5%, suggesting no severe inflammation by implantation into muscle.

2:25 PM

Fabrication of Antireflective Ni-Cu Films in the Broadband: *Baorong Ji*[1]; Yuqiao Zeng[1]; [1]Southeast University

Due to its ability to capture almost all incident light, antireflective materials are widely used in stealth, detection and efficient optical energy conversion facilities, which have high practical value and strategic significance in aerospace, defense industry and energy. Such materials generally have high absorbance and low reflectivity. Here, we demonstrate a simple and cost-effective approach -- dynamic hydrogen bubble template (DHBT) method to fabricate antireflective Ni-Cu films. The antireflective films appear as a honeycomb-like structure on the microscopic scale and as a dendritic structure on the mesoscopic scale. It is this micro-nano composite hierarchical structure that enables the low reflective metal films in broadband. And we have successfully regulated the morphology and composition of the metal films in a certain range. With the optimal experimental parameters, the reflectivity of the mental films is lower than 3.7% in the UV-VIS-NIR region.

2:40 PM

Biological Response to Magnesium-based Foams Modified by Directed Plasma Nanosynthesis: *Viviana Marcela Posada Pérez*[1]; Patricia Fernández-Morales[2]; Juan Ramírez[1]; Ana Civantos[3]; Jean Paul Allain[3]; [1]Universidad Nacional de Colombia; [2]Universidad Pontificia Bolivariana ; [3]University of Illinois at Urbana-Champaign

Directed Plasma Nanosynthesis (DPNS) is a surface modification method that can penetrate the pores and produce dynamic interactions between magnesium foams and physiological environments. Since Mg foams are potential orthopedic biomaterials, the in vitro response of magnesium foams modified by DPNS was evaluated. In this case, the DPNS effect induced the surface transformation on CaP phases that improved on 65% the alkaline phosphatase (ALP) production of hBMMSC compared to the no treated foams. Moreover, the in vitro results suggested that the cultured cells (hBMMSC and J774) presented two different behaviors depending on their location on the foam. hBMMSC cells were wider and spread on the internal part of the pore while they were smaller and more rounded on the surface. In vitro cell proliferation assays, ALP, Alamar blue, TNF-alpha and IL 10 were performed on the foams. The materials were also characterized in terms of chemistry, morphology, and mechanical properties.

2:55 PM

Influence of the Composition and Deposition Process on the Properties of Bioactive Coatings in Porous Titanium: Yadir Torres Hernández[1]; Cristina Domínguez-Trujillo[1]; José Rodríguez-Ortiz[1]; Eduardo Peón Avés[2]; *Ernesto Chicardi Augusto*[1]; Rocío Moriche[1]; Eugenio Velasco-Ortega[1]; Aldo Boccaccini[3]; [1]University of Seville; [2]University of La Habana; [3]University of Erlangen-Nuremberg

Titanium implants fail due fundamentally to two reasons: bone resorption due to stress-shielding phenomena and a deficient osseointegration, which indicates the necessity of improving the biomechanical/biofunctional balance. In this context, the use of porous titanium to reduce the stiffness of implants, as well as coatings of hydroxyapatite and bioactive glasses to improve osseointegration, is widely recognized.However, the use of porous titanium and the demonstrated poor adherence and fragility of the coatings compromise the behavior during the implant's service life. In this work, the role of the substrate porosity (0, 30, 40, 50 and 60 vol. %, with size ranges of 100-200 and 355-500 μm) in mechanical performance, infiltration and adhesion of coatings is analyzed. Additionally, the correlation between the composition of the coatings (HA, BG and polymer based composites), deposition routes parameters (sol-gel, drop sedimentation and electrophoretic deposition) and properties (adhesion, micro-hardness and bioactivity) are also evaluated and discussed.

3:10 PM Break

Design of Porous Metals II

Wednesday PM
August 21, 2019

Room: Erie/Ontario/Huron
Location: Doubletree by Hilton Hotel

Session Chair: Norbert Babcsán, Innobay Hungary Ltd.

3:30 PM Invited

Hybrid Aluminium: Composites, Foams, Sandwiches – 3 to the 5th Power Industry Overview: *Norbert Babcsán*[1]; [1]Innobay Hungary Ltd.

Hybrid aluminium means the group of aluminium matrix composites, aluminium foams, and sandwich structures with aluminium foam core. The hybrid aluminium structure is deliberately designed at nano-, micro- or macroscopic levels. Depending on the complexity of the structure, we define mono- (aluminium matrix composite - AMC), double- (AMC foam) and triple- (AMC foam sandwich) hybrid aluminium. Closed cell aluminium foams are invented nearly 100 years ago. They are mainly targeted as structural materials. There are three main technologies: blowing agent mixing into foamable melt, powder compaction foaming, foaming with gas injection which are used to produce closed cell aluminium foams. Besides the light weight of the closed cell aluminium foams there are three main properties as aesthetics, specific stiffness and mechanical energy absorption which are driving three industrial customer groups: Design and building industry – key property is aesthetic. Defence and safety industry – key property is mechanical energy absorption Mobility and machinery – key property is specific stiffness.Based on public information the recent producers, the main products, the largest projects and market possibilities will be summarised. It will be shown that the most attractive product is the aluminium foam sandwich panel for replacing existing materials on the market if finally, large-scale cost-effective production starts.

3:50 PM

Viscoplastic Behavior of Additively-manufactured Polymeric Lattices with Triply Periodic Minimal Surfaces: *Aliaa Abu Ali*[1]; Oraib Al-Ketan[1]; Reza Rowshan[2]; Rashid Abu Al-Rub[1]; [1]Khalifa University; [2]New York University Abu Dhabi

Recently, the development of additive manufacturing techniques triggered a paradigm shift in the design of functional components allowing for complex topology-driven cellular lattices to be incorporated within these components for the aim of reducing the overall weight, enhancing multi-functionality, and facilitating manufacturability. In this paper, the compressive mechanical properties of different polymeric lattices based on triply periodic minimal surfaces are investigated and compared both experimentally and computationally. Cubic samples were designed, fabricated using powder bed fusion technique, and characterized using Computed Tomography and Scanning Electron Microscopy. The compressive mechanical properties were deduced and a finite-deformation hyperelastic/viscoplastic constitutive model was calibrated and employed to capture the full behavior of the lattices. The numerical simulations were in good agreement with experimental results for the ligament-based TPMS while significant deviation from experimental results was obtained for the sheet-based lattices which were attributed to uncertainty in measuring the actual relative density and manufacturing defects.

4:05 PM

An Auxetic Sandwich Panel for Mobile Devices: *Eun Byeol Park*[1]; Kiju Kang[1]; [1]Chonnam National University

Panels for mobile devices should be deformable to adhere to curved surfaces of human body, such as hips and thighs. However, most of solids have a positive Poisson's ratio and deform into an anticlastic-curvature under bending, resulting in inconvenience to carry in pockets. To date, the only way to let a panel deform into a synclastic-curvature for good physical adhesion is to use a 3D auxetic material composed of lots of unit cells with the size of tens micrometer. However, the fabrication of thin panel of 3D auxetic materials is technically difficult even with a top-notch 3D printer and costly. In this study, we introduce a novel method to fabricate an auxetic thin panel by sandwiching a polyurethane foam core between a pair of 2D auxetic face-sheets of stainless steel. The fabrication process is simple, inexpensive, and virtually no size-limitation. The properties are evaluated through FEA, tensile, and bending test.

4:20 PM

Use of Metalic Foam to Solve Shock Absorption Issies: *Cyrille Grimaud*[1]; [1]NEOLATTICE

The French GRIMS GROUP, expert in metallic foams commercial production since 5 years, developed new design foams in Vénissieux France (suburbs of Lyon). Significant efforts have been made devoted to identify nice metallic foam properties able, in many applications, to improve the behavior and the characteristics of the final products.A significant example of this performance will be presented during the presentation. It is relative to the anti-shock characteristics of a specific foam design wich can be of interest for industries that have to process and transport hazardous or dangerous materials in or out of the plant. A validation campaign at scale 1 of those properties has been organized in a specific testing installation. This will be shown in detail during the presentation.

4:35 PM

Fabrication and Properties of Protective Coatings on Pore Walls for Lotus-type Porous Copper: *Hao Du*[1]; [1]Institute of Metal Research, Chinese Academy of Sciences

Recently, coating has been deposited on pore walls of porous metals for not only fabrication of an alloy layer but also surface protection. In this case, the pore structure presents certain degree of difficulty to the deposition due to the shielding effect from pore walls. In our work, depositions of Ni coating, Ti coating, Al coating and Ni-P coating were achieved on pore walls of lotus-type porous copper by electroplating, arc ion plating(PVD), aluminization and electroless plating respectively. The structure of the coatings on pore walls including thickness, phase composition and its uniformity (distribution) were characterized, as well as the interface layer between coating and pore walls. The properties of the coatings including hardness, compressive properties, wear resistance and corrosion resistance were also evaluated. It is concluded that coatings can be employed to modify surface properties and supply protection for lotus-type porous metals.

4:50 PM

Microstructure Characterization and Investigation on Energy Absorption Properties of LM 9 Foam by Optimization Techniques: *Dipen Rajak*[1]; S Das[2]; Nikhil Mahajan[1]; [1]Sandip Institute of Technology & Research Centre (SITRC) Nashik; [2]Formerly with CSIR-Advanced Materials and Processes Research Institute, Bhopal-India

This paper deals with deformation characteristics of Aluminium alloy (LM9)-SiC composite foam prepared by melt-route. For evaluation of deformation characteristics and energy absorption capabilities, Aluminium composite foam is subjected to axial compression stress at different strain rates. The study shows improvement in energy absorption as a function of strain rates. In addition to the compression tests, two optimization techniques viz. Taguchi and Analysis of Variance (ANOVA) are employed for co-relating effect of pore size, absolute density, relative density, mass, strain rate on the mechanical properties of the foam. Taguchi method helps to establish optimizing parameters whereas ANOVA determines the contribution of each parameter to the plateau stress and energy absorption properties through S/N ratio. These techniques are useful for co-relating the different parameters and to improve the properties of composite foam by optimization of parameters. The LM9 alloy composite foam is characterized by FE-SEM for in-depth analysis of deformed samples.

Fabrication

Wednesday PM August 21, 2019	Room: Michigan Location: Doubletree by Hilton Hotel

Session Chair: Ashley Paz y Puente, University of Cincinnati

3:30 PM Invited

Fabrication of Metallic Lattice Structures via a Decoupled Printing and Alloying Approach: *Ashley Paz y Puente*[1]; [1]University of Cincinnati

Metallic scaffolds are excellent candidates for various structural and thermal applications due to their decreased density and increased surface area as compared to their bulk counterparts. However, many technologically relevant alloys are difficult, if not impossible, to fabricate in such geometries using either traditional manufacturing or newer additive manufacturing techniques. One alternative approach is to decouple the geometry and composition control by using 3D printing to create the geometrically complex scaffold structures from a pure metal or simple alloy as a precursor and then further alloy the part to reach the target composition. This talk will highlight two examples of scaffolds produced using this approach where either direct metal laser sintering or particle-based ink-extrusion 3D printing and gas-phase alloying via pack cementation are combined. Additionally, a route to producing such scaffolds with dual level porosity by hollowing the individual struts of the structure via the Kirkendall effect will be discussed.

3:50 PM

Production of Metal Foam with Sub-mm Bubbles Using a Rotating Gas Injector: *M.A. Noack*[1]; Ningzhen Wang[1]; Francisco García-Moreno[2]; John Banhart[2]; [1]Technische Universität Berlin; [2]Helmholtz-Zentrum Berlin/Technische Universität Berlin

Usually metal foams produced by the gas injection route have large and less uniform cells compared to foams made by the powder metallurgical route. In this work, a rotating gas injection system was used to produce uniform and small-sized gas bubbles in liquid metals. The system was applied to producing foam based on two materials: AlMgSi alloys in which Al2O3 or SiC particles were dispersed and ZnSn alloy containing ZnO. In the latter case, particles were produced in-situ by introducing SnO2 into a ZnSn melt to produce cluster-like ZnO particles surrounded by a Sn-rich phase in the melt. For AlSiMg-alloys, the influence of different particle sizes on the gas bubble diameter and uniformity of foams generated by the rotating system are shown. For both alloys, the influence of the inner diameter of the rotating canula, gas flow rate and the velocity of the canula tip are discussed.

4:05 PM

Sonication for the Porosity Gradation of Foams Meets Replica Templating: A Hybrid Manufacturing Process for Lightweight Multifunctional Structures: *Carmen Torres-Sánchez*[1]; [1]Loughborough University

Advancements in the design of porous structures with high performance properties offer a bright future to many industries such as transport (towards diminished fuel emissions) or medical devices (achieving personalised orthopaedics). However, the manufacturing of those parts lags behind because it is difficult to realise a complex porous structure design via conventional routes. Traditional manufacturing methods (e.g. casting) cannot produce complex porous distributions and new ones (e.g. 3D printing) have a limited palette of processable materials. We propose a hybrid manufacturing process in which a sacrificial cellular structure (i.e. polymeric porous foam) is tailored using a sonication technology [1] that increases density in zones where reinforcement is needed (e.g. stress loading) and decreases it where mass is not needed, achieving lightweight topologically-optimised structures [2]. This template is then used in a replica process to create porous metal structures with an ad-hoc porosity distribution for a bespoke application. [1] DOI: 0.1088/0964-1726/18/10/104001 [2] https://uk.comsol.com/paper/3d-acoustic-structure-interaction-of-ultrasound-in-fluids-for-the-manufacture-of-50351

4:20 PM

Ultra-light and Nanostructured Metallic Foams Synthesized by Plasma Electrolysis: *Ronan Botrel*[1]; Frédéric Durut[1]; Julien Pinot[1]; Cédric Chicanne[1]; Marc Theobald[1]; Vincent Vignal[2]; [1]CEA; [2]CNRS

In order to study laser-matter interactions on the Megajoule Laser facility, CEA has developed an innovative process using the Contact Glow Discharge Electrolysis technique (CGDE) to synthesize metallic foam. Under specific conditions, an uniform gaseous envelop is formed around the immersed cathode in the ionic solution. Due to the high electrical field at the electrode surface, plasma streamers are formed between the cathode and the liquid surface. When the electrical arcs meet the liquid, metallic cations are reduced to form metallic strands with a bush-like shape. In these conditions, several metallic foams can be obtained (Au, Cu, Pt, Ag, alloys ...) with a relative density of 0.5%. All strands of the foam are about 100 nm in diameter and are interconnected together to form porosity about 1 µm. This original process gives access to a new kind of metal foams which could be interesting for the development of new technologies.

4:35 PM
Numerical Simulations and Experimental Studies on the Microstructure and Properties of Nickel-based Lattice Materials: *Yanpeng Wei*[1]; Bo Yu[1]; Quanzhan Yang[1]; Peng Gao[1]; Jingchang Cheng[1]; Xun Sun[1]; Zhiquan Miao[1]; [1]Shenyang Research Institute of Foundry
As a new type composite material, nickel-based lattice materials presented the higher stiffness, strength and higher temperature resistance in comparison with the other metals. In this study, the microstructure of nickel-based lattice materials fabricated through casting combining with indirect addictive manufacturing technology has been studied, and the grain structure of nickel-based lattice materials has been simulated by using of a cellular automaton coupled with finite-element model(CAFE). The calculated grain structure is compared with the microstructure of the real lattice nickel. The results show that pouring temperature and cooling condition are found to be the most important parameters.

4:50 PM
Controllable Continuous Porosity via Powder Bed Fusion: *Scott Roberts*[1]; Ben Furst[1]; Takuro Daimaru[1]; Ryohei Gotoh[1]; Timothy O'Donnell[1]; Eric Sunada[1]; [1]Jet Propulsion Laboratory
In general, porosity is seen as a failure in additive manufacturing processes. However, in some instances, controlled porosity can be used as a positive. Through careful control of various machine parameters in a powder bed fusion machine, we have been able to crate tunable open porosity structures in SS316L, Ti-6-4, AlSi10Mg, and Inconel 625. Pore sizes can range from sub-micron to 250 µm. Porosities span 0 to 60%. Additionally, structures with multiple porosities (or fully solid) regions can be created, enabling greater design freedom than previously available. By combining our porous settings with microtrusses, pore sizes can be as large as desired. We demonstrate this capability to fabricate heat pipes, non-planar 2-phase evaporators, and more. Additionally, we characterize their performance and compare it to current state of the art technologies.

Thursday Plenary

Thursday AM	Room: Michigan
August 22, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Nihad Dukhan, University of Detroit Mercy

8:00 AM Plenary
Porous Metals by Freeze Casting: Challenges and Opportunities: *Ulrike G.K. Wegst*[1]; [1]Dartmouth University
In contrast to freeze-cast ceramics and polymers, few systematic studies on freeze-cast metals have been reported, to date. Reviewed in this presentation will be challenges and opportunities associated with the freeze casting process and its application to metals, also in comparison to polymers and ceramics. Described will be the different mechanisms that drive self-assembly and structure formation during the processing of water-based solutions and slurries by directional solidification, and how the resulting scaffold architecture and mechanical properties are affected, also by further processing steps such as sintering and infiltration with a second phase. Highlighted will be through case studies on the freeze casting of SS316L and Ti-6Al-4V scaffolds, how sedimentation in the slurry during freezing as well as volume shrinkage during burnout and sintering affect both their microstructure and mechanical performance.

8:30 AM Break

Characterization II

Thursday AM	Room: Erie/Ontario/Huron
August 22, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Francisco Garcia-Moreno, Helmholtz Zentrum Berlin Für Matl Und Energie

8:35 AM
Design and Fabrication of a Bronze Syntactic Foam by Low Pressure Injection Molding: Myranda Spratt[1]; *Joseph Newkirk*[1]; K Chandrashekhara[1]; [1]Missouri University of Science & Technology
Metal matrix syntactic foams are particulate composite foams composed of a supporting metal matrix and high strength hollow particles. These materials have higher specific strengths and specific stiffnesses compared to solid metals and metal foams. Reinforcement of the porosity in these foams is the primary cause of this increase in strength to density ratio. Metal matrix syntactic foams can be difficult to manufacture, however, without extensive fracture of the hollow particles. The goal of this study was to produce a component with little to no glass sphere fracture and low matrix porosity. Two testing parameters for this study were the composition of the aqueous binder and the sintering temperature. The strength-to-density ratios of the composite samples were measured with 3-point bending tests. A low-pressure injection molding machine was then used to fabricate components with the optimal binder composition. These samples were used to test the manufacturability of the chosen system.

8:50 AM
Corrosion Studies of Open Cell Aluminum Foam in Simulated Marine Environments: *Ho Lun Chan*[1]; Kevin Guo[1]; Rogine Gomez[2]; Vilupanur Ravi[1]; [1]California State Polytechnic University; [2]Cal Poly Pomona
Aluminum foams are used in aircraft components, e.g. landing gear energy absorbers, breather plugs, etc., because of their high impact absorption capability, low density, and cost-effectiveness. These materials can be subjected to chloride corrosion in marine environments, with the potential to lower the service life of these components. In this project, the microstructure and mechanical strength of aluminum foams pre-and post-corrosion were examined. The corrosion behavior of UNS A96101-T6 aluminum foams was studied as a function of pore density. Corrosion tests were performed by immersing aluminum foams in simulated seawater (ASTM G31) and also by exposing them to salt spray environments (ASTM B117) for periods of time ranging from 1 to 100 hours. The microstructures of the test coupons were subsequently characterized using scanning electron microscopy (SEM). Compression tests (ISO 13314) were conducted on pre-and post-corrosion coupons. The results of these studies will be presented and discussed.

9:05 AM
Effect of Gravity on Drainage and Liquid Imbibition in Evolving Metal Foams: *Felix Bülk*[1]; Francisco García-Moreno[2]; John Banhart[2]; [1]Technische Universität Berlin; [2]Helmholtz-Zentrum Berlin/Technische Universität Berlin
The examination of foams under varied gravity conditions – specifically microgravity – is a well-researched topic. Past research focused on metallic foams under microgravity in order to study viscosity, surface tension, coalescence and drainage. This study concentrates on the effect of drainage, but also of capillary forces and a consequential liquid imbibition. Creating artificial microgravity in parabolic flights allowed for X-ray radioscopic investigation of the foaming process. Hypergravity conditions were produced by a rotation stage, which was used at the same time for tomoscopic monitoring. Samples made of a foamable PM precursor and non-foamable aluminum alloy cast materials were used to analyze imbibition. First results show the ability to imbibe liquid against gravity-induced drainage in not only 1g but 1.8g condition and of drainage in radial liquid redistribution and density. The influence of smaller bubble sizes – due to smaller specimen geometry – towards centrifugal force respectively gravity is discussed.

9:20 AM

3D Characterization of an Open-cell Aluminum Foam under Compression Test with Combined In-situ High-energy X-ray Computed Tomography and Diffraction Microscopy: *Quinton Johnson*[1]; Jayden Plumb[1]; Kristoffer Matheson[1]; Peter Kenesei[2]; Hemant Sharma[2]; Ashley Spear[1]; [1]University of Utah; [2]Argonne National Laboratory

Characterization of open-cell, investment-cast, aluminum foam to compressive loading at the micro- and mesoscale is relatively unexplored and can facilitate a better understanding of foam deformation mechanisms. This work investigates the relationship between 3D grain structure and ligament-scale deformation through integration of far-field high-energy x-ray diffraction microscopy (FF-HEDM) and x-ray computed tomography (CT) data. A sample of 40 PPI foam was crushed in-situ at beamline 1-ID of the APS, allowing FF-HEDM and x-ray CT data to be gathered at four displacement steps. The result is a truly unique 3D foam representation where deformation of ligaments and cells can be analyzed in relation to grain size, grain (crystal) orientation, ligament shape, ligament orientation, and local strain tensor. Conclusions are drawn that highlight preferential ligament and grain orientation leading to deformation or fracture of ligaments and cells. The findings could shed new light on multiscale deformation mechanisms and potential foam size effects.

9:35 AM

Energy Absorption and Deformation Mechanisms of Porous Magnesium/Carbon Nanofiber Composites: *Qizhen Li*[1]; Huiru Xu[1]; [1]Washington State University

Porous magnesium is appealing to be employed in various fields such as automobile, aerospace, and biomedical industries. To further broaden its practical applications, it is crucial to understand the material's mechanical behavior. This work studied energy absorption and deformation mechanisms of porous magnesium/carbon nanofiber composites. The samples were prepared through powder metallurgy, characterized mechanically and observed under scanning electron microscope. The results show that (1) the addition of carbon nanofibers increased the material's energy absorption capability at a given deformation strain level for each overall porosity; (2) both yield strength and ultimate compressive strength decrease with the increase of the overall porosity when the concentration of carbon fiber is fixed; and (3) the porous magnesium composite samples with different porosities show different deformation mechanisms: the composite samples with low porosity exhibit stretch-dominated deformation with hard modes, while the composite samples with high porosity show bending-dominated deformation with soft modes.

9:50 AM Invited

Dynamic Phenomena in Liquid Metal Foams Studied by X-ray Tomoscopy: *Francisco Garcia-Moreno*[1]; Paul Kamm[2]; Tillmann Neu[3]; Felix Bülk[3]; Christian Schlepütz[4]; John Banhart[3]; [1]Helmholtz-Zentrum Berlin für Materialien und Energie; [2]Helmholtz Zentrum Berlin Für Matl Und Energie; [3]Technische Universität Berlin; [4]Paul Scherrer Institute

Dynamic phenomena in liquid metal foams are difficult to observe due to the complex nature of structure evolution and challenging environmental conditions. For this purpose, we use real-time in-situ X-ray tomography with acquisitions rates of up to 200 Hz and above, which we call "tomoscopy". With this technique we are able to observe and clarify key dynamic phenomena in evolving liquid aluminium foams such as nucleation and growth, bubble rearrangements, liquid retraction, liquid imbibition, bubble coalescence and the rupture of films time-resolved and in 3D. Here we also show that two different gas nucleation stages can be observed and that bubble coalescence is mainly caused by local pressure peaks caused by the blowing agent and to less extent by gravity-induced drainage as experiments under weightlessness and samples foamed without blowing agent show.

10:10 AM Break

Freeze Casting

Thursday AM — Room: Michigan
August 22, 2019 — Location: Doubletree by Hilton Hotel

Session Chair: Ranier Sepulveda Ferrer, Universidad de Sevilla

8:35 AM

Spaceborne In-situ Laboratory to Study the Solidification of Powder Suspensions during Freeze-casting in Microgravity: *Robert Lundberg*[1]; Kristen Scotti[1]; Maytham Alzayer[1]; Theodore Broeren[1]; Luke Duros[2]; Dominic Herincx[1]; Yingda Hu[1]; Richard Kunde[3]; Lawrence Luo[1]; Andrew McIntosh[1]; Chelsea Ye[1]; David Dunand[1]; [1]Northwestern University; [2]Trinity College; [3]University of Illinois Urbana-Champaign

Space Interface Convective Effects (SpaceICE) is a 3U CubeSat mission to be launched in 2019 that is designed to investigate freeze-casting in the microgravity environment of low-earth orbit. Freeze-casting is a low-cost, scalable technique for the fabrication of porous materials with application-specific architectures. During freeze-casting, slurries are directionally solidified and subsequently freeze-dried to create porous green body structures with anisotropic, aligned channels and walls. The goals of the SpaceICE mission are (i) to improve Earth-based freeze-casting methods by building a better fundamental understanding of the role of gravity during the solidification of suspensions; (ii) to produce benchmark data to improve modeling efforts of the solidification process; and (iii) to advance the freeze-casting technique as an in-situ resource utilization (ISRU) technology for space- and planetary-based load-bearing structures. Here, we discuss the design and functionality of the SpaceICE CubeSat—the first in-situ laboratory of its kind for microgravity solidification experiments.

8:50 AM

Effects on the Process Condition on the Fabrication of Iron Oxide Porous Materials by Freezes Casting: *Pedro Lloreda-Jurado*[1]; Ranier Sepulveda Ferrer[1]; Antonio Paul-Escolano[1]; Javier Herguido[2]; Jose Peña[2]; [1]Universidad de Sevilla; [2]Universidad de Zaragoza

Freeze-casting process is an attractive method to obtain porous materials with different pore morphology and sizes. It has the advantage of being scalable, cost-effective and environmentally friendly. Porous materials are manufactured in a 4-step process: 1) stable particle dispersion; 2) directional solidification; 3) solvent sublimation, and 4) sintering. The use of camphene as liquid base has certain advantages, its sublimation occur at ambient conditions and porous structures are created by dendritic replication. Nonetheless, the first step of the process is to ensure a stable particle dispersion in camphene, but literature concerning the interaction within this non-polar liquid is limited and scatter. Moreover, no rigorous study have correlate the effectiveness of the mixing process variables with the formation of a stable dispersion, to our knowledge.The aims of this work is determined the influence, of the mixing time, particle size and dispersant amount, over the viscosity and the final pores microstructure.

9:05 AM

Effect of Gravity during Solidification of Aqueous Particle Suspensions for Freeze-casting: *Kristen Scotti*[1]; Lauren Kearney[1]; Emily Northard[1]; Jared Burns[1]; Lucas Duros[2]; David Dunand[1]; [1]Northwestern University; [2]Trinity College

Freeze casting produces materials with aligned, elongated pores via directional solidification of particles slurries, rejection of particles between dendrites, sublimation of ice, and sintering of particles into walls that template the ice. Freeze-casting has the potential to produce porous metals with application-specific microstructures provided solidification conditions are properly controlled. However, the underlying principles that govern microstructure formation are only partially understood, making a priori predictions difficult. Here, we report the results of solidification studies of powder slurries where gravity-induced forces, which contribute to complexity during solidification (e.g., sedimentation, buoyancy, and natural convection), are minimized. Solidification experiments were conducted under reduced gravity conditions on parabolic flights; under normal gravity conditions, the effect of solidification direction with respect to gravity was studied. Through microstructural investigation of sintered samples, several gravity-driven defects have been identified, including tilting of wall orientation and ice lens defects (cracks oriented perpendicular to the freezing direction).

9:20 AM

Sensorization for the Modelling and Simulation of the Freeze-casting Technique: Paloma Trueba[1]; *Ana Beltran*[1]; J Bayo[1]; David Dunand[2]; Diego Larios[1]; Yadir Torres[1]; Jose Rodriguez-Ortiz[1]; [1]University of Seville; [2]Northwestern University

One of the suitable techniques for manufacturing c.p.-Ti with porosity gradient is freeze-casting. In this work, the authors are modelling this process and mechanical properties of the samples. It is based on experimental data: temperature, material and size of the mold, total and interconnected porosity (by Archimedes' method and image analysis) and mechanical behavior (by ultrasonic technique, uniaxial compression tests and instrumented micro-indentation). Here, we present more experiments, performed at different conditions (temperature, size of the Titanium particles); the characterization of the porosity of the samples fabricated under these new conditions are used to validate the model and perform simulations of the process. In particular, temperature is registered at three different distance (near, middle and far) from the cold focus, through the thermal sensorization of the device, so its variation is related to the resulting porosity distribution.

9:35 AM

Fabrication of Fe-Ni Laminated Porous Material by Sequential Freezes Casting: *Ranier Sepulveda Ferrer*[1]; Pedro Lloreda-Jurado[1]; Antonio Paul-Escolano[1]; [1]Universidad de Sevilla

Over the last decade, an increasing scientific research and industrial interes have been devoted to metallic porous materials. The freezes casting (FC) manufacturing process is able to create materials with elongated and highly interconnected pores and porosity range from 50-85%. During FC, a stable particle suspension is pour into directional solidification molds, in order to fabricate a sample. However, it is propose here to modify the pouring process, by switching alternatively suspension with different composition. Therefore, by using camphene suspension of Fe_2O_3 and NiO nanoparticle, a laminated porous material can be created. This work evaluates the influences of the process parameters such as cooling temperature, pre heat treatment, and sintering conditions, over the final microstructure and compression strength. The sample microstructures were characterized by field emission scanning electronic microscopy (FSEM) and tomography measurements (TOM). Mechanical performance, on the other hand, was determined by uniaxial compression test.

9:50 AM Break

Design of Porous Metals & Fluid Flow

Thursday AM	Room: Erie/Ontario/Huron
August 22, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Louis-Philippe Lefebvre, National Research Council Canada

10:35 AM

High-performance Micro/Nano-hybrid Porous Cobalt Oxide/Cobalt Anode for Use in Lithium-ion Batteries: *Hyeji Park*[1]; Kyungbae Kim[1]; David Dunand[2]; Jinsoo Kang[3]; Heeman Choe[1]; Jaehun Kim[1]; Yungeun Sung[3]; [1]Kookmin University; [2]Northwestern University; [3]Seoul National University

An "integrated" micro/nano-hybrid porous Co oxide/Co anode design was achieved using a facile processing method including freeze-casting and thermal oxidation for use as a high-capacity anode material of lithium-ion batteries. First, three-dimensional Co foam containing elongated and aligned micropores was synthesized using a freeze-casting method. Second, it was thermally oxidized to form nano-structured Co oxide coating on the surface of the Co foam. In this electrode design, the hierarchical Co foam was used as both a current collector and a nanowall-like Co oxide anode, which can react with lithium ions during discharging/charging. The integrated porous Co oxide/Co anode exhibited reversible capacity of 989 mAh g-1 even after 50 cycles with an initial coulombic efficiency of 99.4%, being superior to those of the conventional anode design based on Co oxide/Co foil anode (245 mAh g-1). The integrated porous Co oxide/Co anode has promising potential as self-supporting advanced anode for high-performance LIBs.

10:50 AM

Synthesis and Characterization of Metallic Syntactic Foams: *João Roberto Moreno*[1]; [1]Universidadade Tecnologica Federal do Paraná

The method for obtaining the metallic foam was Stir Casting, where the molten composite is agitated by a mechanical impeller. The foam synthesis was successful, and the results of the analyzes could show low wear rate, decrease in the density of the composite in relation to its matrix and homogeneity in the dispersion of reinforcements in the microstructure. The metallic foams are considered MMCs (Metal Matrix Composites), materials that have two or more constituent materials, a matrix that is necessarily metallic, and another material as reinforcement and not necessarily a metal. Generally light alloys such as aluminum, magnesium or titanium are used as a matrix in conjunction with ceramic particles or fibers. Finally, metallic syntactic foams are solid metallic foams, where porosity occurs due to the presence of hollow particles in their structure.

11:05 AM

Analysis of Bubble Accumulation Mechanisms and Cell Structure Evolution in Aluminum Foam with Sub-mm Sized Cells: *Ningzhen Wang*[1]; Mike Noack[1]; Francisco Garcia-Moreno[2]; John Banhart[2]; [1]Technische Universität Berlin; [2]Helmholtz-Zentrum Berlin/Technische Universität Berlin

The cell structure of aluminum foam affects its performance. If the cell size is small enough, the cells could be stable and round. In this work, the cell size of aluminum foam was reduced to less than 1 mm using a rotating gas injection system. The bubble accumulation process was observed by in-situ X-ray radioscopy. It was found that the foam can be divided into an upper dry foam and a lower wet foam as inverted conus. This is mainly formed by the friction between bubbles, which is caused by the pinning of particles between bubble walls. The angle of the inverted conus was also analyzed, which is related to the bubble size. The cell structure of the solid foams was characterized by X-ray tomography, and we found that nearly all cells are spherical if the cell size is concentrated around 0.8 mm.

11:20 AM
The Deformation of Expanded Clay Syntactic Foams during Compression Characterized by Acoustic Emission: *Csilla Wiener*[1]; Kristián Máthis[2]; Frantisek Chmelik[2]; [1]Loránd Eötvös University/MTA-BME Lendület Composite Metal Foams Research Group; [2]Charles University
The deformation and failure mechanisms in metal matrix syntactic foams were investigated in this study. The syntactic foam was produced by the infiltration method using lightweight expanded clay of different shapes as space holder and eutectic Al-12%Si alloy for the matrix. The samples were compressed at room temperature and the acoustic emission (AE) response and the surface deformation were monitored and collated with the deformation curve. Sequential k-means method was performed on the AE data in order to separate the AE events by their origin. Since the different deformation mechanisms during compression were overlapping, a new approach was applied in order to find the dominant deformation processes at a given deformation, making the recognition of the formation of deformation bands possible.

11:35 AM Invited
Structure and Permeability of Porous Structures Deposed by Shock Wave Induced Spraying: *Louis-Philippe Lefebvre*[1]; Nihad Dukhan[2]; B. Guerreiro[1]; E. Irissou[1]; C. Cojocaru[1]; A. Hmad[2]; O. Saad[2]; [1]National Research Council Canada; [2]University of Detroit Mercy
A new process (shock wave induce spraying) has been recently adapted to produce porous structures. During the deposition, the particles remain in the solid state. Unlike sintering, the new process allows the deposition of coatings with porosities up to 40%. This presentation describes the process to produce porous titanium and stainless steel structures, and presents the structure and permeability of the materials. In order to measure the permeability, thick specimens were deposited and detached form the support layer. Layered structures were produced to modify the porosity by depositing powder with different particle size distribution. Thick self-standing specimens allowed the evaluation of air permeability. The results indicate that the material is permeable if the porosity is sufficiently high but the porosity is significantly lower than those generally measured on metallic foams. Consistent with the results in the literature, the pressure drop is inversely proportional with the porosity and pore size.

Fabrication & Fluid Flow

Thursday AM	Room: Michigan
August 22, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Frédéric Topin, Aix-Marseille University-CNRS, Laboratory IUSTI

10:35 AM
Foaming of Al-Mg-X (X = Cu, Zn, Si) Alloys Using Mg as blowing Agents: *Georgy Kurian Kaladimadathil*[1]; Biswaranjan Muduli[1]; Manas Mukherjee[1]; [1]Indian Institute of Technology Madras
Al-15Mg-10Cu alloy foams produced by powder metallurgy route using Mg powder as blowing agent show uniform structure with high strength. The foams produced from this alloy are expected to have poor corrosion resistance. Also, a high amount of Mg in this alloy makes it brittle in nature, which is not suitable for industrial production. In this study, we replaced Cu in Al-15Mg-10Cu alloy by Si and Zn in order to improve the corrosion resistance of such foams. Similar foam structure was obtained by using Si and Zn. Since Si is lighter than Zn, further studies were carried out using Si. Later part of the study dealt with reducing Mg content without compromising the expansion and structure of foams. Mg was varied in the range of 2.5 to 15 wt.%. It was observed that 5 wt.% Mg results in similar expansion and structure as obtained using 15 wt.% Mg.

10:50 AM
Stabilization Mechanism of Cell Wall during Semi-solid Foaming of Al-Si Alloy: *Takashi Kuwahara*[1]; Akira Kaya[1]; Osaka Taro[1]; Satomi Takamatsu[1]; Shinsuke Suzuki[1]; [1]Waseda University
Aluminum foams have ultralight and excellent shock absorbing properties and they are expected to apply for light weight shock absorbing material. To fabricate aluminum foams, aluminum alloy can be thickened by primary crystals at a semi-solid temperature. This method can fabricate foams without additional thickener. However, the stabilization mechanism of cell walls during semi-solid foaming is not evident. To solve the problem, aluminum films were formed by dipping rings into the semi-solid Al-Si alloy at different temperatures (various fractions of solid). Films were held over the melt to generate drainage for various holding times. It was able to form the stable films when the fraction of solid was high, while the films sometimes raptured in low fraction of solid. This is because primary crystals tend to clog inside the film preventing the drainage to accelerate. Also, relationship between morphology of film and drainage time was discussed.

11:05 AM
Shaping of Aluminum Foam by Press Forming during Precursor Foaming: *Yoshihiko Hangai*[1]; Masataka Ohashi[1]; Ryohei Nagahiro[1]; Kenji Amagai[1]; Takao Utsunomiya[2]; Nobuhiro Yoshikawa[3]; [1]Gunman University; [2]Shibaura Institute of Technology; [3]The University of Tokyo
Aluminum (Al) foams are expected as components of vehicles and construction materials. Among the several routes for fabricating Al foams, a precursor foaming route has been commonly used to produce Al foam. In this study, optical heating, which can directly heat a precursor, was employed through metal mesh to obtain Al foam. Fundamental investigations on the press forming of the Al foam using a metal mesh as a die, which can transmit light during foaming, were conducted.

11:20 AM
The Stabilization Mechanism of Semi-solid Foaming Method by Primary Crystals: *Satomi Takamatsu*[1]; Takashi Kuwahara[1]; Ryunosuke Kochi[1]; Shinsuke Suzuki[1]; [1]Waseda University
In the semi-solid foaming method, the primary crystals act as thickener to stabilize the cell walls. As the size and the fraction of the primary crystals are usually larger than those preferable range of the conventional melt-route, the stabilization mechanisms should be different between the semi-solid foaming and the conventional one. The objective of this study is to propose the stabilization mechanism by primary crystals. Aluminum alloy foams were fabricated by adding TiH_2 as blowing agent into Al-6.4mass%Si in semi-solid state and solidifying them. Microscopic images on the cross-section through the center of the foams showed that some cell walls were agglomerated by primary crystals and thus should be stable since the drainage was disturbed by primary crystals. Following the percolation theory, the percentage of clogged cell walls exceeded the threshold, that is, the drainage in whole cell walls were disturbed. The foams are therefore expected to be stable.

11:35 AM Invited

Flow Laws and Heat Transfer in Metal Foams: State-of-the-art Correlations and Current Problems: *Frédéric Topin*[1]; [1]Aix-Marseille University-CNRS, Laboratory IUSTI

Despite the many works dealing with flow low (and heat transfer) in metal foam and similar media during the last half century, many questions remains open. The relation between morphological and transport properties are not still well understood and thus, leads to dispersed results in the literature. This scattering is mainly due to various ambiguities in the definitions, possible misinterpretation of parameters and inconsistencies in the measured quantities definition/terminology. Usually, porosity and pore diameter are used to correlate physical properties with morphological ones (Ergun Like approaches) although several other geometrical parameters play a significant role. On applied point of view there is still huge discrepancies between the various existing state of the art correlations; moreover, the applicability of such correlation on a given foam is not generally a priori known. Also, the growing use of 3D imaging technique and associated numerical simulations lead to changes in the usual definition of geometric parameters and requirements for flow and heat transfer properties definitions/uses. On a more fundamental point of view the flow regime thresholds (Darcy, cubic, Forchheimer, inertia) are still discussed along with associated parameters and conjugate heat transfer dependence on morphology. This talk tries to present recent development and discuss characterization issues by revisiting dedicated literature (with emphasis on fluid flow aspects) and confronting the various results against a dataset obtained from 3D numerical calculations on idealized Kelvin cell structures chosen.

Characterization III

Thursday PM　　Room: Erie/Ontario/Huron
August 22, 2019　　Location: Doubletree by Hilton Hotel

Session Chair: Dinc Erdeniz, Marquette University

1:30 PM Keynote

Performance of Composite Metal Foams against Various Threats, from Insect to Large Bullets: *Afsaneh Rabiei*[1]; [1]Department of Mechanical and Aerospace Engineering, North Carolina State University

Composite metal foam (CMF) is a new class of metal foams created by combining the metal matrix composite with metal foams. In this material, prefabricated hollow spheres are packed tightly into a metallic matrix creating a type of foam that contains both open and closed porosities. As such the performance of the material against various threats have been proven to be very unique. In this talk the performance of composite armors that are manufactured using CMF panels against blast and ballistics will be discussed. Moreover, some recent numerical and experimental studies on the performance of the material against simulated pool fire environment will be discussed. Last but not least, the results of some recent studies on resin infused CMF and its properties against abrasion, and insect adhesion will be discussed.

1:55 PM

Cenosphere/Aluminum Matrix Syntactic Foam via Stir Casting: Characteriastion and Deformation Behaviors: *Jeki Jung*[1]; Su-Hyeon Kim[1]; Cha-Yong Lim[1]; Yun-Soo Lee[1]; Hee-Ju Kim[1]; Yong Ho Park[2]; [1]Korea Institute of Materials Science; [2]Pusan National University

Aluminum matrix syntactic foams can be useful for energy-absorbing materials due to their low density and improved absorption efficiency of impact energy. Stir casting process can significantly help lower production costs as well as increase the homogeneity of aluminum matrix syntactic foams compared to the pressure infiltration process and powder metallurgy.In this study, we have attempted to synthesize the aluminum alloy matrix syntactic foams dispersed with cenospheres by stir casting. Through this process, the cenospheres could be distributed homogeneously into the Al-Mg matrix up to 50% of volume fraction. The magnesium in the melt enhanced the interfacial bonding between the matrix and cenospheres by formation of the MgAl2O4 at the interface. Quasi-static deformation tests and impact tests were carried out in order to understand the deformation properties of the foams. The relationship among microstructure, mechanical properties, and energy absorption capabilities in aluminum matrix syntactic foams was discussed in detail.

2:10 PM

Microstructural Characterization of Porous Cu by Vapor Phase Dealloying: *Qingkun Meng*[1]; Kai Wang[2]; Chonghang Zhao[3]; Lijie Zou[3]; Yibin Ren[4]; Mingyuan Ge[5]; Xianghui Xiao[5]; Wah-Keat Lee[5]; Yu-chen Karen Chen-Wiegart[6]; [1]China University of Mining and Technology/Stony Brook University; [2]China University of Mining and Technology; [3]Stony Brook University; [4]Shenyang Ligong University; [5]National Synchrotron Light Source – II, Brookhaven National Laboratory; [6]Stony Brook University/National Synchrotron Light Source – II, Brookhaven National Laboratory

Dealloying is an effective method to create nanoporous metals by selectively removing constituents from an alloy while the remaining elements self-organize into a continuous structure. Dealloying by aqueous solution or metallic agents rely on the differences in chemical reactivities or mixing enthalpies between elements. A novel method, vapor phase dealloying (VPD) uniquely takes advantage of the saturated vapor pressure difference between constituent elements at an elevated temperature. In this work, a Zn-30Cu (wt.%) alloy was employed to study the processing-structure relationship of this emerging and versatile dealloying method. The microstructural characterization of porous Cu dealloyed at different times and temperatures were carried out to study the feature size, phase constitution, chemical evolution. Moreover, the three-dimensional (3D) morphology was visualized by synchrotron X-ray nano-tomography. The mechanisms of the pore formation by VPD will be discussed. Overall, the work will bring potential development of novel porous materials by this emerging dealloying method.

2:25 PM

Compressive Behavior of Porous Aluminum with Aligned Unidirectional Pores with Various Relative Cell Wall Thicknesses: *Mahiro Sawada*[1]; Tomoya Tamai[1]; Daiki Muto[1]; Tomonori Yoshida[1]; Shinsuke Suzuki[1]; Matej Vesenjak[2]; Zoran Ren[2]; [1]Waseda University; [2]University of Maribor

Compressive deformation behavior of porous aluminum with aligned unidirectional pores was studied at various relative cell wall thicknesses. Although porous metals are used as materials for shock absorbers, its compressive behavior remains to be clarified. This research was done to clarify the cause of occurrence of the plateau region. Compression tests perpendicular to the pores were conducted. Equivalent plastic strain was obtained by digital image correlation. Also, stress and strain distributions were simulated by finite element analysis. Building a beam model enabled calculating plastic collapse stress for unit cell wall. This study revealed that flattening in the stress-strain curve was caused by the plastic collapse of cell walls. Following the collapse, deformation can be distinguished in 3 modes: plastic buckling, fracture, and deformation with neither of them. It turned out that these modes change according to the order of them mentioned above as relative cell wall thickness increases.

2:40 PM
In-situ Observation of Bubble Coalescence in Metallic Foams: *Paul Kamm*[1]; Tillmann Neu[2]; Christian Schlepütz[3]; Francisco García-Moreno[1]; John Banhart[1]; [1]Helmholtz-Zentrum Berlin; [2]Technische Universität Berlin; [3]Paul Scherrer Institute
In order to observe dynamic phenomena in evolving liquid metallic foams such as bubble nucleation, growth, rearrangement and coalescence, it is important to have a sufficient temporal resolution of the underlying method. The time span in which films burst (less than a millisecond) is difficult to resolve by conventional X-ray tomographic means. Limitations due to the usable photon flux, the image acquisition rate and the rotation of the sample should be considered. Our latest experiments attempt to investigate these events using a combination of cutting edge tomoscopic techniques and alternative reconstruction methods. It is shown how the order of topological bubble rearrangements induced by their coalescence can be specified, although this does not seem to be possible considering the high temporal resolution required.

2:55 PM
Compression Behavior of Low-pressure Casted AMC Syntactic Foams with High Porosity: *Pierre Kubelka*[1]; Alexander Matz[1]; Norbert Jost[1]; [1]Pforzheim University
Metal foams represent a class of material, which provides attractive mechanical properties due to the combination of a porous structure with a metallic matrix. This leads to high specific strength with high energy absorption during compressive deformation. In this field, the aluminum matrix composite (AMC) syntactic foams are representing a novel class of closed-cell metal foams. Past investigations of such structures were subjected to the compression behavior of syntactic foams made of Al combined with different ceramic spheres. This work examines the impact of different Al wrought- and cast-alloys on the compressive behavior of AMC syntactic foams with Al_2O_3 hollow spheres. To gain a hollistic understanding on the compression behavior, the influence of the microstructural and casting behavior are taken into account. This includes the interfacial interaction between the aluminum matrix and Al_2O_3 hollow spheres as well as the microstructure of the alloys themselves in the compressed and un-compressed state.

3:10 PM Break

Fabrication of Composites, Syntactic Foams, & Metallic Metamaterials

Thursday PM — Room: Michigan
August 22, 2019 — Location: Doubletree by Hilton Hotel

Session Chair: Simone Mancin, University of Padova

1:30 PM Keynote
A Novel Micro-architected Material, Shellular in a Minimal Surface: *Kiju Kang*[1]; [1]Chonnam National University
Shellular is a ultralight and micro-architectured material, composed of a single thin, smooth, continuous shell. In the form of a triply periodic minimal surface (TPMS), a Shellular exhibits superior strengths, because it has a constant curvature over the entire shell without stress concentration, and supports a load only by means of coplanar stresses, i.e., deforms stretching-dominated. Thus, the surface roughness that inevitably occurs during an additive manufacturing likely significantly decrease the strength and stiffness of a Shellular. A TPMS Shellular divides space into two sub-volumes that are equivalent, independent of, and intertwined with each other. Hence, it can play a role as an interface that blocks or transfers mass or heat between two sub-volumes in addition to supporting an external load. In this talk, the properties, fabrication methods, and potential applications are elaborated.

1:55 PM
study on the infiltration process and compressive behavior of steel matrix syntactic foams: *Quanzhan Yang*[1]; Bo Yu[1]; Yanpeng Wei[1]; Guang Hu[2]; Zhiquan Miao[1]; Jingchang Cheng[1]; [1]Shenyang Research Institute of Foundry Co. Ltd.; [2]Xi'an Jiao tong University
Metal matrix syntactic foams have been attracting considerable attention in recent years due to their potential for weight saving in packaging, armors, and vehicle structures. In this paper, CF-8 cast austenitic stainless steel–hollow Al2O3 spheres syntactic foams were prepared successfully by infiltration casting technology, which contain different outer diameters size of hollow Al2O3 spheres that are about Ø3.11mm, Ø3.97mm and Ø4.79mm, respectively. The effects of ceramic mould preheat temperature and diameter of hollow ceramic spheres on the forming process of infiltration casting of syntactic foams was analyzed. At last, the steel matrix syntactic foam's quasi-static compressive behavior is studied, and mechanical properties in terms of densification strain, yield stress, plateau stress and energy absorption capacity are evaluated.

2:10 PM
A Novel Integrated Preparation Method and Its Process Optimization of the In-situ Ordered Porous Aluminum Filled Tubes: *Hai Hao*[1]; Han Wang[1]; [1]Dalian University of Technology
Foam filled tubes (FFTs), as important lightweight structural materials to automobile industry, are usually prepared by inserting foam fillers into thin-walled tubes. However, there is no metallurgical bonding between foam fillers and thin-walled tubes. The aim of this study is to fabricate the in-situ ordered porous aluminum filled tubes by a novel integrated preparation method. The models of in-situ ordered porous aluminum filled tubes with different wall thickness were designed. The corresponding sand molds were fabricated by selective laser sintering technique. The in-situ ordered porous aluminum filled tubes were prepared by infiltrating the sand molds with molten aluminum at appropriate temperature condition. Due to the complicated internal structure and thin wall thickness, it is necessary to investigate the preparation process of infiltration casting by simulation. By the optimal preparation process, the in-situ ordered porous aluminum filled tubes were fabricated successfully. Their compressive properties and energy absorption behavior were investigated.

2:25 PM
Mechanical Properties of Periodic Interpenetrating Phase Composites Based on Triply Periodic Minimal Surfaces: Oraib Al-Ketan[1]; *Rashid Abu Al-Rub*[1]; [1]Khalifa University
IPCs are composites with co-continuous phases that interpenetrate each other. if one of the phases is removed the remaining phase will form a self-supporting cellular structure. In this work, we investigate the mechanical properties of novel types of 3D printed interpenetrating phase composites (IPCs) with periodic architectures. The topology of the architected phase is based on the mathematically-known triply periodic minimal surfaces (TPMS) that minimize the effects of stress concentrations and provide better reinforcement. Samples were designed using computer-aided design (CAD) and polymer-polymer two-phase IPCs were fabricated using Polyjet 3D printing technology. The mechanical behavior of these printed IPCs is investigated under uniaxial compression. Results show that while the hard phase ensures a larger fraction of the load, the softer phase confines cracks and prevent catastrophic failure. The IPCs follow a bending-dominated deformation behavior and are potential candidates for applications were damage toleration and vibration damping is a requirement.

2:40 PM

Topology-property of Metallic TPMS Metamaterials: Reza Rowshan[1]; *Oraib Al-Ketan*[2]; Rashid Abu Al-Rub[2]; [1]New York University Abu Dhabi; [2]Khalifa University

Mechanical metamaterials exhibit properties that depend largely on their topological attributes. In this work, stretching-dominated metallic metamaterials with triply periodic minimal surfaces (TPMS) topologies have been proposed and fabricated using the powder bed fusion additive manufacturing (AM) technique. The manufacturability of the proposed metamaterials has been assessed using SEM and CT-scanning. The samples were mechanically tested and their compressive mechanical properties were deduced. Results showed that the as-built sheet-based lattices yield better overall mechanical properties as compared to other stretching-dominated strut-based lattices due to the reduced stress concentration effect that is driven by the smoothly-curved shell of TPMS-based lattices. The Diamond lattice showed the best mechanical properties among all the examined topologies. Heat-treated samples exhibited much higher strength values than the as-built samples but at the expense of the ductility.

2:55 PM Break

Design of Porous Metals & Fabrication

Thursday PM	Room: Erie/Ontario/Huron
August 22, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Afsaneh Rabiei, North Carolina State University

3:30 PM Invited

Fabrication and Mechanical Testing of Micro-architectured Shape Memory Alloys: *Dinc Erdeniz*[1]; Ryan Weidinger[2]; Keith Sharp[3]; David Dunand[2]; [1]Marquette University; [2]Northwestern University; [3]Tex Tech Industries

Porous NiTi (nitinol) is of interest for bone implants because of its unique combination of biocompatibility, high strength, low stiffness, and shape-memory or superelasticity. In this work, micro-architectured scaffolds with high permeability and high surface area were 3D woven from shape-memory NiTi wires with a diameter of 190 μm. Subsequently, the following method was applied to bond the wires at contact points to achieve structural integrity: (i) a slurry consisting of a blend of NiTi and Nb powders is deposited on the surface of the NiTi wires after the weaving operation, (ii) the powders are melted to create a eutectic liquid phase which collects at contact points and (iii) the liquid is solidified and binds the NiTi woven structures. A bonded woven sample was deformed in bending and showed near-complete recovery up to 6% strain and recovered nearly half of the deformation up to 19% strain.

3:50 PM

Micro-architected TPMS Shell-based Lattices: Fabrication and Mechanical Testing: *Oraib Al-Ketan*[1]; Rachid Rezgui[2]; Reza Rowshan[2]; Huifeng Du[3]; Nicholas Fang[3]; Rashid Abu Al-Rub[1]; [1]Khalifa University; [2]New York University Abu Dhabi; [3]Massachusetts Institute of Technology

In nature, biological systems exhibiting topological hierarchy that spans over multiple length scales show extraordinary mechanical properties. Mimicking these architectural features can lead to the creation of man-made lightweight, yet mechanically robust materials. Despite their complexity, the emergence of advanced fabrication techniques such as additive manufacturing that can achieve complex architectures at small scales (i.e., nanometer and micrometer) facilitated the fabrication of such topologies. In this work, the fabrication and mechanical testing of micro-architected nature-inspired cellular materials are reported. The proposed lattices are based on triply periodic minimal surfaces (TPMS). These shell-based micro-architected metamaterials with high geometrical complexity were fabricated with feature sizes in the order of several microns using the direct laser writing two-photon lithography technique. The material orientation in the TPMS-based lattices alternates between different geometrical segments providing much efficient load-bearing capacity as compared to strut-based lattices.

4:05 PM

Study on the Technology of Manufacturing Foam Magnesium Alloy by Negative Pressure Penetration Casting Method: *Yihan Liu*[1]; [1]Northeastern University

In recent years, more and more attention has been paid to the development of magnesium alloys and its application.As magnesium is used to prepare the foamed metal, then the foamed magnesium alloy will display both the superior properties of the foam metal and the magnesium alloys.Thus further increase the family members of foam metal, and expand their application field. The fashionable preparation methods of foam magnesium alloys are as follows:Negative pressure penetration casting method, smelting foaming, investment casting, directional solidification, powder metallurgic method,and so on. The preparation methods of opened porous magnesium alloy are negative pressure percolation method, investment casting method and directional solidification method, the others are the preparation methods of closed porous materials. In this paper, the preparation of magnesium foams by negative pressure percolation method is discussed, and the properties and application fields of the foam magnesium materials prepared by this method are briefly introduced.

4:20 PM

Effects of Pore Structure on the Cyclical Oxidation/Reduction of Iron Foams: *Teakyung Um*[1]; Stephen Wilke[2]; Kicheol Hong[1]; Heeman Choe[1]; David Dunand[2]; [1]Kookmin University; [2]Northwestern University

Packed beds of iron powders can cyclically liberate/store hydrogen via theiron/iron-oxide reactions using hydrogen/steam, but they have limited cycle life due to powder sintering which limits, and eventually chokes, gas flow and increases diffusion distances. To address this issue, we synthesized iron foams with open porosity by directional freeze-casting of iron oxide slurries with two types of solvents (water or camphene) to achieve iron foams with elongated porosity. Two such foams - one with dendritic, the other with equiaxed pore structure - were redox-cycled at 800°C under hydrogen and steam. The cycled samples were examined by optical microscopy, scanning electron microscopy, and synchrotron X-ray tomography to assess the evolution of their porosity, as driven by three basic mechanisms: pore closing by sintering and pore formation by the Kirkendall effect (both due to mismatch in vacancy diffusive fluxes), and iron/oxide spalling (due to mismatch stresses from volumetric changes).

4:35 PM

Modeling of the Tape-cast Open-porous Microstructures: *Samih Haj Ibrahim*[1]; Tomasz Wejrzanowski[1]; [1]Warsaw University of Technology

This study deals with modeling of open-porous metallic structures used for high-temperature gas catalysis (i.e. Molten Carbonate Fuel Cells). Numerical models of the open-porous 3D microstructures were generated basing on the tape casting fabrication procedure. Each of the slurry casting components (nickel powder, porogen, liquid polymer and water) is represented by spheres with volume fraction based on real manufacturing recipes and the same size distribution as the powder particles. The discrete element method implemented in LAMMPs software with additional potentials was used to simulate packing and sintering process. To validate the obtained model, porous characteristics were compared with results from quantitative analysis of micro-tomographic images of the real materials. The results indicate that the model reflects the open-porous microstructures with sufficient accuracy. Further studies were extended to investigations of the influence of pore structure on the permeability of the material.

4:50 PM Invited

Implicit Modeling for Functionally Tailored Engineering Cellular Materials and Spatially Varying Structures: *Ryan O'Hara*[1]; [1]nTopology inc.

Advanced Manufacturing of cellular materials (foams, lattices, honeycombs, gyroids, etc.) has recently appeared in a variety of industrial applications, for aerospace and defense to medical implants to consumer products, as they can offer unique combinations of mechanical properties. Using advanced modeling capabilities it is possible to tailor the design and response of these cellular materials to behave in ways that have been previously been unachievable. In this presentation, we will present how implicit geometric modeling can be used to develop tailored cellular materials free from the limitations of mesh-based or feature-based design tools. Unit cells of cellular material can be continuously blended across any path and oriented to any vector field to achieve the desired material properties and structural response that is desired.

Heat Transfer & Fluid Flow

Thursday PM	Room: Michigan
August 22, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Simone Mancin, University of Padova

3:30 PM Invited

Metal Foam Applications: From Laboratory to Market: *Simone Mancin*[1]; [1]University of Padova

Porous media have been subject of intense research for more than a century so far. Open-cell metal foams present high surface area to volume ratio as well as enhanced flow mixing and attractive stiffness and strength. Metal foams have considerable applications in heat exchangers, cryogenics, combustion chambers, cladding on buildings, strain isolation, buffer between a stiff structure and a fluctuating temperature field, geothermal operations, petroleum reservoirs, catalytic beds, compact heat exchangers for airborne equipment, air cooled condensers and compact heat sinks for power electronics. This talk presents the most advanced research activities carried out at the NHT Lab of the University of Padova and at different international laboratories on the direct implementation of metal foams to commercial and industrial applications.Furthermore, this talk will tentatively present which are the still open questions and related issues that in some cases are hindering the deployment of this technology in many different applications.

3:50 PM

Experimental and Numerical Investigation of Heat Transfer Performance on PCM/Copper Foam Composite Heat Exchanger for Electronic Device Thermal Management: Ratiba Sabrina Ferfera[1]; *Brahim Madani*[1]; Rafik Serhane[2]; [1]University of Sciences and Technology Houari Boumediene ; [2]Centre de Développement des Technologies Avancées

Nowadays, there are many studies on the use of phase change materials (PCM) for the thermal management of electronic devices. This is due to their large latent heat storage capacity which usually occurs at a nearly constant temperature during the phase change of the material. However, these materials (PCM) have a major disadvantage: their low thermal conductivity, hence a poor diffusion of heat. Metal foams, which have interesting properties such as low density and high thermal conductivity, offer a promising solution for improving the low thermal conductivity of PCM. The purpose of this work is to experimentally determine the effects on heat transfer and flow of the insertion of cooper foam impregnated with paraffin into heat exchangers. To simulate the transport phenomena inside the composite material (PCM / Metal Foam), a microcellular model as a body-centered cubic geometry (BCC) is developed using the COMSOL Multiphysics software. The results obtained show that copper foam insert improves heat diffusion and thermal conductivity 12 times and 32 times, respectively, compared to a pure paraffi..

4:05 PM

Characterizing Interstitial Heat Transfer in Metal Foam Enhanced Phase Change Materials: *Wim Beyne*[1]; Kenny Couvreur[1]; Michel De Paepe[1]; [1]Ghent University

Thermal energy storage can be an important component for matching the fluctuating supply of renewable energy to an energy demand. One of the methods to store thermal energy is by using the latent heat of solid liquid phase change. To increase the power density, phase change materials can be combined with highly conductive fin structures such as metal foam. Presently, the heat transfer phenomena of solid liquid phase change in such complex three dimensional fin structures is not fully understood. Therefore, the present study investigates the temperature difference between phase change material and metal foam during melting. A set up is constructed which allows melting a rectangular enclosure filled with a metal foam enhanced phase change material. During melting, the temperature of the metal foam and of the PCM is measured for different heat fluxes. The resulting temperature differences allow determining criteria for using thermal equilibrium in modeling.

4:20 PM

The Effect of Geometry on the Thermomechanical Behavior of Metal Foams for Use in Heat Exchangers: Katherine Moody[1]; Skylar Mays[1]; *Mujan Seif*[1]; Matthew Beck[1]; [1]University of Kentucky

Heat exchangers are used to transfer heat from one medium to another. They are composed of an open-cell metal foam capable of effectively transporting heat. Because the foam has a complex random structure, thermomechanical properties are not isotropic throughout the volume. This complexity is generally overlooked, and properties are typically simplified to an imprecise macroscopic average. Here, we present a stochastic modeling approach for metal foam that allows for a thorough assessment of thermomechanical properties as a function of quantifiable structural factors (network coordination state, ligament aspect ratios, reduced density). The approach includes a computational toolkit for generating representative volume elements (RVE's), and a methodology for computing the distributions of thermomechanical properties for each distinct geometry. We report that the geometry has a significant effect on thermomechanical behavior, even while maintaining solid fraction. Based on these results, it is clear that geometry must be a major design consideration moving forward.

4:35 PM
Dynamic Response of Corrugated Sandwich Panels Subjected to a Composite Foam Projectile Impact: *Xin Wang*[1]; Lang Li[1]; Qian-Cheng Zhang[1]; [1]Xi'an Jiaotong University
The combined dynamic loading of blast and fragment caused by cased explosives such as improvised explosive devices (IEDs) and roadside bombings pose serious threat to both military and civilian vehicles in numerous conflict areas. It is an important task to design the corresponding protective structures. In the current work, a modified laboratory technique is employed to simulate this type of combined dynamic loading through using a composite projectile consisting of foam projectile and fragment simulation projectile. Upon this method, the dynamic response of fully clamped corrugated sandwich panels subjected to the composite projectile impact is observed. The deformation and damage modes of sandwich panels are obtained. Besides, the influence of geometrical parameters (face sheet thickness, corrugation core thickness, etc) are analyzed. This work ushers in designing ultralight protective structures to resist the combined loading of blast and fragment, and contributes as further fundamental research on applications, such as military vehicles.

4:50 PM
Oxidation/Reduction Cycling of Freeze-cast Iron Foams: *Stephen Wilke*[1]; Robert Lundberg[1]; David Dunand[1]; [1]Northwestern University
Iron-based material systems are attractive for a variety of energy conversion applications, such as solid oxide iron-air batteries, hydrogen production via the steam-iron process, and carbon capture in chemical looping combustion. However, the lifetime of these active iron materials is limited by sintering and pulverization caused by large volumetric expansions and contractions during oxidation/reduction cycling. To address this challenge, we use water-based freeze casting to create iron foams with lamellar macrostructures (50-80% porous) designed to accommodate the redox volume changes and mitigate sintering. We have characterized the macro- and micro-structural evolution of these foams using ex-situ metallography and SEM, as well as in-situ X-ray tomography. The in-situ study provides mechanistic insights and enables porosity measurement during cycling, which serves as a performance metric to compare the iron foams with iron-composite foams (containing 5-10 vol. % ceria or yttria-stabilized zirconia). The compositing phases dramatically improve foam structural stability and inhibit sintering.

Friday Plenary I

Friday AM	Room: Michigan
August 23, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Nihad Dukhan, University of Detroit Mercy

8:00 AM Plenary
Additive Manufacturing of Porous Metallic Structures with Designed Mesostructure: *Christopher Williams*[1]; [1]Virginia Tech
Taking inspiration from nature, metallic foam processing technologies have afforded the opportunity to fabricate lightweight, porous structures featuring either periodic or stochastic cellular topologies. Additive manufacturing technologies (AM, also referred to as 3D Printing) provide another processing route for metal foams; their layer-wise fabrication approach affords the opportunity to realize metallic structures with designed mesostructure, i.e., where the mesoscale topology is tailored to satisfy multiple design objectives. In this talk, Dr. Williams will present opportunities for leveraging AM to facilitate production of porous metal structures. His talk will highlight both direct printing routes (e.g., binder jetting of porous metal structures) and indirect printing routes, wherein AM is used to print a pattern/mold for traditional processes (e.g.., casting of lightweight metallic truss structures). The opportunities and applications for printing ultra-lightweight structures with hierarchical porosity for graded density and tailored absorption properties will also be discussed.

8:30 AM Break

Nanoporous Metals & Fabrication

Friday AM	Room: Erie/Ontario/Huron
August 23, 2019	Location: Doubletree by Hilton Hotel

Session Chair: Lorenzo Valdevit, University of California, Irvine

8:35 AM
Influence of Zinc on the Compaction and Foaming of AlSi8Mg4 Alloy: *Tillmann Neu*[1]; Jennifer Heßmann[1]; Paul Kamm[2]; Francisco García-Moreno[2]; John Banhart[1]; [1]Technische Universitität Berlin; [2]Helmholtz Zentrum Berlin
In order to improve powder compaction, additives such as different stearates are often added to metal powders and are then usually removed during sintering. Low-melting or highly reactive metals such as Zn, Sn or Mg have also been found to improve compaction quality. Foamable AlSi8Mg4 precursors with additions of 1-5 wt.% zinc are produced by uni-axial hot pressing and an optional heat treatment afterwards. The quality of compaction is assessed by measuring green density, electrical resistance and by microstructure analysis. The precursors are then foamed on a heating plate and foam evolution observed by means of X-ray radioscopy. The number and size of pores of the resulting foams are determined by X-ray tomography. The influence of the addition of zinc on the precursors is an increase in relative density and in nucleation site density together with a slight increase in overall foam expansion.

8:50 AM
Thermal Decomposition of Transition Metal Dichalcogenides as a Route to Synthesize Nanoporous Metals: *Swarnendu Chatterjee*[1]; Joshua Snyder[1]; [1]Drexel University, Chemical and Biological Engineering
Traditional dealloying techniques for synthesis of nanoporous metals are restricted to few noble metals and the primary challenges lie with obtaining homogeneity in precursor alloy and limiting the pore size within 100 nm upon spinodal decomposition. Here, we present gas phase thermal decomposition of transition metal dichalcogenides (TMDs) as an alternative to dealloying that generates nanopores for a broad class of metals including refractory metals like W, Mo, Re etc. The chalcogen is removed from the surface by both reaction with hydrogen and evaporation at temperatures which lead to the rearrangement and surface diffusion of the remaining metal that evolve into an interconnected bicontinuous nanoporous network. Based on varying dynamics of pore formation and residual chalcogen contents for different TMDs, we have proposed a mechanism that emulates the decomposition process. The availability of vast library of TMDs makes it a universal technique that can be utilized to make nanoporous metals.

9:05 AM

Hierarchical Bulk Nanoporous Aluminum for On-board Hydrogen and Heat Generation by Hydrolysis in Pure Water: *John Corsi*[1]; Jintao Fu[1]; Eric Detsi[1]; [1]University of Pennsylvania

Despite the remarkable advantages of hydrogen energy technology, challenges such as clean hydrogen generation and effective hydrogen storage still need to be addressed before a sustainable hydrogen economy can be realized. I will present a sustainable method to produce hydrogen on-board which involves: (i) selective alloy corrosion to fabricate hierarchical bulk nanoporous aluminum composed of both macroscopic and mesoscopic ligament/pore structures, with mesoscopic ligaments in the range of 10-20 nm; (ii) simultaneous recovery of sacrificial material during corrosion; and (iii) use of nanoporous aluminum to produce hydrogen and heat by hydrolysis with pure water with a yield of ~52-85% without any additives. The aluminum hydrolysis product can be recycled by a carbon-free aluminum extraction pathway developed by Elysis, a joint venture composed of high-profile aluminum suppliers and consumers. Finally, I will present the combustion of bulk nanoporous aluminum in ambient air to demonstrate its application as a combustion fuel catalyst.

9:20 AM

Real-time USAXS and WAXS Studies of Morphology Evolution in 3D Nanoporous Gold during Electrochemical Dealloying and Post-dealloying Coarsening: *Samuel Welborn*[1]; John Corsi[1]; Eric Detsi[1]; [1]University of Pennsylvania

I will present a fundamental study on microstructural and crystallographic evolution during electrochemical dealloying and post-dealloying coarsening by combining in situ and operando Ultra Small Angle X-Ray Scattering (USAXS) and Wide Angle X-Ray Scattering (WAXS) experiments we have developed to measure structural change on several length scales.[1] The experiments were realized with the simultaneous WAXS/USAXS capability of the University of Pennsylvania's Dual Source and Environmental X-Ray Scattering facility. Soyarslan and co-workers have investigated the morphological and topological similarities of nanoporous gold and Cahn's spinodal decomposition.[2,3] By fitting WAXS/USAXS curves with this model, we can map material properties to (specific surface area, ligament size), the sample as it evolves under both electrochemical and thermal treatments. 1.Welborn, S.S. & Detsi, E. Nanoscale Horiz. (Invited paper in preparation). 2.Cahn, J. W. J. Chem. Phys. 42, 93–99 (1965).3.Soyarslan, et al. Acta Mater. 149, 326–340 (2018).

9:35 AM

Influence of Heat Treated Calcium on the Stability of 6061 Aluminium Alloy Foam: *Vinothkumar Sundharamoorthi*[1]; Sankaran S[2]; Sathyan Subbiah[1]; [1]Department of Mechanical Engineering, Indian Institute of Technology Madras; [2]Metallurgical and Materials Engineering, Indian Institute of Technology Madras

Closed cell aluminium alloy foams are manufactured through liquid melt route with the addition of gas releasing agent such as TiH_2, ZrH_2 or $CaCO_3$ to the melt. Solidification of this molten alloy containing gas bubbles leads to formation of a closed cell metallic foam. Stability of the closed cell aluminium foams produced by Alporas route is achieved with the addition of calcium. Aluminium alloy foams produced by liquid route are also stabilized through the addition of silicon carbide, aluminium oxide, or magnesium oxide. In this work, heat treated calcium is added to the 6061 aluminium alloy melt to stabilize the liquid foam. Presence of calcium oxide in the heat treated calcium is expected to reduce the coalescence of pores and significantly influence the rheology of liquid in the interfacial region which enhances the stabilizing action. Studies on cell size distribution, cell wall thickness, and mechanical properties are reported.

9:50 AM Invited

Deformation and Damage Mechanisms in Nano-architected Metamaterials with Spinodal Topologies: *Lorenzo Valdevit*[1]; Meng-Ting Hsieh[1]; Yunfei Zhang[1]; Anna Guell[1]; Cameron Crook[1]; Jens Bauer[1]; [1]University of California, Irvine

The mechanical response of nano-architected materials with spinodal topologies is numerically and experimentally investigated. Spinodal microstructures are generated by the numerical solution of the Cahn-Hilliard equation. We show that, thanks to their uniform negative Gaussian curvature, spinodal shell-based materials in the density range of 0.01-1% are exceptionally stiff and strong, outperforming most lattice materials and approaching theoretical bounds for isotropic cellular materials. Next, we fabricate nano-architected ceramic metamaterials with spinodal topologies by pyrolysis of polymeric preforms printed by two-photon polymerization Direct Laser Writing: with the polymeric precursors fabricated at the nanoscale, virtually defect-free ceramic metamaterials ensue, which exhibit unprecedented combinations of specific strength and strain to failure. We show that the combination of the efficient spinodal topology and the exceptional strength of the base ceramic material at the nanoscale result in isotropic nano-architected ceramic metamaterials with exceptional specific strength and progressive failure. Finally, opportunities for scalability are discussed.

10:10 AM Break

Freeze Casting, 3D Printing, & Fabrication

Friday AM — Room: Michigan
August 23, 2019 — Location: Doubletree by Hilton Hotel

Session Chair: Jean-Michel Hugo, TEMISTh SAS, Hôtel Technologique

8:35 AM

Ti-TiB Composite Micro-scaffolds by 3D Printing and Sintering of TiH2+TiB2 Powder-loaded Inks: *Binna Song*[1]; Christoph Kenel[2]; David Dunand[2]; [1]Soochow University; [2]Northwestern University

Open-porosity micro-scaffolds, with regularly arranged Ti-TiB composite struts (~200 µm in diameter), are prepared by 3D-extrusion, at ambient temperature, of inks containing TiH2 and TiB2 particles. Upon heat-treatment of the deposited structures, TiH2 decomposes to Ti and a Ti-TiB composite is formed in-situ by dissolution of TiB2 particles and re-precipitation of TiB whiskers. We study here the kinetics of TiH2 decomposition, TiB2 dissolution, TiB precipitation and densification of the Ti-TiB composite struts for various sintering times and temperatures (1050-1200°C). The microstructure and mechanical properties of the printed Ti-TiB scaffolds are also investigated. This novel strategy for additive manufacturing is demonstrated here for in-situ reinforced Ti-TiB composites micro-scaffolds, but can be generalized to other system, with full control of macroporosity (open channels between struts, via printing) and microporosity (within the struts, via incomplete sintering).

8:50 AM
Iron and Nickel Micro-scaffolds with Porous Struts Created via 3D-extrusion-printing and Reduction of Oxide-particle Inks: *Christoph Kenel*[1]; Nicholas Geisendorfer[1]; Ramille Shah[1]; David Dunand[1]; [1]Northwestern University
We study the densification and pore shape evolution of 3D-printed, porous Fe and Ni micro-trusses produced by extrusion of inks (consisting of oxide powders, removable space-holder particles and binder) into continuous, interconnected struts. Upon heat-treatment in hydrogen, the binder is removed, the submicron oxides are reduced to metal and the microstruts are densified by sintering of these metallic powders while the space-holder particles create interconnected porosity within the metallic struts. The resulting scaffolds exhibit hierarchical porosity, combining inter-strut channels (~400 μm in diameter, e.g., for osseo-integration) with intra-strut pores to tailor the mechanical properties (~5-20 μm in diameter, e.g., to achieve lower stiffness). During the heat-treatment, the evolution of pore shape, size and fraction, the sintering of metal particles, and global and local shrinkage are occurring simultaneously. Using both metallographic cross-sections and in-situ tomographic reconstructions, we present here a study of the kinetics of, and interactions between, these various processes.

9:05 AM
Influence of Sintering Temperature on Fabrication of Open-cell 6061Aluminum Alloy Foams: *Tan Wan*[1]; Yuan Liu[1]; [1]Tsinghua University
The influence of the sintering temperature of space holders on fabrication of open-cell 6061 aluminum alloy foams was studied, while the spherical CaCl2 particles with diameter ranging from1.25-1.60 mm were used as space holders in this research. The results show that the appropriate sintering temperature range is 690-720˚C, space holders could be sintered together, and open-cell 6061 aluminum alloy foams with higher porosity could be obtained. Moreover, the space holders could be removed easily. When the space holders were held 2 hours in the range of 690-720˚C, the spherical CaCl2 particles were sintered together. Therefore, the contact among particles changed from point to surface, and the number of the cells with opening and connecting was increased , which made the space holders remove easily, and the open-cell 6061 aluminum alloy foams had higher porosity.

9:20 AM
Thermohydraulic Characterization of Additive Manufactured Two-phase Heat Exchangers Using Lattice Structure: Cédric Septet[1]; Olivier Le Metayer[2]; Georges El Achkar[3]; *Jean-Michel Hugo*[4]; [1]TEMISTh SAS, Hôtel Technologique/IUSTI Laboratory, CNRS UMR 7343; [2]IUSTI Laboratory, CNRS UMR 7343; [3]Tianjin Key Laboratory of Refrigeration Technology, Tianjin University of Commerce; [4]TEMISTh SAS, Hôtel Technologique
Heatsinks are extensively used to maintain electronic devices below critical temperatures. Due to the increasing power dissipated by integrated circuits and the compactness constraints, improved heatsinks design is needed to enhance the heat transfer released by the working fluid. Besides, the use of a working fluid with phase-change becomes necessary to reduce the temperature gradient inside the electronic component. Moreover, actual manufacturing processes impose additional constraints on the methods used to design the heatsinks. For all these reasons, manufacturers need appropriate tools to assist them in heatsinks design, optimization and manufacturing. In this context, additive manufacturing techniques were used to overcome many of these obstacles, forcing us to reconsider the approach used during the design. Therefore, the design phase requires appropriate numerical models and solvers to describe the fluid flow and heat transfer in the domain, which remains a major challenge in the case of multiphase flows with phase change. This step, however, could be expensive in time as the number of geometric parameters increases and the mesh needs to be fine due to complex treatment of interphase phenomenon. In this paper, an approach involving a combined numerical and experimental study was presented. A 4-equations model, developed for the thermohydraulic characterization of additive manufactured two-phase heat exchangers, was firstly introduced. In this model, the presence of solid matrix and fluid phases were represented at macroscopic scale by homogeneous media and the physical interactions by source terms. Some of the used source terms were linked to intrinsic characteristics of the solid matrix, whose formulations could be found experimentally. Therefore, experiments were carried out for different flow configurations in two-phase heat exchangers prototypes produced by additive manufacturing. The first results and the accuracy of the formulations proposed for the source terms were presented and analyzed.

9:35 AM Break

Composites & Design of Porous Metals

Friday AM
August 23, 2019

Room: Erie/Ontario/Huron
Location: Doubletree by Hilton Hotel

Session Chair: John Banhart, Helmholtz-Centre Berlin

10:30 AM
Innovating Architected Self-healing Materials as Adaptive Plasma-facing Components Designed for Extreme Plasma-burning Fusion Environments: *Jean Paul Allain*[1]; Aveek Kapat[1]; Heather Sandefur[1]; Ana Civantos[1]; [1]University of Illinois at Urbana-Champaign
One of the most significant design challenges for materials performance exposed to extreme environments (e.g. heat, pressure, radiation) is maintaining structural integrity while preventing or minimizing long-term damage. In this work biomimetic properties are adopted to introduce hierarchical surface structures from the nanoscale to the mesoscale to enhance the interface properties of refractory alloy porous metals for design of self-healing, adaptive nuclear fusion materials able to have two specific functions: 1) self-healing in the bulk structural material and 2) surface self-healing properties on the plasma-facing interface. Liquid-phase Li and SnLi coatings and nanoparticles act as a healing agent when the porous tungsten structure is damaged under plasma irradiation. The Li-Sn NPs upon melting begin to "fill" the porous tungsten structure and the lithium predominantly segregate to the surface of the tungsten-based material facing the plasma. Surface nanopatterning within the porous metal structure to enhance wettability and self-healing will be presented.

10:45 AM
Open-cell Aluminum Foam Core Sandwich with Density-graded Foam Core and Multi-metal Sandwich: *Vasanth Shunmugasamy*[1]; Bilal Mansoor[1]; [1]Texas A&M University at Qatar
In this work, we have prepared aluminum foam core sandwich (AFS) using soldering methodology. The methodology is adopted to create heterogeneous foam core containing density-graded core having varying relative density (*= 7%, 29%, and, 42%) foams. The as-received foams (*= 7%) are uniaxially compressed by rolling at room temperature to prepare different relative density foams. The density – graded foams were soldered using zinc filler to Al 1100 facesheets. Similarly as-received foams were soldered to 304 stainless steel (SS) facesheets using Al-Zn based solder to create a multi-metal AFS. The similar and dissimilar solder joints were analyzed using optical and scanning electron microscopes and Energy Dispersive X-ray Spectroscopy (EDS). The joints mechanical integrity are evaluated using Vickers microhardness and nanoindentation. Mechanical properties of sandwich were studied under compression and flexural loadings. The adopted methodology presents a novel way to create density-graded AFS and also multi-metal (Al foam/SS facesheet) sandwich composites.

11:00 AM
A Very Thin Sandwich Panel Reinforced with Diamond-like-carbon: *Yoonchang Jeong*[1]; Kiju Kang[1]; [1]Chonnam National University
A new kind of 3D micro-architectured materials named Microlattice was introduce in 2011. The material is composed of hollow truss elements and has superior mechanical properties at density below 10^{-2}g/cc. In this study, a fabrication method of very thin sandwich panel with Microlattice core and the overall thickness less than 1mm is described. In this process, diamond-like-carbon (DLC) are deposited on the face sheets to maximize its flexural strength and rigidity. To attain material properties of the constituent materials, the tensile test of Ni-P foils, DLC foils, and their composite are conducted. And an optimal design is sought for achieving the highest strength for a given weight. The mechanical behavior of the sandwich with the optimized dimensions is investigated by FEA and three-point-bending tests.

11:15 AM Break

Shellular Materials

Friday AM
August 23, 2019

Room: Michigan
Location: Doubletree by Hilton Hotel

Session Chair: Kiju Kang, Chonnam National University

10:30 AM
Mechanical Behavior of Shellular under Internal Pressure: SeungChul Han[1]; Chenghan Wu[1]; *Kiju Kang*[1]; [1]Chonnam National University
Shellular is composed of a thin, continuous and smooth shell. A triply periodic minimal surface (TPMS) has a continuous geometry with zero mean curvature at every point over the surface. we have found that the deformation of Shellular in a TPMS is stretching-dominated like the previous micro-architectured materials. The shell in a Shellular divides space into two sub-volumes, which can be independently used for mass exchanging, infiltration or electro-chemical reaction. For the applications, its resistance under a pressure difference between the two sub-volumes should be studied. The critical pressure for plastic yielding and elastic buckling and the transition between the two failure modes are investigated by FEA and experiments. And the empirical equations for the critical pressures are presented as functions of two non-dimensional parameters, i.e., volume fraction and relative thickness. Also, the pre-straining effect as a method for improving the pressure resistance and stress equalization of Shellular is investigated.

10:45 AM
Mechanical Properties of Shellular with Minimal Surfaces: *SeungChul Han*[1]; Kiju Kang[1]; [1]Chonnam National University
Shellular is a combination of "shell" and "cellular", and is a new type of micro-architectured material with its density lower than below 10^{-2}g/cc, composed of a smooth thin shell. We believe that the triply periodic minimal surfaces (TPMSs) is the most ideal as the micro-architecture for Shellulars. In this work, we investigate the mechanical properties of TPMS Shellular, fabricated using a novel technique to naturally form a template with the minimal surface. That is, polymer beads are arranged in a regular pattern, and then transformed into a TPMS shape of the template through a chemical process, named Han's treatment. The strength and stiffness of the metallic Shellulars fabricated from the templates are measured under compression, and the deformation is monitored in-situ using a Micro-CT and the results are compared with those of previous micro-architectured materials, composed of hollow trusses.

11:00 AM
A Novel Bioreactor System with a Shellular Scaffold: *Jiafei Gu*[1]; Shiyi Tan[1]; Yun-Jin Jeong[1]; Sin-Gu Jeong[1]; Dong-Weon Lee[1]; Kiju Kang[1]; [1]Chonnam National University
In tissue engineering, limited nutrients and oxygen medium cause hypoxic regions during cell proliferation due to mass transfer limitation. The main approaches to deal with this problem are vascularization of scaffold and culture with bioreactors. Here, we develop a circulation bioreactor system with a Shellular scaffold. The system is composed of Shellular scaffold, peristaltic pump, bioreactor chamber, pressure sensor and so on. The Shellular scaffold comprises two distinct sub-volumes intertwined with each other and separated by a single continuous semi-permeable membrane. One sub-volume is used for cell culture, while the other serves as perfusion channel, which is connected with circulation tubes for proliferation medium. The scaffold made from poly (L-lactic acid) has strength enough to withstand the working pressure and support the cells for bone and cartilage. The mechanical properties, microstructure, and wettability of scaffold are evaluated. The circulation permeability performance and cell growth of the system are also investigated.

11:15 AM Break

Friday Plenary II

Friday AM
August 23, 2019

Room: Michigan
Location: Doubletree by Hilton Hotel

Session Chair: Nihad Dukhan, University of Detroit Mercy

11:20 AM Plenary
Metal Foam Research Direction: Simplicity Versus Accuracy: *Kamel Hooman*[1]; [1]University of Queensland
This presentation summarises our recent work on metal foams mainly as heat exchangers in different industrial applications. Challenges that we face along the commercialization path will be touched on while some peculiar behaviours observed in different experiments, specific to metal foams, will be discussed. Numerical, experimental and theoretical techniques that we have developed or are under development will be presented along with approaches to lower the cost of the foams for application in lighting industry, fuel cells, condensers, waste heat recovery, heat pipes and thermal storage systems.

11:50 AM Concluding Comments

Poster Session

Wednesday PM
August 21, 2019

Room: Great Room
Location: Doubletree by Hilton Hotel

Session Chair: Nihad Dukhan, University of Detroit Mercy

Bonding Properties of Lotus-type Porous Cu/Sn-Ag-Cu/Cu Joint: *Sang-Wook Kim*[1]; Ji-Woon Lee[1]; Taek-Kyun Jung[1]; Soong-Keun Hyun[1]; [1]Inha University

Lotus-type porous metals which have arranged long cylindrical pores have anisotropic mechanical and physical properties due to their anisotropic pore structure. In particular, louts-type porous metals have superior strength and fluid permeability in the pore direction compared to isotropic porous metals. Thus it is expected to be applied to various industrial fields. To use lotus-type porous metals in various industries, a bonding techniques of lotus-type porous metals are essential. Previously, although welding properties of lotus-type porous Cu have been investigated by laser beam irradiation, works with the bonding of lotus-type porous Cu using filler metal have been reported rarely. In this study, lotus-type porous Cu was soldered using Sn-Ag-Cu solder paste with different pore directions. The bonding strength and interfacial microstructures were evaluated and then the relationship between bonding properties and pore structure were discussed.

Change in Compressive Properties of Lattice-structured Al-Si Alloy Fabricated by Selective Laser Melting under Various Heat Treatment Conditions: *Takafumi Wada*[1]; Asuka Suzuki[1]; Naoki Takata[1]; MAkoto Kobashi[1]; [1]Nagoya University

Selective laser melting (SLM) is one of the additive manufacturing (AM) techniques and makes it possible to fabricate lattice-structured materials with complicated shapes. Lattice-structured materials are expected to be applied as light-weight energy absorber. However, it is known that the lattice-structured materials show local shear deformation (shear band) due to its ordered periodic structure, resulting in a decrease in energy absorption efficiency. On the other hand, SLM-fabricated Al alloys exhibit unique microstructure and higher strength than the same alloys manufactured by conventional casting methods. Heat treatments decrease strength and improve ductility, which affects compressive properties of the lattice-structured Al alloys. In this research, effects of heat treatments on compressive properties of lattice-structured Al-Si alloy with bcc type unit cell were investigated. Shear bands formation depends on heat treatment conditions, indicating that compressive properties of lattice-structured Al-Si alloys can be improved by controlling material properties.

Compression Behavior of Low-pressure Casted AMC Syntactic Foams with High Porosity: *Pierre Kubelka*[1]; Alexander Matz[1]; Norbert Jost[1]; [1]Pforzheim University

Metal foams represent a class of material, which provides attractive mechanical properties due to the combination of a porous structure with a metallic matrix. This leads to high specific strength with high energy absorption during compressive deformation. In this field, the aluminum matrix composite (AMC) syntactic foams are representing a novel class of closed-cell metal foams. Past investigations of such structures were subjected to the compression behavior of syntactic foams made of Al combined with different ceramic spheres. This work examines the impact of different Al wrought- and cast-alloys on the compressive behavior of AMC syntactic foams with Al_2O_3 hollow spheres. To gain a hollistic understanding on the compression behavior, the influence of the microstructural and casting behavior are taken into account. This includes the interfacial interaction between the aluminum matrix and Al_2O_3 hollow spheres as well as the microstructure of the alloys themselves in the compressed and un-compressed state.

Decomposition Behaviour of Ti and Zr Hydrides Studied by Neutron Diffraction: *John Banhart*[1]; Clemens Ritter[2]; [1]Technische Universität und Helmholtz Zentrum Berlin; [2]Institute Laue-Langevin

TiH2 and ZrH2 are the most frequently used blowing agents for foaming low melting alloys based on aluminium or zinc. In order to tailor the temperature range of decomposition such hydrides are sometimes oxidised prior to their use. Their decomposition behaviour is usually studied by thermogravimetry and calorimetry. We applied neutron diffraction to gather more information about the decomposition of treated and untreated hydrides. In order to avoid strong incoherent scattering effects from hydrogen (1H) we used deuterated variants and could obtain high-quality diffraction patterns. In this way we were able to quantify the amount of hydrogen for different decomposition stages as well as changes of the lattice structure for a range of Ti and Zr-based blowing agents.

Effect of Process Parameters Manufacture on Aluminum Foams Acoustic Properties: Masoud Golestanipour[1]; *Amir Izadpanahi*[1]; Armin Dehnavi[1]; [1]Materials Research Group, Iranian Academic Center for Education, Culture and Research

Metallic foams are a novel branch of engineering materials have a wide range of industries application as good energy and acoustic absorbers. The current state of the art with regards to the production of aluminum foams is reviewed, with direct foaming of Al melt processing and a CaCO3 foaming agent used to generating lower material cost, a relatively low level of impurity presence, more uniform and finer cell structures to produce aluminum foams, consequently acoustic properties investigated. Calcium carbonate is found to be a highly effective foaming agent for aluminum and silicon carbide used to stabilize foam structure added to the aluminum molten so led to defects elimination, which result significant reduction in the thickness of melt drainage to achieve more uniform foams. Acoustic absorption investigated at various thicknesses and cell sizes which is indicated that enhancing the thickness and decreasing cell size causes improvement of Al-foam as acoustic absorbers

Enhanced Osteoblast Adhesion and Differentiation by Porous Ti Scaffolds Designed Using Space Holder Technique: Ana Fatima Civantos Fernandez[1]; Mercedes Giner-Garcia[2]; *Ana Maria Beltran*[3]; Maria Angeles Vasquez-Garcia[2]; Rocio Moriche[3]; Maria Jose Montoya-Garcia[2]; Jose Antonio Rodriguez-Ortiz[3]; Jean Paul Allain[3]; Yadir Torres[3]; [1]University of illinois; [2]Medicine Department, University of Seville; [3]Department of Engineering and Materials Science and Transportation, University of Seville

The fabrication of porous scaffolds has become an interesting biomimetic approach to anchor implants through bone growth, however, the design of pore volume, size and morphology remains a challenge. In this study, Porous Ti (PTi) samples were manufactured by a powder metallurgy technique (PM) using three different spacer particles size (100-200, 250-355 and 355-500 µm). PTi scaffolds were evaluated in terms of cell viability, adhesion and differentiation of murine and human osteoblasts cell lines. At day 1, PTi did not produce any cytotoxicity effects reaching more than 80 % of osteoblast viability. Osteoblast adhesion was similar to non-porous substrates, but ALP expression was enhanced in PTi. These finding suggest that PTi implants, designed by PM, are good candidates to reduce stress shielding limitation and the required cellular interactions to promote in vivo osseointegration and therefore, implants fixation.

Fabrication of an Ultrahigh Pressure Vessel Based on Shellular: *Yoonchang Jeong*[1]; Kiju Kang[1]; [1]Chonnam National University

Pressure vessels are widely used for fluid storage, under-water vehicles, and aerospace applications. Shellular is a new type of micro architecture, which consists of a continuous smooth shell and has superior mechanical properties at a low density. The unique micro-architecture provides an interface between two distinct sub-volumes that intertwine each other. In this work, a novel pressure vessel that has morphology of Shellular in a triply periodic minimal surface (TPMS) and its fabrication process is described. To achieve high strength for a given weight, a bi-layered shell of diamond-like-carbon and copper is used to form the Shellular. And finite element analysis is carried out to obtain the optimal morphology and dimensions. The mechanical behavior of the pressure vessel is investigated by internal pressure test.

Fabrication of Porous Layer on Fe Substrate through Laser-induced Combustion Synthesis: *Yuto Ueda*[1]; Asuka Suzuki[1]; Naoki Takata[1]; Makoto Kobashi[1]; [1]Nagoya University

Metal/resin joint has been required for multi-material structures, in which the most suitable material is used at each component of vehicle. We have suggested "metal/resin joint via porous layer." Resin was infiltrated into porous layer synthesized on a metal substrate to form interpenetrating phase layer (IPL), in which metal and resin interlocked three dimensionally. In the present study, laser-induced combustion synthesis reaction among Fe-Ti-B powder mixture was applied to fabricate porous layer on a Fe substance. Influence of laser conditions on structure of porous layer and adhesiveness between granular products and Fe substrate was investigated. It was observed that porous layer composed of many granular products was formed in specific ranges of laser power and scanning speed. Area fraction and the number of granular products changes depending on laser conditions but the size did not change much. The results of the adhesiveness will be also presented.

Fabrication of Shellulars with Various Minimal Surfaces Based on Beads Arranged in Regular Patterns: *Anna Na*[1]; Eunbyeol Park[1]; Hyuntaek Kong[1]; Hojung Seo[1]; Jonghyeon Seon[1]; Jaehong Seol[1]; Myeongcheol Jung[1]; Yongju Lee[1]; Seungchul Han[1]; Kiju Kang[1]; [1]Chonnam National University

Shellular is a new type of micro-architectured material. The first Shellular was fabricated based on a template formed by self-propagating photopolymer waveguide (SPPW) technology. Thereafter, the template was coated with a hold material on the surface and then the template was etched out. This configuration was similar to the P surface, one of the Triply Periodic Minimum Surface (TPMS). Subsequent studies showed that the constant curvature of the minimum surfaced shell supports the external load by the coplanar stress without causing bending. In this study, we propose a new fabrication method of Shellular based on regularly arranged beads. The Shellular specimens with various configurations of TPMSs such as P, I-WP, F-RD, N-14, D, and complementary D surfaces are fabricated and compared with mathematical models to check the similarity using X-ray tomography.

Finite Element Simulation of Compressive Behavior of Disordered Cellular Solids: *Takuya Hamaguchi*[1]; Keiji Matsuo[1]; Koichi Kitazono[1]; [1]Tokyo Metropolitan University

Compressive responses of 3D open-cell foams with regular and irregular structures are analyzed using the finite element method in this work. Structures of foams with different levels of randomness are characterized by a cell regularity parameter. Also, 3D Voronoi division is used to create FE model with such open cell foam structures with different cell regularity parameters. First, the effect of cell regularity on mechanical properties of foams is studied. Second, relationship with cell regularity and anisotropy of compressive properties. Subsequently, the effect of regularity parameter on macro destruction of cell structure is also studied. Simulations suggest that cell regularity has significant influence on the plastic characteristics. Also, the lower cell regularity, the smaller anisotropy of compressive properties. Macro destruction at an angle of 45 degrees of cell structure is suppressed according to decreased cell regularity.

Fluxless Soldering of Aluminium Foams: *Amir Izadpanahi*[1]; Meysam Mahdavi Shahri[2]; Masoud Golestanipour[1]; [1]Materials Research Group, Iranian Academic Center for Education, Culture and Research (ACECR), Mashhad Branch; [2]Nomad Neshan Research Center

Present research introduces a novel soldering method for joining aluminum foams to aluminum plates. In this method, a rotating aluminum plate is soldered to the aluminum foam using zinc-based solder material. Rotation of the aluminum plate over the solder material drags the solder material and stirring it during the soldering process and help the wetting in plate-solder-foam interfaces. Mechanical properties of the joint were investigated. Excellent tensile strength was obtained compared to those samples that are welded with the soldering flux but with no rotation involved. The method is introduced as flux-less stir soldering (FSS). Scanning electron microscope examinations showed diffusion has occurred between the solder alloy with both the aluminum foam and the aluminum plate.

Foaming Behaviour and Evolution of Cell Structure of Aluminum Foam with Extrusion Forming Precursor on Condition of Restrictive Foaming: *Lucai Wang*[1]; Yanli Wang[1]; [1]Taiyuan University of Science and Technology

A study of foaming behavior and pore structure of Al foams of PCM(Powder Compact Melting) process ,with extrusion forming precursor on condition of restrictive foaming , by integtrating real-time image pick up into digital analyzing of cross-section image ,has been presented in this paper. The results show that heating time t (sample temperature Ts) and heating rate (furnace temperature TL) are two main factors to affect foaming behavior and cell structure of Al foams for PCM process. When temperature of precursor reaches to its melt point, it will expand slowly with the molten process ongoing.

Impact Energy Absorption of Additively Manufactured Porous Aluminum Alloys with an Axisymmetric Acorn Shape: *Yuta Fujimori*[1]; Koichi Kitazono[1]; Chami Kigawa[1]; [1]Tokyo Metropolitan University

Porous aluminum will be used as an energy absorbing mechanism for the landing leg of the spacecraft landing on a celestial body. It is expected that the landing angle will be accrued when the spacecraft lands. The anisotropy of the compression behavior of the energy absorbing mechanism becomes a problem. In order to suppress the anisotropy at the time of compression, a hemispherical shape was planned to be adopted for the shape of the impact absorbing mechanism. However, when the landing angle is accrued, it is impossible to maintain a sufficient stroke and it is impossible to achieve the designated amount of energy absorption. For that reason, acorn shapes in which hemispherical shapes and cylindrical shapes are stuck are adopted. Therefore, in this study, the compression behavior when diagonal compressed porous aluminum is considered is considered.

Influence of Metal Foam Morphology on Heat and Mass Transfers Inside Methanol Steam Reforming Reactor: Abou Houraira Abaidi[1]; *Brahim Madani*[2]; [1]USTHB; [2]FGMGP/USTHB Algeria

Metal foam provides an ideal prerequisite for construction of heat exchangers, their porosity of up to 85 per cent makes easy for gases or liquids to flow through them, whereby the large surface area of the metal foam pores with the good conductivity of the metal enables the transmission of large amount of heat and low resistance to fluid flow.Many papers used the metal foam for intensification of heat and mass transfers, Settar et al founded that the macro-patterned design is a promising strategy that allows a significant improvement of temperature distribution in a reforming reactor of methane steam reforming. For the current study, we treat the performances of a methanol steam reformer to produce hydrogen, equipped with various metallic foam layers. The principal goal is the investigation of the influences of the metallic foam morphology on heat and mass transfers inside the methanol steam reformer.

Manufacturing and Characterization of Ti, Mg and Mg-Ti Samples for Biomedical Applications: *Julio Guzmán*[1]; Tillmann Neu[2]; Ana Beltrán[1]; Yadir Torres[1]; José Rodríguez-Ortiz[1]; Lia Stanciu[3]; Francisco Garcia-Moreno[4]; [1]Universidad de Sevilla; [2]Technische Universität Berlin; [3]Purdue University; [4]Helmholtz-Zentrum Berlin für Materialien und Energie

The low mechanical resistance of porous bioceramics and polymers compared to that of natural bone provides an opportunity for biodegradable metals such as Magnesium and its alloys to become a new benchmark in the manufacture of scaffolds and bone tissues. Magnesium is biodegrade and it can be completely reabsorbed avoiding the need for second surgeries. The use of magnesium with adequate interconnected porosity improves the stress-shielding. and allows the transport of body fluids through damaged tissues and the colonization of osteoblasts inside the pores. In this work, samples of porous Mg, Ti and Mg/Ti are manufactured by the space holder technique and characterized. The relationship between the variables of the manufacturing process, the porosity characteristics (analyzed by Archimedes' method, image analysis and X-Ray micro-tomography), the degradation rates (assays in simulated fluid), as well as the influence on macro (uniaxial compression and ultrasound) and micromechanical (P-h curves) behavior are studied.

Manufacturing Process and Characterization of Bioactive Gelatins Coated Porous Titanium: Aldo Boccaccini[1]; José Rodríguez-Ortiz[2]; Rocío Moriche[2]; Juan Cauich-Rodríguez[3]; *Paloma Trueba*[2]; Yadir Torres[2]; [1]University of Erlangen-Nuremberg; [2]University of Seville; [3]Centro de Investigación Científica de Yucatán

Porous titanium substrates coated with gelatinous composites are considered potential candidates to solve the stress-shielding problems and the osteochondral defects present in joint cartilages. Porous titanium substrates are coated with different gelatin and alginate based composite (using bioactive glass particles as reinforcement) and evaluating the effect of glutaraldehyde in the crosslinking of the gelatin. The gelatin successfully coated the surface and penetrated inside the pores of the substrate. The highly interconnected porosity of the gelatinous composite is thought to promote cell growth and vascularization. The evaluation of the properties was carried out in terms of elastic recovery, coefficient of friction and wear resistance of the coatings. From these results, the best biomechanical and biofunctional balance was achieved by porous titanium substrates with pore size of 100-200 μm and the coating with a composition of alginate and gelatin (50:50 vol.) filled with 5 vol.% of bioactive glass particles.

Microstructural Effects on Compressive Behavior and Deformation Band Propagation in Open-pore Metal Foams: *Alexander Matz*[1]; Bettina Matz[1]; Norbert Jost[1]; [1]Pforzheim University

Open-pore aluminum foams show high potential for usage in a great variety of applications, which is due to their highly porous structure in combination with its base material. In most cases and independent of their scope of application, their mechanical properties are always of interest.In the present investigation, the mechanical properties of investment casted open-pore metal foams are studied on the example of the binary alloy Al-11Zn subjected to different ageing treatments. Their effects are investigated by mechanical characterization methods. By compression testing of open-pore Al-11Zn foams, we notice microstructural effects being present to a differing extend as a function of the strain ε. At low strains, we observe these differences in mechanical performance to a very high extent, wherein this behavior is in direct conjunction with the deformation band propagation during compressive deformation. Our results are discussed with regard to the microstructural effects induced by the ageing treatments.

Preparation and Properties of Porous Titanium with a Hierarchical Structure Porous by Fibers and Powders: *Shifeng Liu*[1]; Mingjun Shi[1]; Xin Yang[2]; [1]Xi'an University of Architecture and Technology; [2]Xi'an University of Technology

Spherical titanium powder was prepared by plasma rotary electrode treatment and mixed with titanium fibers (D50 = 110 μm) according to different mass ratios.Porous titanium with a fiber/powder hierarchical structure porous was prepared by spark plasma sintering at sintering temperatures of 800˚C, 900˚C and 1000˚C under a sintering pressure of 20 MPa. The results showed that there were no new phases occurred of porous titanium with porosity of 1.24-24.6% after sintering. Titanium fiber and titanium powder were sintered using powder/powder, powder/fiber and fiber/fiber to form composite pore structures. The formation and growth mechanism of the sintered neck was a diffusion-dominated material migration mechanism during sintering. At higher sintering temperatures, the grain size is larger and the grains on the fibers are finer than the grains on the powder. The stress-strain curve of porous titanium showed no obvious yield point, and the compressive strength was higher at higher sintering temperatures.

Processing and Electrical Properties of Ni Foams Synthesized via Freeze Casting: *Sukyung Lee*[1]; Jason Tam[2]; Weiwei Li[2]; Hai Jun Cho[2]; Bosco Yu[2]; Heeman Choe[1]; Uwe Erb[2]; [1]Kookmin University; [2]University of Toronto

Owing to the inherent properties of Ni, including high electrical conductivity, catalytic activity, and corrosion resistance, Ni foams are excellent candidate materials in energy applications such as electrodes for batteries and dye sensitized solar cells, as well as current collectors in solid oxide fuel cells. In this study, we fabricated Ni foams with controlled structure and porosity through a simple and scalable directional freeze-casting technique. Multiscale structural characterization techniques, including XCT, SEM, and EBSD were employed to study the structure of the Ni foams. To demonstrate the applicability of the freeze-cast Ni foam for functional applications, electrical resistivity was measured by four-point probe technique. We found that the effective electrical conductivity of the freeze-cast Ni foam is substantially higher than commercially available Ni foam, owing to higher relative density and greater fraction of S3 twin boundaries present in the freeze-cast Ni foam.

Study on the Mechanical Properties of Composite Metal Foam Core Sandwich Panels: *Jacob Marx*[1]; Afsaneh Rabiei[1]; [1]North Carolina State University

Metal foams are known for their energy absorption under compression, but generally lack strength in tension. Metal foam core sandwich panels can offer a non-porous surface and improve the material's corrosion resistance as well as improving their strength in tension. Composite metal foam (CMF) is a type of metal foam that has superior mechanical properties compared to other metallic foams due to the presence of matrix in between its porosities as well as their uniform cell structure. The mechanical properties of CMF under various loading scenarios are well established, but mechanical properties of CMF core sandwich panels have yet to be reported. This work will report the mechanical properties of CMF core sandwich panels and compare those to bare CMF panel properties. The comparison of the two will offer further understanding of CMF core sandwich panels with variety of different combination of the face sheets and CMF core materials under tension, compression, and bending.

Synthesis and Application of Porous NiO/Ni Anode for Use in Advanced Lithium-ion Batteries: *Youngseok Song*[1]; June-sun Hwang[1]; Sukyung Lee[1]; Hyeji Park[1]; Jae-hun Kim[1]; Heeman Choe[1]; [1]Kookmin University

Lithium-ion batteries are used in a wide range of applications such as mobile phones, electronic devices and automobiles; however, they have not fully satisfied the issues raised by the low theoretical capacity of graphite anode for the current market demanding high capacity and high output. Therefore, transition metal oxides among various high-capacity anode materials are attracting significant attention as a potential high-capacity anode material with high theoretical capacity. Among them, nickel oxide (NiO) has a considerable theoretical capacity of 718 mAhg-1, but its conductivity is rather poor, lowering the charging and discharging time. In this study, Ni foam was fabricated via a freeze-casting method and porous NiO/Ni anode system was then created through a simple thermal oxidation. The microstructure of the fabricated porous NiO/Ni anode system was analyzed using FE-SEM, EDS and XRD. Additionally, its battery performance was evaluated using a standard half coin-cell test.

The Study on the Usage of Foamed Magnesium and Its Alloy: *Yihan Liu*[1]; [1]Northeastern University
Due to their good damping performance, impact resistance, electromagnetic shielding performance, sound absorption performance and biocompatibility, the foamed Mg alloys are widely used in the automotive, aviation, aerospace, shipbuilding industry, and they also have potential applications in all the weapons and equipment, construction industry, medical industry and so on. This paper summarized the Fabrication,characteristics and its usage of the foamed Magnesium and its alloy. The Potential application was Predicted for automobile structure body, spacecraft landing gear, shock absorber, buffer, filters, silencers, signal cabin, human skeletal repair and replantation.

Cooling of PEM Fuel Cell Stacks Using Open-cell Metal Foam: *Ali Hmad*[1]; [1]University of Detroit Mercy
For safe and efficient operation of the proton exchange membrane fuel cell (PEMFC), effective thermal management is needed. This study presents the use of aluminum foam in PEMFC's thermal management using forced air. An analytical study was performed using a bipolar plate air- cooled channel to examine the effects of temperature on fuel cell efficiency, and to study heat transfer and temperature distribution in the stack. The heat transfer and fluid flow for a thin layer of metal foam inserted between two bipolar plates of fuel cell stack was simulated using ANSYS- Fluent. The outcomes, such as local and average Nusselt number, axial pressure drop, and friction factor, were calculated. The velocity and temperature contours were drawn. Numerical results were verified by comparing to experimental results. Based on this simulation, a new design was provided to improve the thermal design of an air-cooled fuel cell by using metal foam.

Barium Transport Mechanisms in Porous Scandate Cathodes: *Mujan Seif*[1]; Thomas Balk[1]; Matthew Beck[1]; [1]University of Kentucky
Thermionic cathodes are key components in a wide range of vacuum electron devices (VEDs), including traveling wave tubes, microwave devices, thermionic energy converters, and more. A high performance subset of these, scandate cathodes, are fabricated by impregnating porous Sc_2O_3-doped W matrices with xBaO-yCaO-zAl_2O_3. The lifetime of these high performance cathodes is thought to depend on the rate at which evaporated surface Ba is replenished by Ba from within the porous bulk. To compute this rate, an understanding of the mechanisms by which Ba moves through porous W is critical. These mechanisms likely include surface diffusion and vapor flow, the latter being our focus. Previous work has calculated surface energies of a number of configurations of adsorbed Ba and O on the dominant facets present in the W grains. Currently, we use ab initio molecular dynamics to investigate conditions that instigate barium desorption from the aforementioned surface configurations.

Characterization and of Metal-foam Flow Field for PEM Fuel Cells: *Yussef Awin*[1]; Nihad Dukhan[1]; [1]University of Detroit Mercy
The efficiency of Proton Exchange Membrane fuel cells depends on the performance of the bipolar plates, which depends on the flow field design. The plates are typically graphite with parallel or serpentine channels. The drawbacks of graphite include weight, fabrication inaccuracy, cost and brittleness. Open-cell metal foam is investigated, via simulation and experiment, as a flow field/bipolar plate and compared to conventional graphite bipolar plates. The benefits of the novel design are established via comparison to conventional flow fields. Results for metal foam flow field show that the cell current and voltage densities were improved, and temperature distribution on the membrane was even, and within the allowable limit. As importantly, there was a significant weight reduction.

Open Porous Metal Fiber Structures for the Next Generation of Sorption-driven Heat Pumps and Cooling Machines: Torsten Seidel[1]; Marcel Fink[1]; André Schlott[1]; *Olaf Andersen*[1]; [1]Fraunhofer Society
Climate change demands the development of increasingly efficient heating and cooling technologies. Salt hydrates offer interesting hydration and dehydration temperatures and energies useful for energy efficient heat pumps, sorption cooling devices and thermal energy storage. As past research on zeolite heat pumps has shown, the combination of active material with advanced heat exchangers based on metal fibers leads to superior power densities for heating and cooling applications. A current project therefore investigates the combination of such heat exchanger technology in combination with different promising salts, like $MgSO_4$ or K_2CO_3, for application in sorption-driven devices.

Cylinder-pack Modeling of Open-cell Metal Foam for Flow and Heat Transfer: Nihad Dukhan[1]; *Omer Saad*[1]; [1]University of Detroit Mercy
Because of its morphology, accessible and huge surface and high porosity, the foam has investigated for flow and heat transfer applications. This study investigates certain staggered arrangement of thin cylinders that can provide the same transport effects as a given foam with known morphology and flow and heat transfer factors. The average cell diameter, surface area density and porosity are used to describe the foam. The transverse pitch of the cylinders is chosen such that the surface area density of the foam and that of the cylinders are equal. The diagonal pitch is determined such that the tortuosity of the foam is equal to the tortuosity of the cylinders, while the diameter of a typical cylinder from the porosity of the foam. By founding a robust, yet minimal, technique for representing the complex morphology of the, substantial savings in computational time and effort will be realized.

Research of Mechanical Characterization for Hypercube Models Created by Direct Metal Laser Sintering Method: *Jeongho Choi*[1]; [1]Kyungnam University
The objective is focus on finding mechanical properties for two models defined as Type 1 (core-filled) and Type 2 (core-spaced) model made by direct metal laser sintering (DMLS). There uses aluminum alloy AlSi10Mg powder and each model created as vertical additive manufacturing with the DMLS. After quasi-static compression, it showed Type1 shows 19% higher elastic modulus, 12% higher compressive yield strength, and 51.6% higher elongation. From the experiment, there found two reasons to make weaker models: melted metals by DMLS are not connected with each other preciously. In addition, anisotropy in a specimen created by the DMLS is the significant factor to decide stiffness or strength. Continuously, the two models hope to be made a sandwich core structure and to be investigating more deeply about bending or shear properties continuously. In a future, it is hope to see more upgraded 3D printing technologies for making more precise complex structures.

Elastic Properties of Open Cell Aluminum Metallic Foam Transformed through Hydrostatic Loading: *Mark Cops*[1]; J. McDaniel[1]; [1]Boston University
The microstructure of open cell metallic foams can be transformed through plastic deformation. This preferential buckling of the foam struts can lead to dramatically different ranges of material properties such as Poisson ratio. Traditional methods reported in the literature include incremental, orthogonal compression using a vice. The drawbacks of this method are that first, it is very time consuming. Second, in uniaxial compression, foam specimens tend to shear, resulting in distorted deformation. In this presentation, a method of hydrostatic loading is described in which the metallic foam is sealed and placed in a hydrostatic pressure chamber. Control of applied pressure yielded nearly instantaneous volume reduction. The resulting microstructure was then prepared and tested mechanically to evaluate elastic properties utilizing a load cell and digital image correlation.

Additively Manufactured Metallic Core for Sandwich Structures: *Okanmisope Fashanu*[1]; J. Newkirk[1]; K. Chandrashekhara[1]; [1]Missouri University of Science and Technology

Composite sandwich structures offer a unique combination of good mechanical performance and low weight, which makes them valuable in marine and aerospace industries. In a sandwich composite, the core increases the stiffness and strength. The cellular construction of core material provides lightweight capability as well as a deformation mechanism that allows efficient energy absorption. The current work focuses on the development of core materials for sandwich structures using metal additive manufacturing. The current work focuses on honeycombs using selective laser melting of 304L stainless steel. The mechanical behavior of the honeycomb was evaluated using out-of-plane compression tests. Results of experiments showed that failure occurs through a plastic buckling mechanism.

Designing Nanostructured Porous Surfaces to Enhance in Vitro Osseointegration: *Ana Fatima Civantos*[1]; Akshath Shetty[1]; Andrea Mesa Restrepo[1]; Jean Paul Allain[1]; [1]University of Illinois

Titanium (Ti) and its alloys have been used for orthopedic and dentistry applications due to its good mechanical and biocompatibility properties. However, the stress shielding effect related to higher Young`s modulus than bone tissue, and lack of bioactivity which contributes to poor osseointegration, reduce their medical application. Designing surface properties of biomaterials mimicking the nano level surface structure of extracellular matrix (ECM) has become an interesting approach to activate cellular functions. Therefore, the biocactivation of porous cp.Ti was developed by Directed irradiation synthesis (DIS). These nanofeatures obtained by Argon ion irradiation were in the entire surface including pores wall. These nanoripples showed an important role on cellular process and as a result, cell viability and adhesion of osteoblast (MC3T3) were increased (more than 85%) at 24h. Using DIS we could show remarkable effect of osteoblast and macrophage cell lines which would improve porous Ti application in bone tissue regeneration

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