THE 1ST TMS SUMMIT ON INTEGRATED

MANUFACTURING & MATERIALS INNOVATIONS

November 15-18, 2015

The Westin Convention Center Hotel | Pittsburgh, Pennsylvania, USA

FINAL PROGRAM

Sponsored by: TMS

www.tms.org/IMMI2015

Events Schedule & Table of Contents

EVENTS SCHEDULE

Sunday, November 15		
Registration	5:00 p.m. to 7:30 p.m.	Rotunda
Welcome Reception	6:00 p.m. to 7:30 p.m.	Pennsylvania West
Monday, November 16		
Registration	7:00 a.m. to 5:00 p.m.	Rotunda
Exhibition Set-up	7:00 a.m. to 8:00 a.m.	Somerset
Opening Plenary	8:00 a.m to 9:10 a.m.	Westmoreland
Break	9:10 a.m. to 9:30 a.m.	Somerset
Technical Sessions	9:30 a.m. to 12:00 p.m.	Westmoreland
Lunch Break	12:00 p.m. to 2:00 p.m.	Pennsylvania West
Technical Sessions	2:00 p.m. to 3:30 p.m.	See pages 10-12 for locations
Break	3:30 p.m. to 3:50 p.m.	Somerset
Technical Sessions	3:50 p.m. to 5:00 p.m.	See pages 10-12 for locations
Summit Dinner	5:30 p.m. to 8:00 p.m.	Allegheny I
Tuesday, November 17		
Registration	7:30 a.m. to 5:00 p.m.	Rotunda
Technical Sessions	8:00 a.m. to 9:10 a.m.	See pages 12-16 for locations
Break	9:10 a.m. to 9:30 a.m.	Somerset
Technical Sessions	9:30 a.m. to 11:00 a.m.	See pages 12-16 for locations
Lunch Break	12:00 p.m. to 2:00 p.m.	Pennsylvania West
Technical Sessions	2:00 p.m. to 3:30 p.m.	See pages 12-16 for locations
Break	3:30 p.m. to 4:00 p.m.	Somerset
Technical Sessions - Panel	4:00 p.m. to 5:00 p.m.	Westmoreland
Networking Reception	5:00 p.m. to 6:00 p.m.	Somerset
Wednesday, November 18		
Registration	7:30 a.m. to 4:00 p.m.	Rotunda
Technical Sessions	8:00 a.m. to 9:30 a.m.	See pages 16-18 for locations
Break	9:30 a.m. to 10:00 a.m.	Somerset
Technical Sessions	10:00 a.m. to 12:00 p.m.	See pages 16-18 for locations
Lunch Break	12:00 p.m. to 2:00 p.m.	Pennsylvania West
Exhibition Dismantle	12:00 p.m. to 2:00 p.m.	Somerset
Closing Plenary	2:00 p.m. to 4:00 p.m.	Westermoreland

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WELCOME TO

THE 1ST TMS SUMMIT ON INTEGRATED MANUFACTURING & MATERIALS INNOVATIONS

On behalf of The Minerals, Metals & Materials Society (TMS) and the summit organizers, I am pleased to welcome you to this unique event. Manufacturing has been dramatically enriched by advances in computational modeling, process control hardware and software, new materials discovery, new types of equipment, and the reapplication of both established and emergent processes. The opportunities afforded by synthesis of these elements are unprecedented, particularly as they relate to the integration of materials innovations with new advances in manufacturing. The 1st TMS Summit on Integrated Manufacturing and Materials Innovations will convene relevant stakeholders—including researchers, educators, and engineers—to assess the state-of-the-art in materials-related aspects of manufacturing, define limitations and barriers to implementation of innovations in this area, and roadmap key areas of future development in the field. It will also serve as an opportunity for members of manufacturing institutes and consortia to report out and coordinate on key issues centered about materials innovations.

We look forward to an exciting meeting of dynamic discussions, outstanding speakers, and interactive panel discussions, and we thank you for your participation in this inaugural Summit!

Warmest regards on behalf of the Summit Organizing Committee.

Frank Gayle,
Summit Organizing Chair

ORGANIZING COMMITTEE:

Frank Gayle, *Deputy Director, Advanced Manufacturing National Program Office, National Institute of Standards and Technology*

Dianne Chong, *Vice President of Materials, Manufacturing, Structures, and Support (retired), Boeing Research and Technology*

Robert Hyland, *Director, Process Technology, U.S. Steel Research*

James McGuffin-Cawley, *Chair, Department of Materials Science and Engineering, Case Western Reserve University; and Executive Committee Member, America Makes*

William Mullins, *Program Officer, Office of Naval Research, U.S. Naval Materials Division*

ADVISORY COMMITTEE:

John Carsley, *Staff Researcher, General Motors R&D Center*

Amber Genau, *Assistant Professor, University of Alabama, Birmingham*

Edward Herderick, *Advanced Technologies Leader, Advanced Manufacturing Initiatives Group, GE Corporate*

Mark Horstemeyer, *Chief Technical Officer, Center for Advanced Vehicular Systems, Mississippi State University*

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Paul Mason, *President, Thermo-Calc Software Inc.*

Farrokh Mistree, *Professor, University of Oklahoma*

Paul Prichard, *Senior Staff Innovation Engineer, Kennametal*

Charles Ward, *Lead for Integrated Computational Materials Science & Engineering, U.S. Air*

Heather Watson, *Senior Application Engineer, Alcoa*

Chenn Qian Zhou, *Executive Director, Center for Visualization through Simulation, Purdue CalumetForce Research Laboratory*

REGISTRATION

Your full registration badge ensures admission to each of these events:

- Technical Sessions
- Sunday Welcome Reception
- Monday, Tuesday, and Wednesday Lunch
- Monday Summit Dinner
- Tuesday Networking Reception

Registration Hours

The registration desk will be located in the Rotunda.

Sunday	5:00 p.m. to 7:30 p.m.
Monday	7:00 a.m. to 5:00 p.m.
Tuesday	7:30 a.m. to 5:00 p.m.
Wednesday	7:30 a.m. to 4:00 p.m.

Internet Access

Complimentary internet access is available for attendees in some public areas of the hotel and in all hotel guest rooms.

Technical Sessions

All oral presentations will be held in the Westmoreland and Cambria of the Westin Convention Center Hotel. All poster presentations will be held in Somerset. See the Technical Program section on pages 9-18 for room locations.

EXHIBITION

Exhibition Hours

The exhibition will be located in Somerset. Visit the table tops during summit hours and programming breaks.

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

CORPORATE SPONSORS

ExOne
ExOne, a publicly traded manufacturing technology company, provides 3D printing machines, 3D printed products and related services to industrial customers in multiple segments including pumps, automotive, aerospace, heavy equipment and energy. The ExOne® process utilizes binder jetting technology with industrial strength materials ranging from metals to silica sand and ceramics to reduce costs, lower the risk of trial and error and create opportunities for design innovation. We collaborate with our customers through the development and production to materialize new concepts. ExOne is the optimal partner for any industrial manufacturer who is transitioning their manufacturing business to the digital age.

Thermo-Calc Software
Thermo-Calc Software is a leading developer of software and databases for calculations involving computational thermodynamics and diffusion controlled simulations. Thermo-Calc is a powerful tool for performing thermodynamic calculations for multicomponent systems. Calculations are based on thermodynamic databases produced by the CALPHAD method. Databases are available for steels, ferrous based slags, Ti, Al, Mg, Ni-superalloys and other materials. Software Development Kits which enable Thermo-Calc to be called directly from in-house developed software or MatLab are available. DICTRA is used for accurate simulations of diffusion in multicomponent alloys. Applications include: homogenization of alloys; microsegregation during solidification; coarsening of precipitates; and joining. TC-PRISMA is a new tool for predictions of concurrent nucleation, growth, dissolution, and coarsening of precipitate phases.

Sente Software
We offer materials-focused simulation software for modeling the behavior and properties of multi-component alloys used in industrial practice. JMatPro® calculates: stable and metastable phase equilibrium, solidification behavior and properties, mechanical properties, thermo-physical and physical properties, phase transformations and chemical properties. Data export available to casting, forming, forging and heat-treatment simulation packages. www.jmatpro.com.

SPONSORS

U.S. Department of Energy,
Advanced Manufacturing Office (AMO)

National Science Foundation (NSF),
Civil, Mechanical and Manufacturing Innovation (CMMI) Division

National Institute of Standards and Technology (NIST),
U.S. Department of Commerce,
Materials Measurement Laboratory and Materials Science and Engineering Division
Award 60NANB15D271

Summit Policies and Information

POLICIES

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

Refunds
The deadline for all refunds was October 23, 2015. No refunds will be issued at the Summit. 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.

Anti-Harassment
In all activities, TMS is committed to providing a professional environment free of harassment, disrespectful behavior, or other unprofessional conduct.

TMS 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 a 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.

NETWORKING & SOCIAL EVENTS

Welcome Reception
The Welcome Reception will be held on Sunday, November 15 from 6:00 p.m. to 7:30 p.m. in Pennsylvania West.

Summit Dinner
The dinner will be held on Monday, November 16 from 5:30 p.m. to 8:00 p.m. in Allegheny I at the Westin Hotel.

Networking Reception
A Networking Reception is planned for Tuesday, November 17 from 5:00 p.m. to 6:00 p.m. following the technical sessions in Somerset. Don't miss this great networking opportunity!

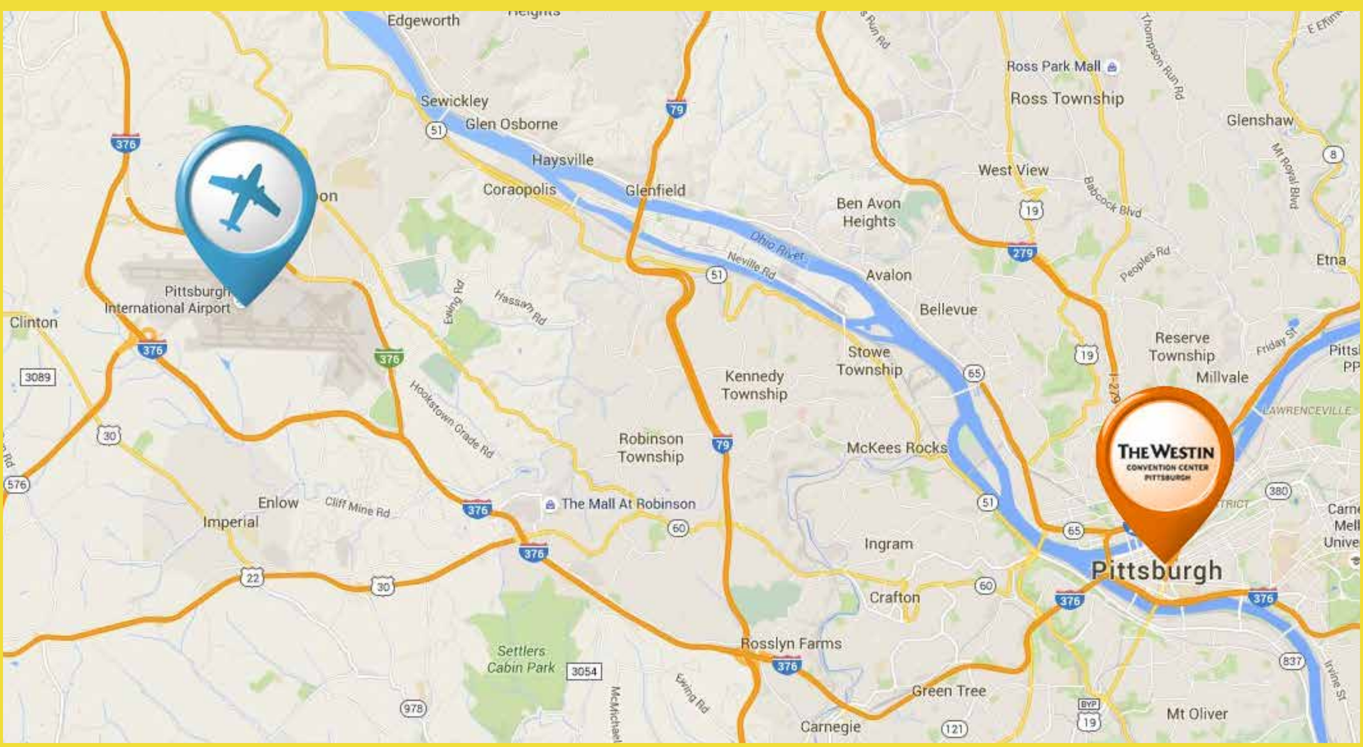
ABOUT THE VENUE

The Westin Convention Center Pittsburgh immerses you in the heart of the city, making travel convenient for both business and leisure guests. Countless attractions are within walking distance from this hotel location. Whether you enjoy sports, theatre and art, or unique dining options, this hotel puts you in the middle of it all. The hotel offers complimentary high-speed internet access in all guest rooms. For more information, visit www.westinpittsburgh.com.

Parking and Shuttle Service

The Westin is 17 miles (25 minutes) from the Pittsburgh International Airport. There is an airport shuttle bus that provides convenient transportation between our Pittsburgh hotel and Pittsburgh International Airport. The shuttle runs 24 hours a day and advance reservations are required. Please call 1-800-258-3826, or visit www.supershuttle.com to make your reservation. The shuttle costs $24 one way and $46 round trip.

The hotel offers on-site hotel valet parking with in and out privileges for $26 per night. Self-parking without in and out privileges is subject to availability for $22 per night. For alternative off-site parking or oversized vehicle parking (over 6') please contact the hotel for assistance. The complimentary Westin hotel shuttle operates within a one mile radius of the hotel Monday through Friday from 7:00 a.m. to 11:00 p.m. Contact the hotel for additional information.



Driving Directions From Pittsburgh International Airport

Take Route 60 towards Pittsburgh through the Fort Pitt Tunnel and exit at Liberty Avenue. Follow Liberty Avenue to 10th Street. Turn left, and the hotel is on the right. For the most convenient and least costly trip from the airport to The Westin Convention Center, take the SuperShuttle. For pricing and more information, visit the SuperShuttle website.

Summit Speakers

OPENING PLENARY SPEAKERS

David Britten
Senior Vice President-Chief Technology Officer, United States Steel Corporation

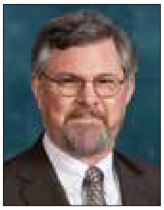
Susan Helper
Frank Tracy Carlton Professor of Economics, Case Western Reserve University

Mark Johnson
Director,
Advanced Manufacturing Office, Energy, Efficiency, and Renewable Energy, U.S. Department of Energy

Ed Morris
Director,
America Makes – National Additive Manufacturing Innovation Institute

Alan Taub
Chief Technical Officer,
Lightweight Innovations for Tomorrow (LIFT), American Lightweight Materials Manufacturing Innovation Institute (ALMMII)

CLOSING PLENARY SPEAKERS

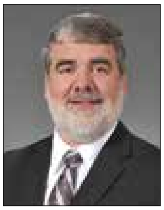


John Allison
Professor and Director,
PRedictive Integrated Structural Materials Science (PRISMS) Center, University of Michigan

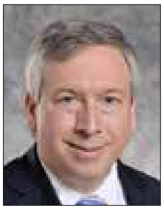
Edward Herderick
Advanced Technologies Leader, Advanced Manufacturing Initiatives Group, GE Corporate

Elizabeth Hetrick
Technical Expert, Welding and Processes,
Ford Research and Advanced Engineering

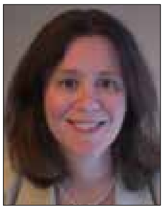
GOVERNMENT PROGRAM OFFICERS PANEL



Richard Fonda
Program Manager,
Office of Naval Research



David Forrest
Technology Manager,
U.S. Department of Energy



Alexis Lewis
Program Director,
National Science Foundation

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TECHNICAL PROGRAM

Plenary Session

Monday AM
November 16, 2015

Room: Westmoreland
Location: The Westin Convention Center Hotel Pittsburgh

8:00 AM Introductory Comments

8:10 AM Invited
Product and Process Innovation at U.S. Steel - The Customer Driven Solutions Provider: *David Britten*[1]; [1]U.S. Steel

8:40 AM Invited
Challenges and Opportunities of Incorporating Materials Innovations into Supply Chains: *Susan Helper*[1]; [1]Case Western Reserve University

9:10 AM Break

9:30 AM Invited
Perspectives from U.S. Department of Energy: *Mark Johnson*[1]; [1]U.S. Department of Energy

10:00 AM Invited
Perspectives from "America Makes": *Ed Morris*[1]; [1]America Makes - National Additive Manufacturing Innovation Institute

10:30 AM Invited
Manufacturing Challenges to Reduce Weight in Transportation Applications: *Alan Taub*[1]; [1]University of Michigan

New solutions are needed to reduce the weight of the machines that move people and goods on land, sea and air. The potential for reducing weight using high-strength steels, aluminum, titanium and magnesium alloys is well established. Key is to achieve the weight reduction economically and ranges from about $5/kg saved for automobiles to over $500/kg saved for aircraft. This requires optimizing the material properties and developing robust, scalable manufacturing technologies. Lightweight Innovations for Tomorrow (LIFT) was established to accelerate the adoption of advanced metallic structural components and serves as the bridge between basic research and final product commercialization. Our industry partners in collaboration with an extensive network of universities and the national and federal laboratories are developing these advanced manufacturing processes. Commercialization of the resulting technologies is enabled by the early integration of the full production supply chain from material producers and metal formers to OEM's.

11:00 AM Panel Discussion
Mark Johnson, US Department of Energy; *Ed Morris*, America Makes - National Additive Manufacturing Innovation Institute; *Alan Taub*, University of Michigan

Additive Manufacturing I

Monday PM
November 16, 2015

Room: Westmoreland
Location: The Westin Convention Center Hotel Pittsburgh

2:00 PM Keynote
Modeling the Metal Additive Manufacturing Process at the Scales of the Part and the Powder: *Wayne King*[1]; [1]LLNL

A physical understanding of the metal powder bed fusion process can provide insight into engineering margins, uncertainties in margins, and sensitivity of engineering margins to process parameters. Such an understanding should also enable increased control of the process, which in turn improves the likelihood of producing qualified parts. Modeling and simulation of the additive manufacturing process provides a mechanism to develop this understanding. In this presentation we discuss a model at the scale of the powder that is used to computationally model the melting of powder and its resulting densification. It resolves randomly distributed individual powder particles in 3D. We also discuss a model at the scale of the part that is used to computationally build a complete part and predict properties such as residual stress in 3D. We also discuss the role of data mining and uncertainty qualification in the modeling and simulation process and describe future applications. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This work was funded by the Laboratory Directed Research and Development Program at LLNL under project tracking code 13-SI-002.

2:30 PM
Tailoring the Mechanical Anisotropy of Ni-base Superalloys Processed by Selective Laser Melting: *Thomas Etter*[1]; Fabian Geiger[1]; Karsten Kunze[2]; Hossein Meidani[1]; [1]ALSTOM (Switzerland) Ltd; [2]ETH Zurich

Selective Laser Melting (SLM) is an additive manufacturing technology used to produce metallic parts from powder layers. To evaluate the anisotropic mechanical properties, tensile test specimens of the Ni-base superalloys Hastelloy X and IN738LC were built with the loading direction oriented parallel (z-specimens) and perpendicular to the building direction (xy-specimens). Specimens were investigated at room temperature and 850°C in the "as-built" condition and after heat treatment. Tensile mechanical properties of "as-built" material are different for z- and xy-specimens. The anisotropy is well reflected in the Young's modulus. It is shown that suitable scanning strategies allow tailoring the texture and thus anisotropy of mechanical properties. Otherwise, the anisotropy can significantly be reduced by a subsequent recrystallization heat treatment. The characterisation of microstructural and textural anisotropy was done by Electron Back Scatter Diffraction (EBSD) analysis. Predictions on Young's modulus calculated from the measured textures compare well with the data from tensile tests.

2:50 PM
Design and Optimization of Alloys for Overlay and Freeform Fabrication by Laser Hot Wire Process: *Shenjia Zhang*[1]; Paul Denney[1]; James McGuffin-Cawley[2]; Badri Narayanan[1]; [1]Lincoln Electric; [2]Case Western Reserve University

The Laser Hot Wire process is a wire-based metal deposition and joining process that has commercial applications in overlay, welding, and freeform fabrication. The dual heat source – laser beam and resistively heated wire consumable – not only enables high deposition rate but also more flexible and robust control in shape and metallurgy of metal deposits, and it also brings new possibilities to alloy development for a variety of applications. Nickel alloys and titanium alloys have been deposited with Laser Hot Wire over a range of process parameters. Robust control of chemistry (e.g. dilution for nickel overlays, oxygen and nitrogen for titanium alloys) and important microstructure attributes (e.g. prior-ß grain size in titanium alloys) were achieved. Overlays for hardfacing and low friction applications were developed with tubular wires deposited with Laser Hot Wire taking advantage of its ability to deliver consistent and well-controlled metallurgy.

3:10 PM
Alloy Design of Metallic Components of SS316L with Varying Percentage of Molydenum Using Powder Bed Additive Manufacturing: Sin Chien Siw[1]; Zhou Yu[1]; Chris Shade[2]; Minking Chyu[1]; *C. Isaac Garcia*[1]; [1]University of Pittsburgh; [2]GKN Powder Metallurgy

This paper will describe the effect of Molybdenum (Mo) content at the room and high temperature tensile properties of a standard powder based 316L SS, fabricated using powder bed Additive Manufacturing (AM). The levels of Mo additions varied from 3, 5 and 7wt %, respectively. The suggested novel powder alloying approach permits that a large number of alloying elements can be effectively combined without any concerns regarding solubility limits, which is projected to enhance the strengthening mechanisms through solid solution and/or precipitation strengthening that leads to superior mechanical properties. Furthermore, with higher Molybdenum content, it is expected that the nature of the austenitic matrix in the SS316L model alloy is largely preserved, as it would be expected during conventional melting and solidification reactions due to changes in the (Cr/Ni) equivalent ratio. In this research study, optimum sintering parameters are developed to produce samples with the highest mechanical properties.

3:30 PM Break

3:50 PM

Electron Backscatter Diffraction Analysis of Inconel 718 Parts Fabricated by Selective Laser Melting: *Kevin Chou*[1]; Xibing Gong[1]; [1]University of Alabama

In this study, Inconel 718 alloy fabricated by selective laser melting (SLM), a powder-bed laser-based additive manufacturing process, was experimentally investigated by electron backscatter diffraction (EBSD). The intent is to examine the crystallographic texture produced by SLM. To evaluate the anisotropic properties of SLM parts, both the side-surface (X-plane) and scanning-surface (Z-plane) specimens were analyzed. The major findings are summarized as follows. (1) The side surface is characterized by the columnar grains along the build direction and the width of columnar grains is in the range of about 50 to 100 µm. (2) The scanning surface shows numerous patches (each about 100 µm by 100 µm) resulted from the raster scanning pattern; the scanning surface also exhibits equiaxed grains. (3) The crystallographic texture seems to be random for the scanning surface, which implies less anisotropy in mechanical properties compared to the side surface. (4) From the grain boundary map, the SLM microstructures are composed of high angle boundaries. However, the specimen contains a higher fraction of subgrain boundaries and a lower fraction of twin boundaries.

4:10 PM

Computational Modeling and Experimental Characterization for Additive Manufacturing of Equiaxed Superalloys Processed Through Scanning Laser Epitaxy: *Amrita Basak*[1]; Ranadip Acharya[1]; Suman Das[1]; [1]Georgia Institute of Technology

This paper focuses on simulation-based and experimentally-validated optimization of Scanning Laser Epitaxy (SLE), an additive manufacturing process applied to the manufacture and repair of gas turbine hot-section components made of Ni-base superalloys. SLE creates equiaxed, directionally-solidified or single-crystal microstructures from superalloy powders melted onto like-chemistry substrates using a high power laser beam. In this work, a transient coupled-flow-thermal approach is implemented to simulate the melting and solidification process in SLE. The laser movement is modeled as a Gaussian moving heat source, and the thermophysical properties of the alloy powders are dynamically adjusted based on the local thermal field. Simulations are performed for the SLE processing of equiaxed alloys such as IN 100, René 80, and MAR-M247. The simulations are compared with experimental results and reasonably good agreement is achieved for the melt depth and the average melt pool temperature. This work is sponsored by ONR through grants N00014-11-1-0670 and N00014-14-1-0658.

Modeling and Simulation

Monday PM November 16, 2015	Room: Cambria Location: The Westin Convention Center Hotel Pittsburgh

2:00 PM Keynote

Implementation of Computational Modeling Techniques in the Primary Manufacturing of Steel Alloys: *Stephane Forsik*[1]; [1]Carpenter Technology Corporation

The design and primary manufacturing of steel alloys has greatly benefited from emerging computational modeling techniques such as neural-network models, finite-volume models, and simulation tools based on the Calculation of Phase Diagram (CALPHAD) method. These tools have allowed a better understanding of phase transformations and microstructures resulting from complex industrial processes. The predictive capability of these models has played a major role in reducing the number of necessary experimental trials, accelerating the discovery of new alloys and the development of new products. This presentation reviews some examples of the usage of modeling techniques in the processing of a tool steel ingot, the simulation of the hot isostatic pressing (HIP) of a cladding steel, and the design of new high-strength stainless steels.

2:30 PM

Mechanical Behavior and Micro Mechanism of High Strength TWIP Steel at High Strain Rates: Xu Mei[1]; *Mi Zhenli*[1]; Wu Haipeng[1]; Xu Yapeng[1]; [1]National Engineering Research Center for Advanced Rolling Technology, University of Science and Technology Beijing

To meet the requirements of energy-saving and environmental protection, the technique of lightweight become the trend of automobile business. The application of high strength steel in automobile has been more and more recently. Therefore the traditional research method such as slow strain rate tensile could not present real state to deformation of the material. The vehicle crash-resistance property is related to material's absorptive energy at high stain rate. In this article, the high and slow strain rate tensile test will be used for high strength TWIP steel. The mechanical behavior will be tested. The microstructure evolution and deformation mechanism will be analyzed. The evaluation methods at high strain rate to TWIP steel will be put forward. This research could provide theoretical bases for the application of TWIP steel in automobile.

2:50 PM

The Mechanism and Its Change of Borax Coating During the Dry Drawing of the Steel Wire: Yu Zhi Chen[1]; *Mi Zhen Li*[1]; [1]University of Science & Technology Beijing

The lubricant has been used in the process of wire drawing which could form a lubrication layer between the wire and drawing die. It can reduce the friction between the interface, and prevent the temperature rise to ensure the processing go smoothly. With the continuous raising of drawing speed at the cold drawn steel wire, the role of lubrication in the drawing process is more important. Lubricant carrier (borax coating) + soap powder is generally adopted for dry drawing at present. But the action mechanism and its change in drawing process of borax coating are still not clear. Using numerical simulation, SEM and EDS, the borax coating of steel wire will be studied during wire drawing. The influence of high temperature and high pressure to the morphology and properties of borax coating will be researched also. The results could provide the theoretical basis for improving lubricating conditions during wire drawing.

3:10 PM

Integration of Advanced Simulation and Visualization for Manufacturing Process Optimization: *Chenn Zhou*[1]; [1]Center for Innovation through Visualization and Simulation

The integration of simulation and visualization can provide a cost-effective tool for process optimization, design, scale-up and troubleshooting. The Center for Innovation through Visualization and Simulation (CIVS) at Purdue University Calumet has developed methodologies for such an integration with applications in various manufacturing processes. The methodologies have proven to be useful for virtual design and virtual training to solve problems addressing issues on energy, environment, productivity, safety, and quality in steel and other industries. In collaboration with its industrial partnerships, CIVS has provided solutions to companies, saving over $38 million. CIVS is currently working with Steel industry to establish an industry-led Steel Manufacturing Simulation and Visualization Consortium through the support of National Institute of Standards and Technology AMTech Planning Grant. The consortium focuses on supporting development and implementation of simulation and visualization technologies to advance steel manufacturing across the value chain.

TUESDAY

3:30 PM Break

3:50 PM
Multiphase Modeling of Additive Manufacturing: Application to Electron Beam Melting of Ti6Al4V and to Selective Laser Sintering of PA12: *Guglielmo Vastola*[1]; Gang Zhang[1]; Qing Xiang Pei[1]; Yong-Wei Zhang[1]; [1]A*STAR Institute of High Performance Computing

Modeling of final part geometry requires careful consideration for the phase transformations of melting, solidification and remelting during powder-based additive manufacturing (AM). We present a Finite Element Method (FEM) model that explicitly incorporates phase transformations, where material properties are dependent on phase and the boundary conditions are tailored to the industrial AM machines. We apply our modeling to the cases of Electron Beam Melting of Ti6Al4V and to Selective Laser Sintering of PA12 and show the details of powder melting and solidification for one-layer scanning. For Ti6Al4V, we include details of the melt pool calculation of length, width and depth, while for PA12 we show how non-isothermal kinetics of crystallization can be incorporated into the FEM model to predict the final crystallinity of the part. Our model can be used as a tool to accurately predict and optimize final part geometry, hatch scan strategy, and part crystallinity of additively-manufactured parts.

4:10 PM
Comprehensive Numerical Modeling of the Blast Furnace Ironmaking Process: *Chenn Zhou*[1]; Tyamo Okosun[1]; Bin Wu[1]; Armin Silaen[1]; [1]Center for Innovation through Visualization and Simulation

Blast furnaces are counter-current chemical reactors, widely utilized in the ironmaking industry. Hot reduction gases injected from lower regions of the furnace ascend, reacting with the descending burden. Through this reaction process, iron ore is reduced into liquid iron that is tapped from the furnace hearth. Due to the extremely harsh environment inside the blast furnace, it is difficult to measure or observe internal phenomena during operation. Through the collaboration between steel companies and the Center for Innovation through Visualization and Simulation, multiple Computational Fluid Dynamics (CFD) models have been developed to simulate the complex multiphase reacting flow in the three regions of the furnace, the shaft, the raceway, and the hearth. The models have been used effectively to troubleshoot and optimize blast furnace operations.

4:30 PM
Finite Element Modeling and Validation of Thermal-Mechanical Behavior of Additive Manufacturing of Ti-6Al-4V: *Qingcheng Yang*[1]; Albert To[1]; [1]University of Pittsburgh

Additive metal deposition processes using laser or electron beam heat sources are becoming increasingly popular due to their potential of manufacturing near net shape structural components. In this work, a 3D finite element model is developed and validated for predicting the thermo-mechanical behavior of Ti-6Al-4V during a laser engineered net shaping (LENS) process. The double ellipsoid volumetric heat source mode proposed in [1] is employed as the heat input model. The thermal problem is solved with hexahedral element using the element activation/deactivation technique. The mechanical problem is solved by employing a thermo-elastic-plastic constitutive model in which the material parameters are calibrated based on the tensile test experiments at different temperature and strain rates with the printed Ti-6Al-4V samples. Temperature and deformation measurements are performed in order to validate the simulation model. It is shown that the computed thermal history and mechanical deformations are in reasonable agreement with the experimental measurements.

Additive Manufacturing II

Tuesday AM November 17, 2015	Room: Westmoreland Location: The Westin Convention Center Hotel Pittsburgh

8:00 AM Keynote
Additively Manufactured Metallic Components with Tailored Microstructures and Properties: *Sudarsanam Babu*[1]; Ryan Dehoff; L Love[2]; William Peter; [1]The University of Tennessee Knoxville; [2]Oak Ridge National Laboratory

Additive manufacturing of metals is considered as a disruptive technology to produce limited number of high value components with topologically optimized geometries and functionalities. Realization of the above potential for real-world applications is stifled by lack of standard qualification of computational design-tools; material feed stock characteristics, methods to probe thermo-mechanical processes under in-situ conditions, and microstructural homogeneity, as well as, anisotropic static- and dynamic-properties. This presentation will discuss the needed interdisciplinary science and technology ranging from robotics and automation, process control, multi-scale in-situ and ex-situ characterization methodologies, as well as, high-performance computational tools to address these challenges. Specific focus on understanding and controlling physical processes will be stressed, including powder/wire/tape, powder sintering, adsorption and dissolution of gases, microstructure evolution under extreme thermal gradients, and residual stress evolution under complex thermal gyrations. Case studies demonstrating the usefulness of these strategies will be presented. Emerging pathways to scale up metal additive manufacturing) in Fe-, Al- and Ti- alloys to large sizes (>1 m) and higher productivity (5 to 20 kg/h), while maintaining the mechanical performance and geometrical flexibility expected by the additive manufacturing, will be discussed.Research supported by US Department of Energy, Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office (AMO)

8:30 AM
Predictive Modeling of the Direct Metal Laser Sintering Additive Manufacturing Process: *Bryan Webler*[1]; Shi-chune Yao[1]; [1]Carnegie Mellon University

This paper documents a multi-scale numeric model for accurate prediction heat transfer and residual stress during the Direct Metal Laser Sintering (DMLS) additive manufacturing process. There has been much development of the DMLS process in recent years; however, challenges such as part fracture during production and control of microstructure remain. Improved process models will help address these challenges and reduce the number of trials needed to obtain a functional part. The multi-scale, numeric model developed here has been used to predict melt pool geometry, time/temperature behavior, residual stress, and distortion after substrate separation for several part geometries. Model predictions of distortion were validated with Ti-6Al-4V parts fabricated via DMLS. Connections were also made between predicted time/temperature history and microstructure. With appropriate input parameters, the developed model can be generalized to different materials in various product shapes to enable prediction of microstructure and product integrity during the DMLS fabrication process.

8:50 AM
Additively Manufactured Transition Metal Intermetallic Coating to Enhance Corrosion Resistance of Aluminum: *Hitesh Vora*[1]; Ravi Sanker Rajamure[2]; Srinivasan Srivilliputhur[2]; Narendra Dahotre[2]; [1]Oklahoma State University; [2]University of North Texas

The corrosion resistance of Al can be substantially increased by development of transition metal (TM) intermetallic (AlxTMy). But due to lower equilibrium solid solubility of TM in Al (<1at%), the formation of solid solution is not feasible with using conventional alloying methods. In light of this, laser aided additively manufactured TM intermetallic coating is a promising approach. Here, the attempts were made to study the intermetallic of Al-Mo system as a potential corrosion resistant coating on aluminum via integrated computational and experimental approach. A finite element and optimization model was developed for the additive manufacturing process to predict the dilution of Mo with Al and find the optimal processing parameters to obtain a microstructure suitable for improved corrosion resistance. Additionally, first principle calculations of thermodynamic, electronic and elastic properties of intermetallics in Al-Mo system were also thoroughly investigated to correlate the corrosion performance of Al-Mo coating with these properties.

9:10 AM Break

9:30 AM Keynote
Direct Digital Manufacturing of Ceramics to Enable Advancement in Investment Casting: *John Halloran*[1]; [1]University of Michigan

Ceramic cores for investment casting of airfoils can be produced by direct digital manufactured using several additive manufacturing techniques. Several methods are briefly reviewed, with emphasis on Large Area Maskless Photopolymerization (LAMP), developed in collaboration with Suman Das at Georgia Tech and DDM Systems Inc. LAMP is a layered manufacturing method where 100-micron layers of liquid photopolymerizable ceramic suspensions are cured using UV exposure of bitmaps using a digital mirror device. The design and operation of the LAMP device, production rates, and factors limiting feature resolution are discussed in terms of the machine characteristics and the formulation of the ceramic photosuspension. Recent progress in understanding the photopolymerization of ceramic suspensions will be reviewed. These methods enable the use of designs cores which cannot be readily produced by conventional means, and make possible improvements in the investment casting process.

10:00 AM
Cold Spray Powder Deposition Technology for Coatings and Near-Net Shape Manufacturing: *Ben Maier*[1]; Ben Hauch[1]; Kumar Sridharan[1]; [1]University of Wisconsin-Madison

The cold spray process involves propulsion of powder particles at supersonic velocities to form coatings with specific functionalities or for the manufacture of near-net shape parts. The particle temperature in the cold spray process is low and deposition occurs in solid state. This confers a number of benefits, such as deposits relatively free of oxidation, porosity, compositional segregation, and thermal decomposition effects during spraying, and the ability to fabricate coatings and parts of nanostructured and amorphous materials. The process is environmentally clean in that no hazardous liquids or green-house gases are generated. The deposition rates are high and deposition is carried out in ambient environment, which contribute to high throughput and improved economics. The results of cold spraying of a broad spectrum of materials including low melting point aluminum-alloys, reactive metal titanium, high temperature Ni-based alloy, carbide ceramics, and nanostructured steels will be discussed.

ICME and Modeling

Tuesday AM November 17, 2015	Room: Cambria Location: The Westin Convention Center Hotel Pittsburgh

8:00 AM Keynote
From Materials Genome to Flight: QuesTek Innovations' ICME-Designed High-Performance Materials: *Jason Sebastian*[1]; Greg Olson[1]; [1]QuesTek Innovations

QuesTek Innovations LLC (Evanston, IL, USA) utilizes its Materials by Design® technologies and its Integrated Computational Materials Engineering (ICME)-based methods to successfully design, develop, and insert advanced new materials. These include five new high-performance gear and structural steels (Ferrium C61, C64, M54, S53, and N63) that are now commercially available with AMS and/or MMPDS handbook specifications. The presentation will provide an overview of the design, development, materials properties, benefits, and applications of these four new alloys (including recent Navy and Air Force applications). The presentation will emphasize QuesTek's use of ICME modeling methodologies and tools (e.g., CALPHAD databases, solidification models, strength models, etc.) during the design of these alloys, and also QuesTek's use of advanced characterization techniques (e.g., atom probe tomography [APT]) during the development and calibration of its computational models and databases. QuesTek will also briefly cover several other new high performance alloys including alloys being designed specifically for additive manufacturing processes.

8:30 AM
The Center for Hierarchical Materials Design: Realizing the Vision of the Materials Genome Initiative: *Emine Gulsoy*[1]; Peter Voorhees[1]; Gregory Olson[1]; Juan De Pablo[2]; [1]Northwestern University; [2]University of Chicago

Center for Hierarchical Materials Design (CHiMaD) is a NIST-sponsored Center of Excellence for Advanced Materials Research focusing on developing the next generation of computational tools, databases and experimental techniques in order to enable the accelerated design of novel materials and their integration to industry. CHiMaD aims to focus this approach on the creation of novel hierarchical materials which exploit distinct structural details at various scales, from the atomic on up, to obtain enhanced properties. CHiMaD is currently concentrating its efforts on database and methodology development for both organic and inorganic advanced materials. Implementing of the CHiMaD materials design principles will be demonstrated using examples of the integrated materials engineering process we are employing for Ni-based and Co-based alloys as well as several organic materials.

8:50 AM
Constitutive Modelling of High Temperature Flow Behaviour of Various Types of Steels: *Sivaprasad Palla V*[1]; Narendra Girase[1]; [1]Sandvik Asia Pvt Ltd

Finite element modelling of manufacturing processes play an important role in deeper understanding of the process and thus microstructural evolution. Constitutive equations are generally employed to represent flow behavior of materials in Finite Element Analysis. The present paper discusses the evaluation of various cconstitutive equations to describe the flow behaviour of 9Cr-1Mo ferritic steels, 316 L austenitic stainless steel and SAF 2507 duplex steel. In the first part of the paper, the experimental stress-strain data obtained on 9Cr-1Mo steel were analysed. The constitutive equation relating stress, strain rate and temperature were derived by taking into account the compensation for strain and strain rate. Towards this end a modification of Zener – Hollomon parameter was proposed. The second part of the paper discusses on development of an optimisation technique to evaluate nine material constants of Hansel-Spittel material model used for describing flow behavior of type 316L and SAF 2507.

9:10 AM Break

9:30 AM
Towards Designing Continuous Casting Process for Nb Microalloyed Gear Steel: *Viktor Kripak*[1]; Ulrich Prahl[1]; [1]RWTH Aachen

Simulation platform for integrative development of materials and process chains has been developed for the numerical design of case hardened steel. In the present study the influence of alloying elements, process parameter and continuous caster geometry on castability of Nb alloyed gear steels is analyzed. The solidification process is simulated on micro-/macroscopic scale. Using the phase-field method by means of the commercial program MICRESS the segregation behavior, phase evolution and precipitation morphology are simulated under continuous casting cooling conditions on the microscopic scale. 3D FE model of the continuous casting in ABAQUS with integrative flow curves represents the local strass as a function of the time, temperature and deformation on the macroscopic scale. The combination of ABAQUS and MICRESS simulations provides the requirements for as-cast structure and casting parameters, which make it possible to avoid the hot crack formation on the surface and ensure the stable fine grain structure.

9:50 AM
The Use of Through Process Modeling as a Design Tool for High-Strength Al Alloy Castings: Carl Reilly[1]; *Andre Phillion*[1]; Daan Maijer[1]; Kumar Sadayappan[2]; [1]University of British Columbia; [2]CanmetMATERIALS, NRCAN

Through-Process Modeling (TPM) is a recently developed materials engineering design approach that can be used to optimize component performance by taking the complete manufacturing process into consideration. TPM studies couple models of heat transfer, stress development, microstructure, and defect formation in order to predict the in-service performance of a fabricated component. In this talk, a framework for TPM as applied to a high-strength aluminum alloy, B206, will be presented, including a discussion of the required material properties, defect phenomenological laws, and validation methods. The framework will then be applied to the casting of a critical component of tidal-based clean energy-generating systems – the hub that transfers load from a turbine's blades to the shaft of the generator.

10:10 AM
Predicting Mechanical Properties of Cast Aluminum Alloy Component via Integrated Solidification and Heat Treatment Models: Chang Kai Wu[1]; *Salem Mosbah*[2]; [1]Dow Corning; [2]Think Solidification

In this paper, an integrated modeling tool is presented which computes the local mechanical properties of cast and precipitation hardening heat treated aluminum alloy component. The model simulates both casting and heat treating processes, and it computes the local hardness, yield strength and ultimate tensile strength, that developed in the casting during each step. Both alloy solidification and the casting heat treatment are simulated. The casting model takes into account nucleation and undercooling to predict the growth of the dendritic and eutectic microstructures. The predicted secondary dendrite arm spacing (SDAS) is used to calculate the local strengths in the subsequent heat treatments steps. The heat treating model takes into account solutionizing, quenching and aging steps. The integrated model uses an extensive database that was developed specifically for the A356 alloy under consideration. The database includes the mechanical, physical, and thermal properties of the alloy all as functions of temperature.

Additive Manufacturing III

Tuesday PM November 17, 2015	Room: Westmoreland Location: The Westin Convention Center Hotel Pittsburgh

2:00 PM Keynote
AM Manufacturing Science at ONR: *Richard Fonda*[1]; [1]Office of Naval Research

Additive manufacturing (AM) holds tremendous promise for many applications including rapid prototyping, small lot manufacturing, complex structure fabrication, and reduced part count structures. However, gaps in our understanding of the AM process limit its potential for both DoD and commercial applications. To address this, the Manufacturing Science Office of ONR is supporting efforts to develop the scientific foundation required to improve manufacturability of metallic components using additive manufacturing. In particular, we are supporting efforts to detect, control, and remediate defects that develop during AM in near real-time. This presentation will discuss those efforts.

2:30 PM
Designing Structures in Alnico Alloys by LENS Synthesis: Matthew Kramer[1]; *Iver Anderson*; Emrah Simsek[1]; Matthew Besser[1]; Ryan Ott[2]; [1]Ames Laboratory (USDOE); [2]Ames Laboratory (USDOE)

While the importance of rare earth (RE) permanent magnets in numerous energy and defense technologies is well known, developing RE-free permanent magnets with exceptional properties (e.g., high BHmax and Hc) is critical due to = supply and demand instabilities associated with RE elements. Furthermore, developing advanced processing routes for these RE-free magnets is necessary. The Alnico system is particularly interesting due to the excellent magnetic properties that can be achieved in designed microstructures and their potential adaptability to additive manufacturing methods. Here we discuss using laser engineered net shaping (LENS) to synthesize Alnico alloys with designed microstructures. Starting from pre-alloyed powder, we have printed bulk samples using different processing conditions to control the thermal gradients and the solidification rates. The interconnection between the processing conditions, the phase equilibria, texture and magnetic properties are identified. From this, appropriate pathways for creating high-performance RE-free permanent magnets via additive manufacturing are identified.

2:50 PM
Additive Manufacturing of Nd2Fe14B Based Bonded Magnets: *Mariappan Paranthaman*[1]; Huseyin Ucar[1]; Orlando Rios[1]; Christine Hatter[1]; Brian Post[1]; Cajetan Nlebedim[2]; Matthew Kramer[2]; R McCallum[2]; Scott McCall[3]; [1]Oak Ridge National Laboratory; [2]Ames Laboratory; [3]Lawrence Livermore National Laboratory

The main goal of this research is to develop a viable additive manufacturing technique for the fabrication of Nd2Fe14B based bonded magnets. One of the ways to minimize the generated waste associated with permanent magnet manufacturing and reduce the overall cost is to develop polymer additive methods to create complex geometries of bonded magnets without any waste. We have successfully prepared bonded magnets of up to 60 volume % using anisotropic MQA magnet powders with suitable polymers. We have determined the process conditions and magnetic fields necessary to fully align the magnetic particles in a polymer matrix. We will report our findings about the uniformity of magnetic particle alignment and correlation of magnetic properties with process conditions. This work was supported by the Critical Materials Institute, an Energy Innovation Hub funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office.

3:10 PM
Additive Manufacturing Initiatives at TMS and Beyond: *Justin Scott*[1]; [1]TMS

Interest in additive manufacturing (AM) has grown swiftly over the past decade due to its promise for reducing design restrictions, tailoring material composition and properties, decreasing material waste, shortening time to market, and increased potential for customization, among other opportunities. Yet, many hurdles remain to broader adoption of the technology. One of the major roadblocks to implementation is a lack of understanding of the fundamental materials science at work in AM. Research is needed to develop our understanding of processing-structure-property linkages including aspects such as how feedstock and build parameters impact residual stress and distortion, post-processing considerations, mechanical properties, and end-product performance. This talk will provide an overview of some key publications, meetings, and initiatives that have attempted to address this deficiency in materials understanding of AM. Activities at TMS and beyond will be covered, with special attention given to metal-based AM technologies. Critical gaps in the materials science knowledge base of AM will also be highlighted along with some perspectives on the future of the field.

3:30 PM Break

Data for Decisions

Tuesday PM November 17, 2015	Room: Cambria Location: The Westin Convention Center Hotel Pittsburgh

2:00 PM
CALPHAD-Driven Manufacturing Innovations: *Carelyn Campbell*[1]; [1]National Institute of Standards and Technology

Announced in 2011, the Materials Genome Initiative renewed the emphasis on methods to reduce the time and cost of alloy development and deployment. CALPHAD-based approaches provide an essential tool linking processing-structure and structure-property relationships to the design and manufacture multicomponent multiphase materials. This presentation will highlight several industrial applications employing CALPHAD-approaches to control processing to produce desired microstructures and properties. Multicomponent diffusion simulations are used to predict the optimum bonding of a Ni-base alloy using a transient liquid phase and avoiding the presence of any detrimental precipitates. Multiphase solidification and heat treatment simulations are used to improve additive manufacturing post-build heat treatments. To expand the use of the CALPHAD-approaches to new manufacturing methods NIST is building a materials data infrastructure that can easily curated, shared and transformed phase-based property data. Application of this data infrastructure to develop new CALPHAD-based databases will be demonstrated.

2:30 PM
Simplifying the Mosaic: A Machine Learning Approach to Modeling the Laser Assisted Cold Spray Process: *Aaron Birt*[1]; Joseph Dallarosa[2]; Diran Apelian[1]; [1]Worcester Polytechnic Institute; [2]IPG Photonics

Modern manufacturing processes must become increasingly complex in order to reduce costs, increase efficiencies, and produce products to meet extreme working conditions. Many of these processes have variables so numerous that they are exceedingly difficult to model with accuracy and speed using physics based models. One such process that has been developed over the last decade is called laser assisted cold spray (LACS). The process includes such complex physics as supersonic fluid dynamics, submicrometer heat transfer, dynamic recrystallization, secondary phase formation, high strain rate deformation, and variable material systems. Rather than use physical models to quantify LACS, a data driven machine learning model was selected to encompass all of these variables. The work reported here discusses selection of the physical inputs and outputs that can be measured to accurately represent LACS. This representation is statistically validated and serves as the stepping block to a predictive machine learning model for LACS.

2:50 PM
A Review of Data Analytics for Computational Materials Science and Engineering: *Larry Berardinis*[1]; Scott Henry[1]; [1]ASM International, CMD Network

Data mining and analytics are among the least explored but potentially most important links in the computational materials design chain. They are also the focus of several goals and milestones in the Materials Genome Initiative Strategic Plan, the fulfillment of which requires a detailed assessment of current tools and how they have been or could be applied in the context of materials science and engineering. The results of such an assessment now underway will be disseminated for the first time in this paper. The paper will address ways in which data analytics can be used to facilitate experiments and simulations and to enhance process-structure-property integration. Critical supporting areas – including data management, education, and community development – will be assessed as well, providing a comprehensive picture of how data analytics might look in the future and a roadmap for how the materials data community can achieve the vision.

Government Program Officers Panel

Tuesday PM
November 17, 2015

Room: Westmoreland
Location: The Westin Convention Center Hotel Pittsburgh

4:00 PM Richard Fonda, Office of Naval Research

4:05 PM Alexis Lewis, National Science Foundation

4:10 PM David Forrest, U.S. Department of Energy

4:15 PM Panel Discussion
Richard Fonda, Office of Naval Research
Alexis Lewis, National Science Foundation
David Forrest, U.S. Department of Energy

Poster Session

Tuesday PM
November 17, 2015

Room: Somerset
Location: The Westin Convention Center Hotel Pittsburgh

Unlocking the Potential of Blast Furnace Modeling with High Performance Computing: *Aaron Fisher*[1]; [1]Lawrence Livermore National Laboratory

Blast furnaces play a significant role in the steal making process, accounting for approximately 95% of the pig iron produced in the US. Computational Fluid Dynamics (CFD) modeling of these furnaces is increasingly being utilized to improve operational efficiency, evaluate improved designs, and provide valuable insight for furnace engineers. However, CFD modeling is very computationally intensive producing slow turnaround times for these simulations and holding back progress. We present our recent work in utilizing High Performance Computing (HPC) to improve this turnaround time. This includes running a parameter study with a serial blast furnace code using multiple compute nodes to improve the turnaround time by a factor of 100. We also include a scaling study of a parallel model of a molten steel ladle pour. This study highlights the reductions in run time and the gains in resolution that can be obtained by utilizing large HPC clusters.

Reduction Roasting and Ammonia Leaching of High Iron-bearing Zinc Calcines: Bing Peng[1]; Ning Peng[1]; Xiao-bo Min[1]; Ke Xue[1]; [1]Central South University

The separation of iron from zinc is a big challenge faced by the zinc smelting industry using high iron-bearing zinc ores. This paper proposed a kind of pyro-hydrometallurgy process for this problem. Firstly, the zinc calcine was selectively reduced into magnetite and zinc oxide, and the ammonia leaching was carried out to extract zinc from roasted product, consequently, the iron was preserved in the leaching residues as magnetite and recovered by magnetic separation. The optimal conditions were as follows: temperature, 30°C; reaction duration, 1h; solid-to-liquid ratio, 1/7; stirring speed, 200rpm. Under these conditions, extraction of zinc and iron were 88.56% and 4.20% respectively. The recovery and grade of iron in concentration of magnetic separation were 86.46% and 46.5% respectively.

Evolution of Texture and Microstructure in 1.35%Si Non-oriented Electrical Steel: Qiang Sun[1]; *Zhenli Mi*[1]; Mei Xu[1]; [1]University of Science and Technology Beijing

Materials were cut from columnar crystal region in casting slab and hot rolled vertical to <100> direction. Microstructure and texture evolution in the whole process was studied. Experimental results indicate that initial <100> texture affects the evolution of texture in non-oriented steel. Texture distribution and microstructure along thickness of hot-rolled sheets is inhomogeneous. In subsurface layer, Goss texture, cupper-type texture and brass-type texture are dominant. The microstructure is recrystallized in subsurface layers. In the 1/4 and center layers, γ-fiber texture and {100}<011> texture are dominant. The microstructure in center layers is banded structure. The cold rolled texture is characterized by γ-fiber texture and {100}<011> texture. The annealed texture is occupied by γ-fiber texture. With increased annealing temperature, mean size of recrystallization grains is increased and the γ-fiber texture is strengthened while cube texture and {100}<011> texture are weakened. The magnetic property of test steel is optimized by increased annealing temperature.

TUESDAY

Influence of Nd and Dy Addition on Grain Refinement and Formation of Intermetallic Compounds of Mg-5Al-3Ca Based Alloy: *Hyeon-Taek Son*[1]; Yong-Ho Kim[1]; [1]Korea Institute of Industrial Technology

The magnesium alloy is the lightest structural metallic alloy commercialized to date, and has excellent specific strength and elastic modulus together with a density of 1.74 g/cm3. However, the magnesium alloy has lower strength at elevated temperature and is more susceptible to corrosion than other lightweight alloys. Ca is a promising additional element because the addition of Ca significantly improves the high temperature strength and creep resistance. Thus, the Mg–Al–Ca ternary system is considered as one of the most important systems for further alloy development. Moreover, it has been proved that rare earth (RE) metals are beneficial to the mechanical properties of magnesium alloys without affecting other properties. In this work, Mg-5Al-3Ca based alloy with Nd and Dy were produced by a mould casting process. The influences of Nd and Dy addition on microstructure and mechanical properties such as grain size, grain morphology and Al-RE intermetallic compounds were investigated.

Thermodynamic Modeling of High Temperature Oxidation in NiCrAl Alloys with Hf Additions: *Austin Ross*[1]; T. Gheno[2]; G. Lindwall[3]; X. Liu[3]; B.C. Zhao[3]; Z.K. Liu[3]; B. Gleeson[2]; [1]The Pennsylvania State University ; [2]University of Pittsburgh; [3]The Pennsylvania State University

A common method used to improve the oxidation resistance of a-Al2O3 forming alloys is to add small amounts of reactive elements, typically Hf, Y, or Zr. These additions can slow the growth of a-Al2O3 and improve its adherence to the alloy. However, when too much reactive element is added the beneficial effects are lost and oxidation resistance will be severely reduced. To avoid this over-doping effect it is important to understand which phases will be present before and during the corrosion process. In this study computational thermodynamics, in conjunction with experimental equilibrium phase data and thermodynamic data from first principles, were used to calculate the compositions required to avoid over-doping with Hf. Experiments carried out for Hf additions to NiCrAl alloys were in reasonable agreement to these calculations.

Atomic and Electronic Basis for the Solid-Solution Strengthening and the Precipitation Hardening of Advanced Mg Alloys: *William Yi Wang*[1]; Shun Li Shang[1]; Yi Wang[1]; Kristopher Darling[2]; Laszlo Kecskes[2]; Xi Dong Hui[3]; Zi-Kui Liu[1]; [1]The Pennsylvania State University; [2]U.S. Army Research Laboratory; [3]University of Science and Technology Beijing

In the current work, the solid-solution strengthening and the precipitation hardening of advanced Mg alloys are studied by an integrated first-principles calculations and electron work functions (EWF). With the knowledge of bonding charge density, effects of the solute atoms and the fault layers in stacking faults (SFs) and long periodic stacking ordered structures (LPSOs) on the total energy, the bonding structures and EWF are discussed. It reveals the HCP->FCC bond change in the bulk for the formations of SFs and LPSOs. Based on the interactions between the solute atoms and the matrix, the EWF dependent hardness of Mg alloys is captured, providing an insight into the solid-solution strengthening mechanism of Mg alloys. Under the guidance of electron redistributions, it is believed that the precipitation hardening of age-hardenable Mg alloys caused by LPSOs can be studied in term of EWF.

Materials Innovations

Wednesday AM
November 18, 2015

Room: Westmoreland
Location: The Westin Convention Center Hotel Pittsburgh

8:00 AM
The Use of Integrated Development Tools to Coordinate Alloy and Process Design: *Fritz Grensing*[1]; [1]Materion Performance Alloy

The market introduction of new alloys and tempers requires the coordination and integration of numerous functions within a business. Traditionally much development work was done in serial and process development could take years and miss both market windows and customer needs. The use of integrated development tools to coordinate alloy and process design has improved the effectiveness of new products and these alloys are now used safely and reliably in many modern device. While the transition from a lab scale process to a commercial product is fraught with risk, methods to control the risk will be discussed. The tool set used to introduce new tempers of Cu-Ni-Sn will be described and examples will be show that highlight risk mitigation.

8:20 AM
Developing Topology Optimization Tools that Enable Efficient Design of Additive Manufactured Cellular Structures: *Lin Cheng*[1]; Pu Zhang[1]; Emre Biyikli[1]; Albert To[1]; [1]University of Pittsburgh

Cellular structures are promising candidates for additive manufacturing to design lightweight and complex parts for reducing material cost and enhancing sustainability. We focus on designing cellular structured components by integrating micromechanics modeling and topology optimization. In order to expedite the simulation-design process, a totally new design-optimization methodology is employed. Firstly, the cellular structures are modeled in a homogenization approach based on the computational micromechanics theory. Secondly, a topology optimization algorithm is developed to optimize a given 3D component within the framework of continuum topology optimization by using the homogenized cellular structure models. Both the minimum compliance problem and constrained stress optimization are studied and incorporated in the topology optimization toolbox. Thirdly, a reconstruction algorithm is proposed to convert the relative density profile from topology optimization into explicit cellular structures. The whole design-optimization process is implemented and validated by designing a cellular structured pillow bracket and conducting experimental tests.

8:40 AM
Using a Novel Processing Method to Rapidly Fabricate Product Forms that have Bulk Nanostructures and High Performance Properties: *Glenn Grant*[1]; Jun Cui[1]; Anthony Reynolds[2]; Suveen Mathaudhu[3]; Curt Lavender[1]; Saumyadeep Jana[1]; Jens Darsell[1]; [1]Pacific Northwest National Laboratory; [2]University of South Carolina; [3]University of California Riverside

Excellent mechanical, magnetic or electric performance has been seen in tests on small scale specimens in a wide range of advanced nanostructured materials. For many materials the barrier to their implementation is a lack of scaleable, high-volume manufacturing methods. To realize the advantages available from nanostructured metals, new manufacturing processes need to be developed that can produce useable product forms (rod, tube, plate or sheet) that retain the nano- or high performance microstructures in the bulk materials. Recent research at PNNL and the University of South Carolina, has demonstrated a high-shear, solid-state processing method that can fabricate bulk materials from nano-powders, or solid billets of nanostructured or non-equilibrium compositions. The process is called Shear-Assisted Extrusion. This presentation will outline the methods, equipment and performance of extrusions made by the process in several different materials: magnesium for vehicle applications, magnetic materials for electric motors and Ferritic ODS alloys for extreme environments.

9:00 AM Question and Answer Period

9:30 AM Break

Sustainable Manufacturing

Wednesday AM
November 18, 2015

Room: Cambria
Location: The Westin Convention Center Hotel Pittsburgh

8:00 AM Keynote
Sustainability & Efficiency: A Holistic View of Machining Processes: *Christoph Gey*[1]; Paul Prichard[1]; Michael Verti[1]; [1]Kennametal Inc.

This presentation will address multiple resource challenges confronting the global manufacturing community. Geopolitical conflicts, rising resource prices, and growing international competition make resource efficiency a competitive determining factor. Sustainability through process efficiency is an increasingly important element in securing the future of a company. It is especially true for manufacturing companies that outcomes such as time, cost and quality needs to be focuses on which in detail also includes other criteria such as resource efficiency, increasing customer individual production and the reduction of emissions and at the end the customer demand for greener products. World class metal cutting tooling manufacturers consider the life cycle costs, environmental impact in the functionality of the products as well as their manufacturing processes. Using a sound understanding of physical processes in metal cutting highly productive and environmental protective cutting tools can be generated.

8:30 AM
Molten Oxide Electrolysis: Cleaner Metals for a Greener World: *Robert Hyers*[1]; [1]Boston Electrometallurgical Corp.

Extractive metallurgy is critical to both traditional and advanced manufacturing, and to the high standard of living we currently enjoy. However, metals come at a large cost in environmental impact and energy usage. For example, production of steel contributes about 7% of all anthropogenic CO2 emissions and constitutes 5% of all human energy consumption. With the growing consciousness of environmental impact and the explosive growth in renewable electricity, the time has come to re-examine extractive technologies that can better fit today's landscape. One such technology, molten oxide electrolysis (MOE), has the potential to provide higher quality metals at a lower cost, while reducing emissions and energy usage. This talk will address the current status of this technology and the path for integration into the current manufacturing network to give metals that are faster, better, cheaper, and greener.

8:50 AM
Efficient Decolorization of Methylene Blue Using Fe-based Amorphous Alloy in an Oxalate Solution: *Xingzhou Li*[1]; Ye Pan[1]; [1]Southeast University

A new Fenton-like system for decolorization of organic matter was built with a combination of Fe-based amorphous alloy (Fe-Si-B amorphous ribbon) and oxalic acid. On the decolorization of methylene blue (MB) by the new Fenton-like system, the effect of the various reaction parameters such as oxalate dosage, temperature, initial pH value, Fe-Si-B dosage and initial MB concentration were studied. Almost complete degradation of MB ($10mgL^{-1}$) was achieved in 10min under solar light. Kinetic analyses showed that the degradation process could be described by a pseudo-first-order kinetic model. Since this process does not require the addition of hydrogen peroxide and shows good efficiency under solar light, it is an economocally viable method for pre-treating and/or decolorizing wastewaters containing dyes.

9:10 AM Break

Integration

Wednesday AM November 18, 2015	Room: Westmoreland Location: The Westin Convention Center Hotel Pittsburgh

10:00 AM Keynote
A Machine Vision Approach for Analyzing, Classifying, and Utilizing Microstructural Image Data: Brian DeCost[1]; *Elizabeth Holm*[1]; [1]Carnegie Mellon University

Incorporating microstructural data into the design and control of manufacturing processes will require significant advances in microstructural image analysis. In this project, we apply the 'bag of visual features' image representation, based on computer vision concepts, to create generic microstructural signatures that can be used to automatically find relationships in large and diverse microstructural image data sets. Using this representation, a support vector machine (SVM) was trained to classify microstructures into one of seven groups with high (>80%) accuracy over 5-fold cross validation. The bag of visual features was also implemented as the basis for a visual search engine that determines the best matches for a query image in a database of microstructures. By developing an automatic and objective machine learning system for finding relationships between microstructural images and their processing and property metadata, this approach opens a new data space to inform process control, qualification, design, and optimization.

10:30 AM
Assessment of Slab Microstructure Effects on the Quality of Hot Rolled Microalloyed Steel: *Susan Farjami*[1]; [1]U.S. Steel Corporation

In the manufacturing of sheet products that are supplied to the end customer in the as-hot rolled condition, processing challenges arise in assuring microstructure uniformity to meet critical properties and thus maximize yield. As part of efforts to improve the microstructure engineering in hot strip mills, this study aims at investigating the microstructure in the as-cast and reheated slab as related to the quality of the hot-rolled microalloyed steel products. First, an overview of methods employed to better understand the segregation behavior and the quantitative distribution of alloying elements in the as-cast slab will be presented. The second part of the talk focuses on the evolution of microstructure as a function of reheating condition prior to hot rolling. A summary of metallographic techniques to reveal the prior austenite grain boundaries and image analysis work to measure and document the grain size distribution will be given.

10:50 AM
Integrating Manufacturing with Topology Optimization for the Design of Material Architectures: Josephine Carstensen[1]; Andrew Gaynor[1]; *James Guest*[1]; [1]Johns Hopkins University

Recent advancements in manufacturing have provided unprecedented abilities to realize engineered materials with defined pore architectures. This has presented new opportunities in design, with topology optimization (TO) in particular being particularly well-suited to explore this now expanded design space. Topology optimization is a systematic design methodology where material may be added or removed freely within the design domain, meaning architectural connectivity and shape may evolve during the design process. This design freedom enables discovery of new material architectures, often predicted to approach theoretical bounds, but typically comes at the price of reduced manufacturability and increased cost. This talk will discuss the integration of manufacturing into the TO design process so that designed architectures respect manufacturing constraints and leverage new manufacturing capabilities. Various manufacturing processes are considered (additive manufacturing, etching, 3D weaving) and are presented in the context of material architecture design for optimized mechanical, thermal, and/or fluid permeability properties.

Hybrid Manufacturing

Wednesday AM November 18, 2015	Room: Cambria Location: The Westin Convention Center Hotel Pittsburgh

10:00 AM
Advancing Thermal Manufacturing: A Roadmap to 2020: Larry Berardinis[1]; Warren Hunt[2]; Ross Brindle[2]; *Richard Sisson*; [1]ASM International, CMD Network; [2]Nexight Group LLC

Thermal manufacturing consists of processes that use thermal energy to alter the structure or properties of materials and products to achieve desired performance characteristics for a given application. ASM International, through NIST AMTech program support, has led development of a comprehensive roadmap to guide coordinated technology development and implementation efforts throughout the broader thermal manufacturing.The resulting roadmap identifies common barriers that currently constrain the use of advanced technologies in thermal manufacturing and calls for action to develop, adapt, and implement these technologies in the next five years. This presentation will review the background and proposed technology development and implementation pathways of the Advancing Thermal Manufacturing roadmap.

10:20 AM
Single-Stage Processing of Magnesium Alloy into Sheet by Hybrid Extrusion-Machining: *Dinakar Sagapuram*[1]; Kevin Trumble[1]; Srinivasan Chandrasekar[1]; [1]Purdue University

Magnesium sheet opens up new possibilities for lightweighting in the automotive and aerospace industries. However, its widespread application is limited mainly because of its low workability, both in primary processing by rolling and secondary sheet forming. This talk describes a novel hybrid extrusion-machining method for producing Mg sheet/foil in a single deformation step. By utilizing a constraining edge placed across from the cutting tool edge, the usual machining process is transformed into a continuous shear deformation process. The confinement of deformation zone in extrusion-machining and resultant near-adiabatic heating minimizes pre-heating of the workpiece that is intrinsic to Mg sheet manufacturing by rolling. Furthermore, the deformation parameters (strain, strain path, strain rate) can be independently controlled to induce severe microstructure refinement and engineer crystallographic textures. A detailed application of parametric deformation control to create tilted-basal textures and ultrafine grain sizes in Mg alloy sheet for enhanced combinations of formability and strength is presented.

10:40 AM
Developing Smart Hybrid Manufacturing Systems for Additive Manufacturing: *Christian Widener*[1]; Robert Hrabe[2]; Joshua Hammell[1]; [1]South Dakota School of Mines and Technology; [2]VRC Metal Systems

Until recently, additive manufacturing (AM) has been utilized much more as a prototyping tool rather than as a cost-competitive, high-rate production technique for manufacturing. However, additive manufacturing can be used to produce whole parts or used to selectively add features and even a higher performance material where needed in order to complete the part. This approach has particular appeal if combined in a hybrid manufacturing arrangement by blending AM with traditional CNC machining and inspection operations on the same platform or in-line to both increase the speed and the reliability of AM. In this way, a complete part-production cycle can be automated to produce parts with integrated quality control inspections. By developing machine tools with this capability, AM can be brought into traditional manufacturing cells in less time with a much more predictable cost/benefit analysis.

11:00 AM
Small Things Can Come in Big Packages: Using Bulk Catalysts to Grow Carbon Nanofibers and Creating Bulk Parts from those Nanofibers in One Step: *Mark Atwater*[1]; [1]Millersville University

Carbon nanofibers (CNFs) can serve in a host of advanced applications including composites, filtration and electronics. The processes for creating these fibers are often complex and only capable of creating disconnected fibers similar to powder in form. This research presents the combination of two nanoscale processing techniques to create a scalable bulk product. The first process is mechanical alloying, which is capable of creating nonequilibrium, nanocrystalline alloys and provides new opportunities for low-cost catalyst development. The second process is the constrained formation of CNFs to directly synthesize mechanically stable, nonwoven structures centimeters in size, which are entirely fibrous. These structures are capable of being repeatedly compressed and bent without significant degradation and can be grown to replicate three-dimensionally detailed molds using a one-step process. The benefits and challenges of integrating these methods for commercial manufacturing will be highlighted, and examples from the Ni-Cu and Fe-Cu systems will be detailed.

Closing Plenary

Wednesday PM	Room: Westmoreland
November 18, 2015	Location: The Westin Convention Center Hotel Pittsburgh

2:00 PM Invited
Integrated Computational Materials Engineering: A New Approach for Accelerating Manufacturing Innovation: *John Allison*[1]; [1]The University of Michigan

2:30 PM Invited
Manufacturing Innovations to Enable Lightweight Vehicle Construction, The Aluminum F-150 as a Case Study: Elizabeth Hetrick[1]; [1]Ford Motor Company

3:00 PM Invited
Industrial Implementation of Metals Additive Manufacturing: Past, Present and Exciting Future: *Edward Herderick*[1]; [1]GE

Over the past 30 years additive manufacturing technologies have evolved from simple rapid prototyping applications to supporting key industrial product lines. In this presentation, a brief history of early additive approaches will be introduced, followed by GE industrial case studies, and finally some thoughts on where the additive industry is headed and its future potential.

3:30 PM Concluding Comments

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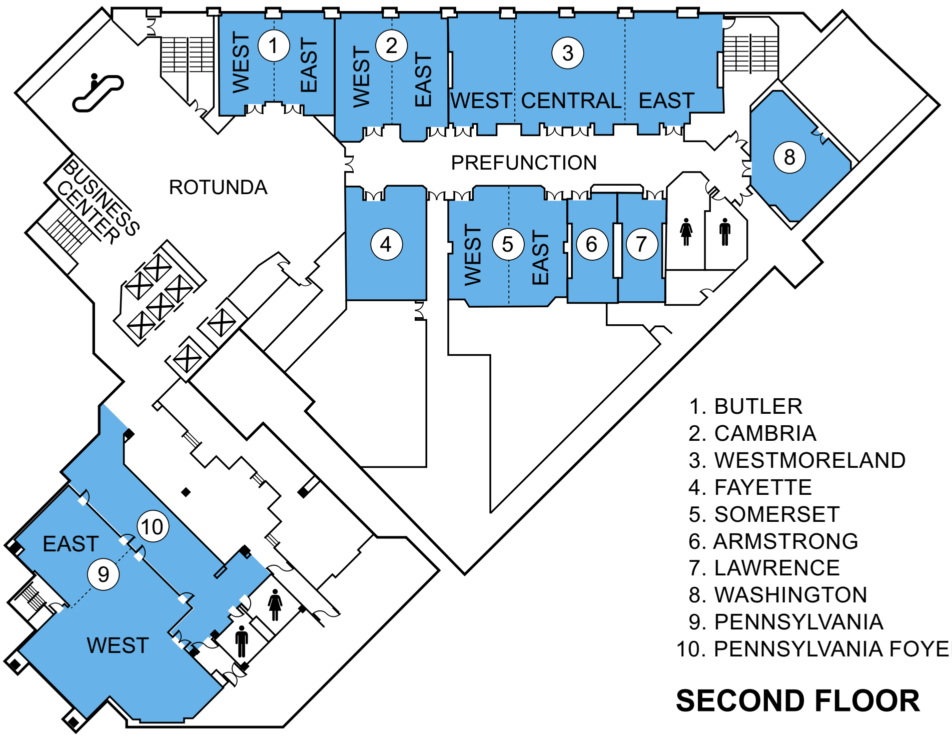

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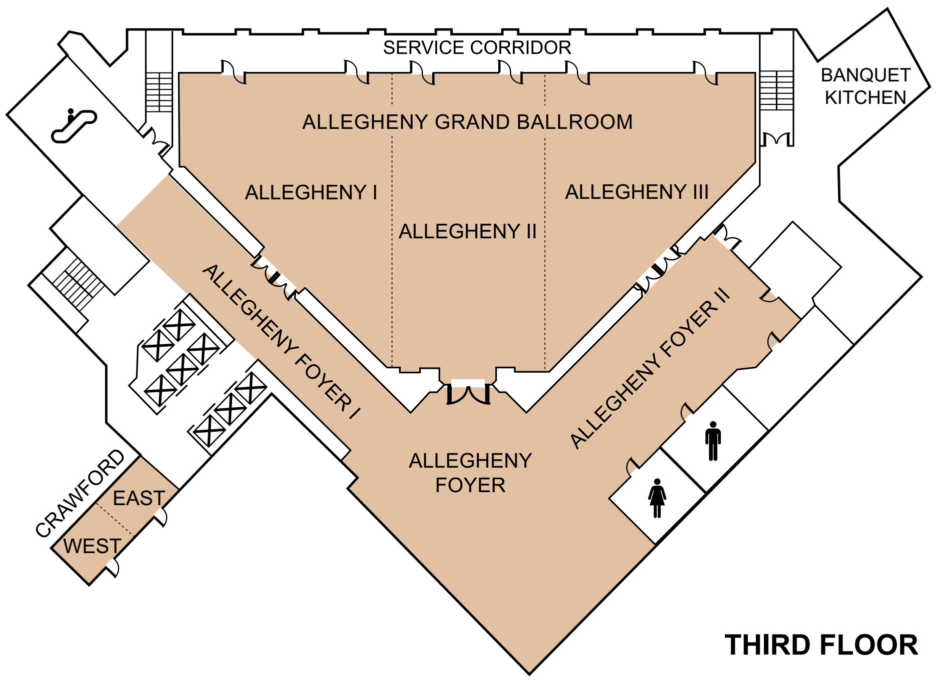

THIRD FLOOR

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2016 TMS Meetings and Events

TMS2016
145th Annual Meeting & Exhibition

TMS 2016 Annual Meeting & Exhibition (TMS2016)
February 14–18, 2016
Downtown Nashville, Tennessee
www.tms.org/TMS2016

THE 10TH INTERNATIONAL CONFERENCE ON MOLTEN SLAGS, FLUXES AND SALTS 2016

10th International Conference on Molten Slags, Fluxes, and Salts (Molten16)
May 22–25, 2016
Seattle, Washington
www.tms.org/Molten16

The 3rd International Congress on 3DMS 3D Materials Science 2016

3rd International Congress on 3D Materials Science (3DMS) 2016
July 10–13, 2016
St. Charles, Illinois
www.tms.org/3DMS2016

Pittsburgh ReX GG 2016
6th International Conference on Recrystallization and Grain Growth
July 17 – 21, 2016

6th International Conference on Recrystallization and Grain Growth (ReX&GG 2016)
July 17–20, 2016
Pittsburgh, Pennsylvania
www.tms.org/ReXGG2016

DIVERSITY IN THE MINERALS, METALS, AND MATERIALS PROFESSIONS (DMMM2)

Diversity in the Minerals, Metals, and Materials Professions (DMMM2)
July 25–26, 2016
Northwestern University, Evanston, Illinois
www.tms.org/Diversity2016

SUPERALLOYS 2016

13th International Symposium on Superalloys
September 11–15, 2016
Seven Springs, Pennsylvania
www.tms.org/Superalloys2016

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MATERIALS SCIENCE & TECHNOLOGY

Materials Science & Technology 2016 (MS&T16)
October 24–27, 2016
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