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mean pore diameter

15

Actual (µm)

20

Not extrapolating
 Extrapolating

10

20

5

Predicted (µm) 12 12

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About the Cover

Shown is a scanning electron microscopy image of a three-dimensional (3D) hierarchical rose-like Bi₂WO₆ (BWR) superstructure. For details, see "Synthesis of 3D Hierarchical Rose-Like Bi₂WO₆ Superstructure with Enhanced Visible-Light-Induced Photocatalytic Performance," by Yanan Wang, Yiqing Zeng, Shule Zhang, and Qin Zhong.



June 2019 Guest Editors

Powder Materials for Energy Applications *Powder Materials Committee* Kathy Lu, Virginia Polytechnic Institute and State University

Rare Metal Recovery from Secondary Resources: Part I

Hydrometallurgy and Electrometallurgy Committee Sheikh Abdul Rezan, Universiti Sains Malaysia Takanari Ouchi, The University of Tokyo Hojong Kim, Pennsylvania State University Gisele Azimi, University of Toronto

About JOM:

The scope of *JOM* (ISSN 1047-4838) encompasses publicizing news about TMS and its members and stakeholder communities while publishing meaningful peer-reviewed materials science and engineering content. That content includes groundbreaking laboratory discoveries, the effective transition of science into technology, innovative industrial and manufacturing developments, resource and supply chain issues, improvement and innovation in processing and fabrication, and life-cycle and sustainability practices. In fulfilling this scope, *JOM* strives to balance the interests of the laboratory and the marketplace by reporting academic, industrial, and government-sponsored work from around the world.

About TMS:

The Minerals, Metals & Materials Society (TMS) is a professional organization that encompasses the entire range of materials and engineering, from minerals processing and primary metals production to basic research and the advanced applications of materials.

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Aluminum and Magnesium: High Strength Alloys for Automotive and Transportation Applications: Part II

Aluminum Committee and Magnesium Committee Dmitry Eskin, Brunel University

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in the final analysis

"If you see harassment happening, speak up. Being harassed is terrible; having bystanders pretend they don't notice is infinitely worse."

—Celeste Ng

Oftentimes when I write In the Final Analysis, I worry that my premises, references, and word play may be too "American" for many readers. Relevant topic selection is another challenge in addressing a global audience. Is there anything about which I could write that would be meaningful to our worldwide reader base? Not many things: perhaps such universals as the importance of professional integrity in science and engineering, the value of mentorship, the power of innovation in problem solving, the criticality of resource optimization, and, unfortunately, the need to be more proactive in acting to prevent harassment in the community.

The emergence of the "Me Too" movement almost two years ago brought light to longhidden harassment issues, partly via social media and partly by the number of famous people being revealed as having behaved in repulsive ways in the shadows of what had been illustrious careers. The perturbation was global. For example, Wikipedia states that the social media hashtag #MeToo trended in at least 85 countries and in many languages. Harassment knows no international boundaries.

The association community also knows no international boundaries. Indeed, we in the association field work to erase boundaries. Within TMS, we host thousands of people from dozens of countries at events where attendees almost universally comport themselves with professionalism, curiosity, enthusiasm, consideration, and mutual respect. There can be times, however, when someone crosses a line-saying, doing, or presenting something that others experience as harassing. Perhaps an attendee is not the focus of the bad behavior him or herself, but witnesses it. Within TMS, we have created mechanisms to address harassment situations, and we are committed to act quickly when made aware that there is an incident.

Last year, TMS participated in a multi-society initiative to advance professional and ethical conduct, climate, and culture in the science, technology, engineering, medicine, and mathematics (STEMM) areas. This led to the 2019 creation of the Societies Consortium on Sexual Harassment in STEMM. TMS is a member. The consortium "will help societies fulfill their roles as standard bearers and standard setters for science (natural, social, and behavioral), technology, engineering, mathematics, and medical (STEMM) fields, by producing impactful resources and guidance to address sexual harassment, in all of its forms, in societies' own operations and broadly in STEMM fields." I anticipate that the consortium's work will help drain the safe harbors for harassers.

As we engaged with the consortium, we also undertook to develop the TMS Meetings Code of Conduct, which attendees of future TMS meetings will be required to acknowledge and accept when attending our events. It says, in part, "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." The code describes expected behavior by event participants, characterizes unacceptable behavior, outlines consequences of bad behavior, and references the processes that TMS will employ when handling reports of unacceptable behavior.

The thumbnail version: treat each other with respect; if you experience harassment or see someone being harassed, tell us; we will work hard to investigate promptly and fairly. If someone is a bad actor, the behavior will have to change immediately or he or she will be removed from the event and potentially denied access to future ones.

Harassment is terrible, and TMS refuses to be a passive bystander when it happens.



Number 6

June 2019



James J. Robinson Executive Director

"Within TMS. we have created mechanisms to address harassment situations, and we are committed to act quickly when made aware that there is an incident."

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Do you have business or industry news of interest to the minerals, metals, and materials community? Submit your announcement or press release to Kaitlin Calva, JOM Magazine Managing Editor, at kcalva@tms.org for consideration.

In Case You Missed It: Business News from the Field

Aluminium Bahrain Successfully Starts 106 Pots Askar, Kingdom of Bahrain:

Aluminum producer Aluminium Bahrain (Alba) successfully started 106 pots in its new line as part of their Line 6 Expansion Project. The 106 pots are 25% of the full production potential for Line 6, which comprises 424 pots. Alba projects that Line 6 will reach full capacity, starting up the remaining 318 pots by the third quarter of 2019.

Cyber Attack Impacts Hydro Operations

Oslo, Norway: Norwegian aluminum and renewable energy company Norsk Hydro (Hydro) was subject to a cyber attack. The attack affected multiple business areas, including Rolled Products and Extruded Solutions. Hydro determined the root cause of the problems stemming from the attack and developed a plan to restart the company's IT systems in a safe and sound manner. Hydro initially switched several of their areas to manual operation while they worked on restarting their IT systems. At press time,



Zwijndrecht, Belgium: Global Sea Mineral Resources (GSR), a subsidiary of Dredging, Environmental and Marine Engineering NV (DEME), has unveiled a pre-prototype of a mineral nodule collector. The collector, named the Patania II, is slated to embark on its first journey this year, when the vehicle will temporarily store nodules for data collection before returning them to the test area. Test data will then be used by GSR to validate the technology's performance and environmental impact. (Photo courtesy of DEME.)

four of five business areas are operating at normal speed, but with some manual workarounds.

RUSAL Launches New Production Line

Krasnoyarsk, Russia: Russian aluminum producer RUSAL began production at its Boguchansk aluminum smelter in Siberia. The start of the new line comes after the United States removed RUSAL from a sanctions list. Part of a larger expansion project, the new line nearly doubles the plant's yearly production capacity from 150,000 tonnes to 298,000 tonnes of aluminum.

Petra Diamonds Recovers 425 Carat Diamond

Cullinan, South Africa: British diamond mining company Petra Diamonds Limited has announced the recovery of a 425.10 carat diamond at their historic Cullinan mine. The diamond is a D color Type II gem quality diamond. Petra believes this particular recovery indicates a more ubiquitous presence of similar stones within the Cullinan orebody. Furthermore, Petra predicts that its plant will be able to recover the full spectrum of diamonds at this mine.

Jupiter Invests in Beech Bottom Facility

Beech Bottom, West Virginia,

USA: Jupiter Aluminum is investing \$12 million in its paint lines in Beech Bottom, West Virginia. The lines were part of a former steel facility that Jupiter cleaned up and renovated through a partnership with the Business Development Corp. of the Northern Panhandle, the U.S. Economic Development Agency, the West Virginia Department of Environmental Protection, and the U.S. Environmental Protection Agency. Jupiter hopes to renovate 140,000 square feet of the old facility with this investment, allowing them to boost their current workforce from 24 employees to more than 60.



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TMS Foundation Celebrates Those Who Make a Difference at TMS2019

Kaitlin Calva



"You are people who care, who make a difference, who make an impact on young lives and careers," said Garry W. Warren, Chair, TMS Foundation Board of Trustees, as he welcomed attendees of the TMS Foundation Donor Appreciation Dinner held during the TMS 2019 Annual Meeting & Exhibition. "You are the top donors who are building the future of the materials professions. Thank you from the TMS Foundation and from the lives you touch."

Warren thanked donors for their contributions and attendance at the evening's festivities, while also highlighting good news about the Foundation's progress over the past year, as 2018 marked the Foundation's 25th

You Can Make a Difference, Too

Those who give to the TMS Foundation are helping to not only provide financial support, but also meaningful experiences to TMS members in the most critical stages of their career development. Join your colleages in making a gift to the Foundation, and you could see your name on the 2019 Annual Giving Honor Roll or on the Lifetime Giving Honorific Societies lists. To contribute online, and to see all donation options, visit www.TMSFoundation.org. anniversary. It was a top year for donations, both during the year-end appeal and through a division scholarship fundraising campaign; the number of new donors increased over 2017; and a new endowed award was established through the TMS Foundation—the William D. Nix Award. (For more details on the Foundation's 2018



Bill Nix (right) took a moment to thank and highlight the accomplishments of his Ph.D. students, who fully funded and established the new William D. Nix Award in his honor through the TMS Foundation in 2018.

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Michael and Cecilia Mills (center, right) receive their pin as new members of the Silver Society from Andrew Baker (left), recognizing lifetime giving to the Foundation of at least \$5,000 up to \$10,000.

activities, see the May 2019 *JOM* article, "The TMS Foundation: Success in 2018.")

"As donors, you share a common goal to support students and young professionals in the critical early years of their careers. Their contributions to research, academia, and industry will advance the global society," Warren said. To help acknowledge the great philanthropic spirit of the group before him in collectively working toward this goal, Warren then introduced Andrew Baker, a Materials & Process Engineer at Boeing Research & Technology and one of the 2019 Structural Materials Division Young Leaders Professional Development Award recipients. Baker shared his story with the crowd, noting the role the Foundation has played along the way. As a student, he received a travel grant to attend a TMS meeting, where he became more involved in the Society. Later he attended the Emerging Leaders Alliance conference through the support of the Foundation. And today, Baker is not just a TMS member and current Young Leader, but an active volunteer, using his expertise to serve the Society as a member of several technical and functional committees.

The evening concluded with Warren and Baker presenting 2018 TMS Foundation Lifetime Giving Honorific Society inductees with their society pins, and one more note of thanks. "You have distinguished yourselves as scientists, mentors, leaders, and philanthropists. Thank you for your ongoing commitment and generosity to the TMS Foundation," Warren said. The inductees, pictured below, are: (front row, from left) Kevin and Maria Oliva Hemker (Titanium Society); Jeffery Gibeling (Silver Society); William Harrigan (Silver Society); Jean and Bill Nix (Silver Society); Wendelin Wright (Silver Society); Timothy Wiehs (Silver Society); Bonnie and David Shifler (Titanium Society); Dan Miracle (Titanium Society); Deepankar Pal (Titanium Society); (back row, from left) Carl Cady (Gold Society); Cheryl and Warren Oliver (Titanium Society); Vivien and Jim Earthman (Silver Society); Cecilia and Michael Mills (Silver Society); Marilyn and George Pharr (Titanium Society); and Marc Meyers (Gold Society).



The TMS Foundation welcomed new members to its Lifetime Giving Honorific Societies at the 2019 Donor Appreciation Event held in conjunction with TMS2019.

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"The state of our union is strong." With these words, Kevin J. Hemker, 2018 TMS President, assured the audience at the 2019 TMS-AIME (American Institute of Mining, Metallurgical, and Petroleum Engineers) Awards Ceremony of the health of the Society—and the numbers were there to back up this claim. A total of 4,494 minerals, metals, and materials scientists, engineers, and students from around the world gathered in San Antonio, Texas, March 10–14, for the TMS 2019 Annual Meeting & Exhibition (TMS2019), making it the third best attended conference in TMS history.



Attendees could choose from more than 3,400 technical presentations at more than 80 symposia, meet with representatives from 80 companies in the TMS2019 Exhibit Hall, and access the collected knowledge contained in 13 proceedings volumes.

This year's conference also included the sixth installment of the REWAS 2019 symposium, which was held as a co-located meeting with TMS2019. "Part of the goal of the REWAS symposium series is to inspire the broader community to make sustainable materials possible," said Randolph Kirchain, Massachusetts Institute of Technology, in his introduction to the REWAS plenary session. "Holding REWAS as a meeting within a meeting helps us to get this message out to a broader audience." In addition to the plenary session held on March 12, REWAS featured five technical symposia, a reception, and the full-day International Round Table on Materials Criticality, which was coordinated by ESM Foundation, Switzerland, and co-sponsored by the Federation of European Materials Societies. The roundtable featured nine international speakers and focused on the topic, "How Does Industry Manage Criticality in Product Development?" One goal of the roundtable was to gather input that will ultimately result in a Roadmap on Criticality to provide advice for authorities and policy makers throughout the world.

TMS was also joined by the German Materials Society (DGM) to present the one-day TMS-DGM Symposium on Lightweight Metals: A Joint U.S.-European Symposium on Challenges in Light Weighting the Transportation Industry, which focused on use of aluminum and magnesium.

The June 2019 issue of *JOM* offers a series of articles showing the people and events that made up the complete TMS2019 event. For an even fuller picture of TMS2019, browse hundreds of photos from networking events, sessions, award presentations, and other meeting activities at www.flickr.com/photos/tmsevents.



TMS Installs New Leadership



Each year, the TMS Annual Meeting & Exhibition marks the transition to the new year's TMS president. Also at this time, several members of the TMS Board of Directors end their leadership terms and new directors begin their cycles. Pictured in this section are the volunteers who served, or are beginning to serve, at the highest levels of leadership in the society for 2019–2020.

James C. Foley (pictured above, right), Sigma-1 Group Leader, Los Alamos National Laboratory, was installed as 2019 TMS President during the TMS-AIME Awards Ceremony & Banquet at TMS2019. Foley addressed TMS2019 attendees at the awards ceremony, explaining that he plans to do the following as TMS president: "Volunteer my time. Nominate people for awards and positions. Donate to the TMS Foundation. Promote TMS. And encourage others to do the same."

He challenged all of those present at the awards ceremony to adapt this simple plan for their own use in the coming year. "Just think of what we can do as a community if every TMS member checked all of these boxes."

2018 TMS President Kevin J. Hemker (pictured above, left) moved into the role of TMS Past President. The change in TMS leadership also included Thomas Battle, extractive metallurgy consultant, moving into the role of 2019 TMS Vice President. Battle will serve as TMS president in 2020.

TMS2019 Proceedings

Thirteen proceedings volumes were published in conjunction with TMS2019 and are now available for purchase through the TMS Bookstore. TMS members are eligible for 40% discounts on these and other TMS proceedings, as well as 20% off all other Springer products. Log in to the TMS Bookstore at www.tms.org/Bookstore to receive your discount codes.



2018 TMS President Kevin J. Hemker (left) presented a copy of *Light Metals 2019* to the volume's editor, Corleen Chesonis.



Hemker also presented a copy of *Magnesium Technology 2019* to three of the volume's editors. Pictured, from left, are: Dmytro Orlov, Hemker, J. Brian Jordon, and Neale R. Neelameggham. Not pictured is Vineet Joshi.

The TMS Board of Directors made the transition from the 2018 to the 2019 boards during its meeting on March 14. Pictured are board members from both years, from left to right: Mark Stoudt, Alexis Lewis, Eric Nyberg, Ellen Cerreta, Brad Boyce, Amy Clarke, James Foley, John Howarter, David DeYoung, Cynthia Belt, Kevin Hemker, Raymundo Arróyave, Adrian Deneys, Alan Luo, James Robinson, Michele Manuel, Thomas Battle, and Daniel Miracle.





TMS2019 by the Numbers

Here is a glimpse of who attended TMS2019, which sessions they attended, and the types of presentations they experienced.



- 10. Mechanical Behavior Related to Interface Physics III
- 9. 10th International Symposium on High Temperature Metallurgical Processing
- 8. 5th Symposium on Advanced Materials for Energy Conversion and Storage
- 7. Computational Thermodynamics and Kinetics
- 6. Mechanical Behavior of Nuclear Reactor Components
- 5. Advanced Characterization Techniques for Quantifying and Modeling Deformation
- 4. Additive Manufacturing and Welding: Physical and Mechanical Metallurgy of Rapidly Solidified Metals
- 3. Phase Transformations and Microstructural Evolution
- 2. Characterization of Minerals, Metals, and Materials
- 1. High Entropy Alloys VII

TMS2019 Exhibit





The TMS 2019 Exhibit Hall featured 80 exhibiting companies and was open Monday through Wednesday, March 11–13. The hall acted as a hub for meeting with clients, discussing new technologies, and displaying products and services. This year, the exhibit hall hosted two poster sessions, the bladesmithing exhibition, an opening reception, a happy hour, and three lunches to bring attendees together with exhibitors.

For more on the 2019 TMS Bladesmithing Competition, including a list of competition winners, see the article, "The 2019 Bladesmithing Competition: Where Science and Craft Come Together," in the June 2019 issue of *JOM*.

TMS2020 Now Accepting Abstracts



Plans are now underway for the TMS 2020 Annual Meeting & Exhibition (TMS2020), which will be held February 23–27, 2020, in San Diego, California. Abstracts are now being accepted for symposia on a wide range of materials science and engineering related topics.

A highlight of the 2020 conference will be the 9th International Symposium on Lead and Zinc Processing (PbZn 2020), co-located with TMS2020. This symposium will bring together operators, engineers, and researchers to exchange information about all aspects of current processing technologies for primary and secondary lead and zinc, as well as emerging technologies for both metals.

Visit the programming section of the TMS2020 website at www.tms.org/TMS2020 for more details about the symposia being planned for this year's meeting.

Short Courses and Workshops

Mark Shaw (pictured), industrialization and certification leader at GE Additive, was one of four instructors to lead the Additive Manufacturing Standards, Qualification, and Certification Workshop, held on Sunday afternoon, March 10, at TMS2019. This new course complemented the established Additive Manufacturing Materials and Processes introductory course, which was held on Sunday morning at TMS2019 and has been held previously at both TMS annual meetings and MS&T. A third course, Powder Handling for Safety and Quality, rounded out the professional development offerings held in conjunction with TMS2019.





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This year marks 100 years of flight for GE Aviation. In honor of that milestone, Luana Iorio, who is general manager, Engineering Material Systems, at GE Aviation, looked at the "Next Materials Frontier for Flight" at the TMS 2019 Annual Meeting & Exhibition (TMS2019) allconference plenary session on Monday, March 11.

Iorio discussed how additive technologies, digital data, and integrated computational materials engineering can help to accelerate materials and process development, using examples from her own company.

"All major accomplishments have a story," Iorio told the audience at the plenary session, which brought together a total of 1,072 conference attendees. Iorio shared with them the story of the GE9X jet engine. "It's the largest engine in the world," she said, "but it makes extensive use of composites, which takes 1,000 pounds of weight out of the engine." The 9X, which is expected to enter service in 2020, represents a step-change in application, according to Iorio.

The engine uses 19 3D-printed fuel nozzles, initially developed for GE's LEAP engine, to help reduce weight, and stiffer carbon fan blades meant that only 16 fan blades were needed, compared to 22. The engine also made use of silicon carbide-silicon carbide (SiC-SiC) ceramic matrix composites for additional weight savings.



More than 1,000 TMS2019 attendees gathered in the Lila Cockrell Theatre at the Henry B. González Convention Center in San Antonio, Texas, for the plenary session.

"SiC-SiC is our most capable material, and it is one third the density of the alloy it replaces," Iorio noted. "It also has metal-like damage tolerance, which is an extremely important attribute."

Bringing the material into widespread use, however, required creating a new supply chain and the development of new facilities. "Maturing a material takes commitment, persistence, and resolve," said Iorio.

Gathering data on previous ceramic matrix composite parts that GE produced was also key. According to Iorio, GE has the ability to interrogate all the LEAP engines it produces for instantaneous traceability.

"By having all of this data, we gain a sense of the health of our processes," she explained. "It is difficult to overstate the value we have realized from this."

Similarly, while creating digital infrastructure for additive manufacturing wasn't an enormous challenge (because it's natively digital), it does result in a *lot* of data, Iorio pointed out, and the volume grows quickly.

Having this data available, though, can lead to accelerated material and process development. Iorio suggested that a robust digital infrastructure could lead the



Luana E. Iorio, General Manager, Engineering Material Systems, GE Aviation, delivers the TMS2019 all-conference plenary presentation, "The Next Materials Frontier for Flight."



Members of TMS leadership met with Iorio after her talk. Pictured are (from left to right): James C. Foley, 2019 TMS President; Kevin J. Hemker, 2018 TMS President; Iorio; David H. DeYoung, 2017 TMS President; and James J. Robinson, TMS Executive Director.

way through the so-called Valley of Death of intermediate technology readiness levels by providing insights into key process variables that affect product quality and performance.

"We're changing the paradigm," said Iorio, from the number of years it takes to produce a new material to the number of new materials that can be produced in a year. "There's an unrelenting push for introducing new materials." The future of materials engineering, she added, is faster development cycles.

Given the increased focus on data and technologies, Iorio offered the following advice to students in the audience. "Build digital skill sets, along with a deep understanding of materials fundamentals. It will serve you well."

She ended her presentation by

sharing a short video from GE Additive, "The Anything Factory." In the film, a young girl rides her bike past a factory whose name changes each day. One day, it's the Unbreakable Bone Factory, then the Everlasting Satellite Factory, then the Supersonic Racecar Factory. Finally, she goes inside to find scientists who, the narrator tells us, are "3D printing magical parts to help the whole world."

At the end, the message of the film—and the promise of additive manufacturing—are summarized in these brief but hopeful words: "When a factory can make anything, anything is possible."

A Look at the Technology

Attendees were able to view GE Additive technologies related to Iorio's talk at a display located outside of the TMS2019 Exhibit Hall. Throughout the week, representatives from GE Additive Materials groups were on hand to answer questions.



Luana lorio (right) discusses some of the items at the GE Additive Manufacturing display with TMS presidents Kevin Hemker (center) and James Foley (left).







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More than 3,400 presentations at 80 technical symposia in 15 topic areas made up the core content for the TMS 2019 Annual Meeting & Exhibition (TMS2019), held March 10–14, in San Antonio, Texas. Included in this were a number of keynote sessions and invited presentations that covered a wide range of topics, from sustainability and machine learning to diversity and inclusion and science policy. What follows are excerpts from just some of these featured sessions held over the course of the week at TMS2019.

MONDAY FEATURED SESSIONS

Light Metals Keynote Session

The 2019 Light Metals Keynote Session focused on the trends, risks, challenges, and changes to be managed in the industry over the next decade, as well as the industry's rapidly changing landscape over the last several years. Chris Bayliss, International Aluminium Institute, kicked off the session with his presentation, "The Aluminum Story," where he projected a large increase in primary aluminum demand through 2040 and beyond.

The key messages for the industry to send, he said, are to demonstrate that it can produce responsibly, through mitigating environmental impacts; that it brings a net benefit to society, in terms of the reduced environmental impact; and, at the end of life, that the value of the metal is retained through recycling or energy recovery.

He explained that the overall aluminum story is "a positive one, in terms of demand," noting that primary aluminum will continue to meet the bulk of the demand through that 2040 scenario, but that "increased recycling rates only offer limited potential because of the long product life."

Bayliss was one of five speakers in the keynote session presenting their "Vision for the Next Decade." All presentations are available on the Light Metals Keynote Session page, under the Featured Sessions section at www.tms.org/TMS2019.



Pictured are the 2019 Light Metals Keynote organizer and presenters, from left: Olivier Martin, Rio Tinto, Aluminum Committee chair and session organizer; Todd Summe, Novelis Inc.; Mo Xinda, China Nonferrous Metals Industry Association; Hans Erik Vatne, Norsk Hydro ASA; Chris Bayliss, International Aluminium Institute; and Vincent Christ, Elysis.

Be a Part of TMS2020



Don't miss your chance to contribute to the conversation at the TMS 2020 Annual Meeting & Exhibition (TMS2020), scheduled for February 23–27, in San Diego, California. Visit www.tms.org/TMS2020 to view technical topics and symposia, and to submit your abstract today.

Magnesium Technology Keynote Session

TMS's popular annual Magnesium Technology symposium opened with a keynote session featuring four invited speakers. The first three speakers looked primarily at the role of magnesium in the automotive industry.

While magnesium castings have achieved some success in automotive applications, presenters could point to only two significant examples of magnesium sheet currently used in cars: the roof of the Porsche GT3 and a trunk component of the Renault Samsung SM7.

"Property-wise, magnesium sheet has everything we need," said Christopher Romanowski, Danieli FATA Hunter. "The problem is it costs too much."

Another key concern of automakers, he said, is that there are only two suppliers in the world who can produce magnesium sheet of high enough quality to be used in automotive applications.

Sarah Kleinbaum, who gave an overview of magnesium research being conducted at the U.S. Department of Energy

(DOE) and national laboratories, agreed. "One of the biggest challenges is supply chain," she said.

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Kleinbaum discussed a study she conducted at the DOE of 35 automobiles, which found that only 20 components (less than 0.1%) in all of these vehicles were made from magnesium. Most of those were interior components that were not exposed to elements or engine heat.

"Strategically, we have to move away from using magnesium only in interior components," said David Klaumuenzer of Volkswagen AG, who talked about work being done at Volkswagen on a recent prototype manufacturing project for a magnesium Passat decklid.

Sean Agnew of the University of Virginia closed out the session with the presentation, "Thermally Activated Plasticity in Textured Magnesium and Its Alloys." The results of the work, he said, could offer ideas about how to determine optimal strength in alloys.

Diversity in STEM and Best Practices to Improve It

2019

Diversity in STEM and Best Practices to Improve It: Being Out in STEM Monday, March 11

Among the many benefits of having a diverse work force is that it can make your group smarter. "We work harder on an argument when we know we're going up against someone who is different from us," said Roberta Beal, Los Alamos National Laboratory. "It makes us think harder."

Beal was one of ten invited speakers to provide insights on fostering a more diverse and inclusive work environment at the full-day session, Diversity in STEM and Best Practices to Improve It, held at TMS2019.

Speakers covered a range of topics, with the first part of the day mainly focused on presenting case studies of successful programs and the afternoon session taking a look at the complexities of being LGBTQ+(lesbian, gay, bisexual, transgender, and queer/questioning) in the workplace, discussing the common needs of transgender people, and relaying individual experiences of coming out in STEM.

The conversation surrounding diversity and inclusion will continue at Diversity in the Minerals, Metals, and Materials Professions 4 (DMMM4), a co-located conference with the TMS 2020 Annual Meeting & Exhibition in San Diego, California. Abstracts are now being accepted for the 2020 symposium at www.tms.org/TMS2020.





Jonathan Madison, Sandia National Laboratories

Pictured are presenters and organizers (from left): Angus Wilkinson, University of Oxford; Megan J. Cordill, Erich Schmid Institute; Carolyn Hansson, University of Waterloo; Jessica Krogstad, University of Illinois, Urbana-Champaign; Asheley Blackford, Air Force Research Laboratory, Wright-Patterson Air Force Base; Thomas Reeve, Purdue University; Roberta Beal, Los Alamos National Laboratory; Matthew Korey, Purdue University; and K. Cunningham, ATI Specialty Alloys & Components. (Not pictured are speakers Andrea Hodge, University of Southern California; Isabella Van Rooyen, Idaho National Laboratory; and Jonathan Madison, Sandia National Laboratories.)



Highlights From The TMS2019 Session Rooms

Additive Manufacturing Joint Keynote Session

"Where the community has taken additive manufacturing in the last 10 years is amazing," said Ryan Dehoff, Oak Ridge National Laboratory, session organizer, and Additive Manufacturing (AM) Committee chair, expressing appreciation for the hard work by the community for making the technology so successful. The session, held on Monday afternoon, March 11, provided attendees with insights into specific technologies and materials used in the AM industry, such as superalloys, titanium alloys, printable alloys, and integrating machine learning into the future of the AM industry.

On the subject of superalloys, Tresa Pollock, University of California, Santa Barbara, noted that "while superalloys are becoming more and more relevant to additive manufacturing, the challenge is connecting structure to additive applications," during her presentation, "Solidification of Superalloys: From Single Crystals to Additive Manufacturing."

Pollock was one of five keynote speakers during the session.



The Additive Manufacturing Joint Keynote Session featured (from left) Tresa Pollock, University of California, Santa Barbara; Greg Olson, Northwestern University and QuesTek Innovations; Hamish Fraser, The Ohio State University; Elizabeth Holm, Carnegie Mellon University; session organizer Ryan Dehoff, Oak Ridge National Laboratory; and Sudarsanam Babu, The University of Tennessee, Knoxville

TUESDAY FEATURED SESSIONS Materials and Manufacturing Innovation Keynote

"The idea is to automate as much as possible of the scientific process, while recognizing that you can't ever remove humans from the process," said James Warren, National Institute of Standards and Technology (NIST), as he introduced the Materials and Manufacturing Innovation keynote session, focused this year on Autonomous Materials Research.

Stefano Curtarolo, Duke University, first looked at how understanding large amounts of data leads to disorder, but also to new descriptors for discovering materials in his talk, "Data, Disorder, and Materials." Taking a glimpse into the future, Curtarolo said that "trying to use the data to understand disordered materials will play a big role."



Benji Maruyama, Air Force Research Laboratory, also looked to the future, saying that "the future is autonomous, closed-loop research" in his talk, "Autonomous Research Experimentation Applied to Carbon Nanotube Synthesis." He discussed the need to advance from the current, "painfully slow" process of doing research to doing things "not just faster, but faster, better, and cheaper." This is where ARES, a "first-of-its-kind Autonomous Research System," comes into play, using a three-pronged approach of automation, autonomy, and modeling to work both faster and smarter. The real key, though, is teaming the human "knowledge workers" with robots and computers that can do the tedious or dangerous work.

Later, Carla Gomes, Cornell University, described a specific system for materials discovery in her talk, "SARA: Scientific Reasoning Agent to Accelerate Materials Discovery." Gomes said that the SARA system will combine materials science, artificial intelligence (AI), and computer science to accelerate the discovery and development of new materials. "Materials discovery is an amazing domain for us to push AI forward," she said.

Finally, in his lecture, "Towards Autonomous Materials Research Systems," Jason Hattrick-Simpers, NIST, said that he is "very excited to use AI to find the 'miracle' materials, or to optimize existing ones." While he discussed the many barriers to AI implementation (lack of reproducibility, insufficient incorporation, and the lack of standards, to name a few), he noted that "the time is now for AI. This is the opportunity to get involved and be relevant."

Pictured from left, are participants in the Materials and Manufacturing Innovation Keynote: Jason Hattrick-Simpers, NIST; Benji Maruyama, Air Force Research Laboratory; Stefano Curtarolo, Duke University; Carla Gomes, Cornell University; and session organizer James Warren, NIST.

Frontiers of Materials Research: A Decadal Survey

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TMS2019 featured a special session on *Frontiers of Materials Research: A Decadal Survey*, a new consensus study report released by the U.S. National Academies of Sciences, Engineering, and Medicine. The report was written by a committee of materials scientists and engineers that included 2018 TMS President Kevin Hemker and several TMS members. The study was focused on the development



of materials research (MR) over the past decade and covered topics such as MR fields that could be supported by other disciplines and international trends in MR.

The session opened with an overview of the study by Hemker, who said "it's been a remarkable paradigm change in advances that have been made in materials research over the past decade." Hemker attributed much

> of this shift to advances in computation that have enabled modeling, simulation, and advanced manufacturing.

The panel was moderated by Steven Zinkle, University of Tennessee, and featured (pictured, from left) Ian Robertson, University of Wisconsin; Linda Horton, Department of Energy; Susan Sinnott, Pennsylvania State University; Linda Sapochak, National Science Foundation; and Mark Weaver, University of Alabama, as panelists. The study is available for free download from the National Academies Press at www.nap.edu/25244.

REWAS 2019 Plenary Session

The REWAS 2019 symposium, held as a co-located event with TMS2019, featured a plenary session of seven invited speakers who examined the symposium's theme of Manufacturing the Circular Materials Economy from a variety of viewpoints.

Toru Okabe, vice president of the University of Tokyo, opened the symposium with a discussion on recycling of critical metals. "When I started my career, no one recognized the importance of smelting or recycling these specialty metals," said Okabe. "Now everyone does."

In his talk, David Wagger, Institute of Scrap Recycling Industries (ISRI), noted that currently a very small percentage of rare earth materials are recycled. "We need to make them easier to extract if we want to recycle them."

Ben Jones, a market analyst at CRU International Limited, looked at supply chains for battery materials from the investment side of the issue. The low-carbon transition is happening, he said, and will require new technologies. "Growth means investment, so we need new dollars in these markets," he said.

Additional talks looked at aluminum recycling, new processes for metals recycling, and the challenges of the circular economy, tying together the main themes of the REWAS symposium.



Pictured are REWAS 2019 organizers and plenary presenters (from left to right): Neale Neelameggham, IND LLC; Camille Fleuriault, Gopher Resource; Toru Okabe, University of Tokyo; Ramana Reddy, the University of Alabama; Adam Powell, Worcester Polytechnic Institute; David Wagger, Institute of Scrap Recycling Industries, Inc.; Ben Jones, CRU International Limited; Elsa Olivetti, Massachusetts Institute of Technology; Chris Bayliss, International Aluminum Institute; Randolph Kirchain, Massachusetts Institute of Technology; Markus Reuter, Helmholtz-Institute Freiberg for Resource Technology; and Gabrielle Gaustad, Alfred University.



Callie Babbit discusses a project from the Golisano Institute for Sustainability at the Rochester Institute of Technology that compiles data on a cumulative material footprint for electronic devices in average U.S. households at the REWAS plenary.

Highlights From The TMS2019 Session Rooms

Acta Materialia Symposium

"The real world is a tough place. It's not ever clear how science will make an impact," Alexander King, Iowa State University, said in his talk, "When Science Matters." King spoke as part of the TMS2019 Acta Materialia Symposium, which honored three TMS members receiving high-level Acta Materialia awards.

King was accepting the Acta Materialia Hollomon Award for Materials and Society, and his talk focused on the impact that scientists can have on broader societal issues. He spoke of his experience working for a year in the U.S. Department of State as a Jefferson Science Fellow



Xavier Sauvage

and pointed to several examples of how an unbiased scientific eye can be of value, even in an area outside of the scientist's expertise. As an example, he pointed to a report on avian flu in Africa that landed on his desk. While not in his area of expertise, he noticed that the migration patterns of birds that could potentially spread the disease looked wrong in the report and suggested widening the area that they were monitoring. His instinct proved right when the disease occurred outside of the range that had been identified by the migration patterns, and, as a result, they were able to act quickly and contain the disease to a few farms when it did break out.

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"A strong general scientific mind can make a big impact in government," he concluded.

In addition to King, Ke Lu, of the Chinese Academy of Sciences was honored with the Acta Materialia Gold Medal Award. His colleague, Yi Li, accepted the award on Lu's behalf and presented his talk on stabilizing nanostructures in metals.

Xavier Sauvage, Groupe de Physique des Materiaux, CNRS, Universite Rouen Normandie, accepted the Acta Materialia Silver Medal Award, delivering the lecture, "Generation of Interfacial Dislocations Loops to Overcome the Nucleation Barrier of Tetrahedron Shaped Precipitates."

WEDNESDAY FEATURED SESSIONS Science Policy within the Materials Research Community

"Having the chance to organize a symposium as graduate students was a tremendous opportunity, both to get experience in the logistics of putting together a symposium and to contribute to the TMS meeting in a new way," said Kathleen Chou, University of Michigan (UofM), and one of the organizers of the 2019 TMS Student-Run Symposium. This symposium was one in a series in which a member of the TMS Education Committee mentors students on how to organize a TMS symposium. Chou's fellow organizer, Peter Meisenheimer echoed her sentiments: "The organizing process, as well as the session itself, was a valuable experience and we are thankful for the opportunity."

The student group from UofM, consisting of Chou, Meisenheimer, Max Powers, and Ashley Hilmas, focused this year's symposium on Science Policy within the Materials Research Community. "We wanted to choose a topic that would benefit both student and professional attendees, and science policy seemed to be a topic that would be interesting and relevant," Chou said. The group lined up a variety of presentations for the symposium, with speakers



Organized by a group of students from the University of Michigan (UofM), the session featured the following participants: (back row, left to right) Max Powers, UofM; Scott Litzelman, 2017–2018 TMS/MRS Congressional Science & Engineering Fellow; (middle row, left to right) James Warren, National Institute of Standards and Technology; John Vetrano, Office of Basic Energy Sciences, Department of Energy; John Allison, UofM; Charles Ward, Air Force Research Laboratory; Alan Taub, Lightweight Innovations for Tomorrow (LIFT) and UofM; and Peter Meisenheimer, UofM; (front row, left to right) Edward Herderick, The Ohio State University; Alexis Lewis, National Science Foundation; Kathleen Chou, UofM; Ashley Hilmas, UofM; and Iver Anderson, Ames Laboratory and the University of Iowa. addressing topics "ranging from forming industry-academic partnerships, to determining directions for federal funding, to developing and managing huge initiatives like the materials genome initiative," said Meisenheimer.

The day-long symposium ended with a panel discussion featuring John Allison, UofM, Edward Herderick, The Ohio State University, and Iver Anderson, Ames Laboratory and the University of Iowa. The panelists answered a number of questions from the audience, such as, "How do scientists advocate for science that is constantly changing?" "What are some obstacles to transitioning from a technical background to policy?" and "How do we communicate to the public in a way that we don't lose the scientific explanation?" The parting thoughts of each panelist were applicable to many of the questions asked during the session.

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"The important thing is that you can make a difference on that issue," said Allison of navigating advocacy for complex political issues. Anderson agreed, advising attendees to "find the things that will technologically make our future brighter, and then advocate the heck out of it."

Herderick's advice ran along the lines of sharing your scientific expertise with others—not just in policy, but even at your same institution or organization. When talking with students, he always reminds them that "it's such a big world out there. There are so many people, in so many fields...sometimes literally right across the street. Don't underestimate the adjacency and opportunity of being an expert in your chosen field."

Effective Business Improvement Methodologies for the Minerals, Metals, and Materials Industries

Robert Hyers of the University of Massachusetts introduced the Wednesday afternoon symposium, Effective Business Improvement Methodologies for the Minerals, Metals, and Materials Industries, as an experimental session, with its focus on case studies that would have practical applications for all industries.

Cynthia Belt, Metals Energy Management LLC, opened the session with a presentation of case studies for continuous improvement projects in the areas of energy and melt loss. Her discussion included different approaches to save money and improve processes. No matter which technique a company chooses—a long-term Six-Sigma project or a one-day Gemba Walk—the key to success, she stressed, is follow-up.

"Continuous improvement is critical to the materials industry," said Belt. "All projects require follow-up so the gains are not lost."

Nicholas E. Cherolis, Baker Engineering and Risk Consultants, cautioned the audience to take care of the little things so you won't get bit by the big ones. "Major failures often do not occur as one isolated issue or event," he warned. "There are often less severe precursors to a major event, so find out what minor failures can tell you. Major catastrophic events can be minimized or prevented if you get to the bottom of a problem," he said.

Adrian Deneys, Praxair Inc., presented separate case studies illustrating one approach for proprietary technologies (when a new idea is being patented and formulated) and a second experience-based approach (for non-proprietary issues). These aimed to identify and reinforce successful practices.

Eric Schmidt of Vallourec Star delivered a case study on unpredictable anode production that emphasized the importance of observing the work on the shop floor. "We get caught up in fundamental materials science, but sometimes something as small as a nozzle can cause huge problems."

The session closed with a panel discussion that tied together the common threads of the presentations and answered audience questions.





Nicholas E. Cherolis

TMS2019 Features Distinguished Award Lecturers

Roughly 50 people filled the room to hear Hael Mughrabi of the University of Erlangen-Nürnberg discuss, "Revisiting 'Steady-State' Monotonic and Cyclic Deformation: Emphasizing the Quasi-Stationary State of Deformation," at the Institute of Metals (IOM)/ Robert Franklin Mehl Award lecture on March 13. During this talk, Mughrabi "put a big question mark" next to some long-standing assumptions.

"Instead of speaking of steady state, we should speak of quasi-stationery deformation," he said, with his final slide concluding: "Steady state deformation is quasistationary!"

On March 11, two additional recipients of high-level TMS awards presented their featured lectures. Sridhar Seetharaman delivered the Extraction & Processing Division Distinguished Lecture, "The Importance of Transient Phenomena in Metallurgical Processes," where he reviewed examples and case studies of slag/ metal reactions and precipitations in melt and oxidation where the transient trajectory paths revealed how metallurgical processes can be affected.

Mark D. Asta also gave the William Hume-Rothery Award lecture, "Order within Disordered Materials— Insights into the Nature and Impact of Short-Range Order in Concentrated Solid Solutions," on Monday, March 11. Asta discussed the approaches underlying atomistic simulation methods and their application in the modeling of properties of concentrated alloy solid solutions. His talk also focused on the role of shortrange order (SRO) in oxide metal solutions.



Hael Mughrabi



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Sridhar Seetharaman



Mark Asta

View the TMS2019 Photo Gallery on Flickr

Want to see more? Additional photos from the sessions featured in this article, as well as snapshots from other technical sessions, social events, and networking activities that made up TMS2019, are now available to view on Flickr. Visit www.flickr.com/photos/tmsevents/ to browse the complete collection on our photostream or go to the albums section of the site to view photos from





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At the heart of the TMS 2019 Annual Meeting & Exhibition (TMS2019) were the social and networking events that brought together scientists and engineers from around the world to discuss common interests, offer advice, and build friendships.

From the Meet a Mentor event, where professional relationships take root, to division luncheons where those with like interests can meet and learn about common topics, to diversity and inclusion gatherings, which provide safe spaces for honest discussion, networking events bring people together to form lasting personal connections.

Nowhere was this more powerfully on display than at the 2019 TMS-AIME Honors & Awards Ceremony on Wednesday, March 13, which included presentation of awards by the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME), of which TMS is a member society. More than 50 individuals were recognized for their significant achievements over the course of the evening. The event took a more personal turn when it was time for the TMS Fellows, the highest honorees of the evening, to take the stage and accept their awards.

This year, their number included **Thomas Bieler**, who thanked God for the chance to be curious for a living and his wife, a historian, for helping him to see more broadly than his microscopic career; **Grace Burke**, who recalled



Three of the recipients of the AIME Champion H. Mathewson Award (from left): Patrick Villechaise, Damien Texier, and Jonathan Cormier.

the impact of a letter she received in high school from Julia Weertman; **Dennis Dimiduk**, who acknowledged the many professionals he has met through TMS who have guided him throughout his career; **Roderick Guthrie**, who called TMS a force for the global good; **Elizabeth Holm**, who thanked a long list of influential women in the materials community for providing both inspiration and awe; **Nack Joon Kim**, who expressed hope that more international members like himself would be added to the prestigious list of TMS Fellows in the future; and **Alan Taub** and **Dan Thoma**, who reflected on their early days at TMS, their first Society meetings and early presentations, and the distance they had come since then.





Four of the night's honorees (from left): Ashley Spear, Elsa Olivetti, Jennifer Carter, and Saryu Fensin

Forging and Reinforcing Connections at TMS2019



Desne Crossley accepts the TMS Fellow Award on behalf of her father, Frank Crossley.



From left: Christina Meksers, Henry Colorado, Gwen Bailey, and Luca Masi.

Perhaps the most moving speech of the night came from someone outside of the materials community, when Desne Crossley accepted the Fellow award on behalf of her father, **Frank Crossley**, who passed away on April 15, 2018, at the age of 93.

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"He'd be over the moon happy to have his career recognized in this way," she said, noting that she had learned things about her father that she hadn't known by reading the letters written by his nominators. "Through this process with TMS, I came to know my father in a new way."

She reminded the audience that Crossley, the first African American to receive a Ph.D. in metallurgy, had been working at a time when the science and engineering disciplines did not permit recognition of black scientists. "None of us can comprehend the magnitude of his achievements under such circumstances."

Her speech was met with a standing ovation.

After the close of the ceremony, awardees and their guests enjoyed a banquet dinner and dessert reception.

The awards ceremony was just one of many networking events held at TMS2019. The following pages provide an overview of additional events that connected attendees throughout the week.

Diversity and Inclusion Events

New for TMS2019 was the LGBTQ+ and Allies Networking Mixer, held on Sunday evening and open to all TMS2019 attendees. More than 150 people participated in this event, which was designed to provide an evening of informal networking in a safe space to celebrate shared experiences as TMS LGBTQ+ (lesbian, gay, bisexual, transgender, and queer/questioning) individuals and allies. The event was sponsored by TMS Pride, a new group formed by the TMS Diversity Committee in October 2018 to advocate for and facilitate the inclusion, recognition, and networking of LGBTQ+ students and professionals in the minerals, metals, and materials fields. GE Research and the National Institute of Standards and Technology were Champion-Level sponsors for this event, with Case Western Reserve University sponsoring at the Advocate level.





On Wednesday morning, attendees gathered for **Fresh Coffee, Fresh Ideas: Diversity and Inclusion Breakfast**, now an established event at the TMS Annual Meeting. This year, participants at each table engaged in discussion on a variety of topics, including best practices, unconscious bias, intersectionality, breaking barriers for physical disabilities, international members, gender and sexual minorities, the importance of allies, anxiety issues, and the TMS Diversity Summit. These discussions will be used to shape directions for future Diversity Committee initiatives, as well as to provide insights to TMS staff and leadership on how to continue to advance diversity, inclusion, and engagement within the Society and the professional community at large.

Student Events



The Colorado School of Mines took home their seventh **Materials Bowl** championship on Sunday, March 10, at TMS2019. Their team, the Orediggers (pictured, right), competed against the University of Tennessee Knoxville team, The VOL-ymer Blends (pictured, left), in the final round of the 2019 TMS Materials Bowl, following a day of elimination rounds. 2018 TMS president Kevin Hemker (pictured, center) presented the trophy to the winning team from Colorado.

The TMS Materials Bowl, held each year at the TMS Annual Meeting, is a materials-themed knowledge and trivia competition for university students. A dozen university teams, made up of undergraduate and graduate students, competed in this year's event, which was sponsored by Goodfellow.



Upon introducing themselves, each of the panelists at the **Student Career Forum** on Tuesday, March 12, noted how their own career paths have taken "the long and winding road" to where they are now. "Don't get fixed on a certain path. Be open to other opportunities, or at least seeing what that might be like," said Jonathan Zimmerman, Sandia National Laboratories.

Six individuals, joined by moderator Kyle Johnson of the Young Professionals Committee, drew from their own experiences as an audience of undergraduate and graduate students sought advice on a variety of subjects—from avoiding common interview or resume mistakes, to making a career switch between sectors, to networking in order to move forward.

On that last point, Veronica Livescu, Los Alamos National Laboratory, noted that "it's good to make contact directly with the people you want to work for." "And if you don't want to contact someone directly," added Raul Rebak, GE Global Research, "see if you have a common connection who would be willing to recommend you or pass along your resume."

Panelists encouraged students to utilize all available resources and opportunities, such as attending a TMS annual meeting, to meet new people and find mentors. "You should be building a mentor network and reaching out to them," said Tori Miller, North Carolina State University, "because it's not just one mentor, it's a whole network. Don't expect one person to be everything."

The Student Career Forum was organized by the Young Professional Committee.

Panel participants included (left to right): Raul Rebak, GE Global Research; Douglas Stauffer, Bruker Nano Inc.; Veronica Livescu, Los Alamos National Laboratory; Tori Miller, North Carolina State University; Jonathan Zimmerman, Sandia National Laboratories; Robert Maass, University of Illinois at Urbana-Champaign; and Kyle Johnson, Young Professionals Committee vice chair and Sandia National Laboratories.

Young Professional Events

The **Young Professional Tutorial Luncheon Lecture** on Tuesday, March 12, featured presentations from both of the 2019 TMS Early Career Faculty Fellow award recipients.

Ashley Spear, assistant professor and director of the Multiscale Mechanics & Materials Laboratory at the University of Utah, presented "Data-Driven Materials Science: Successes, Challenges, and Opportunities." Spear talked about the emergence of a fourth paradigm in materials science, citing specific examples of success in the fatigue community.

"We really now have access to a lot of data," Spear said, "which leads us to step back and ask, 'What can we do with data?'; 'How can we learn from it...and predict?"" She explained how in the last thousand or so years, science has evolved from experimental, to theoretical, to computational—all leading to today's age of data-intensive science. "Scientists can get overwhelmed, with data sets coming from many different sources," Spear noted.

When looking to the future, Spear addressed the need to combine data science with materials science, really moving into the era of knowledge so that practitioners can learn from the many different data sources and make meaningful predictions from their findings, and answer those questions she first posed. However, the task is easier said than done.

"If we want to go from heterogeneous materials databases all the way up to knowledge, there are a lot of steps in between."



Elsa Olivetti, the Atlantic Richfield Associate Professor of Energy Studies at the Massachusetts Institute of Technology, followed Spear with a talk entitled, "Data Mining towards Resource-Effective Materials, Processes, and Systems."

Olivetti first compared the availability of materials data to other data residing on the internet—looking at Amazon, Netflix, or cat videos, as examples. "In comparison, we don't have a lot of data. It's actually very scarce," she said. "Our biggest challenge is that we have to continue to remind ourselves that we are not big data."

To address this challenge, Olivetti suggests three things: "we need to continue to build up our data sets"; "find clever ways to augment our data"; and master transfer learning, where you take knowledge from one system and transfer it to another where there is less knowledge. When these things can be accomplished, computational learning can be used to help accelerate the pace of identifying advanced materials for commercial use—a process that is still very much limited by trial-and-error.

Even more challenges exist, however, when considering how to accomplish these tasks. Data volume and representation, prediction tasks, uncertainty in models, sample bias, establishing domain knowledge, and interpretability are all often barriers to creating a successful predictive synthesis system to aid in materials design and processing. Above all, Olivetti said, "we need to be able to interpret to know whether the models are valuable at all."





Ashley Spear (top), University of Utah, and Elsa Olivetti (bottom), Massachusetts Institute of Technology, both 2019 TMS Early Career Faculty Fellows, gave presentations during the Young Professional Tutorial Lecture.

Finding a work-life balance, navigating workplace communications, and transitioning from a student to a professional were among the topics discussed at the 2019 TMS **Meet a Mentor** event, held on Monday evening, March 11. This annual event provides young professionals the opportunity to engage in discussion with more experienced TMS members about issues of importance to their careers.

Networking Receptions

On Sunday, March 10, TMS2019 attendees kicked off the meeting with the **President's Welcome Reception** (below), where they could socialize, become acquainted with other attendees, and enjoy light refreshments before the start of technical programming on Monday.



The **TMS Fellows Reception** (below), also held on Sunday evening, offered distinguished TMS members and their invited guests an opportunity to catch up with old friends and make new acquaintances in a relaxed setting.



Luncheons Bring Divisions Together

Division luncheons offer TMS members the chance for a meal with colleagues working in fields closely related to their own and also provides the opportunity to bestow division-level awards, including scholarships, young leaders professional development awards, and scientific achievements. Each luncheon is topped off by a presentation from an invited speaker.



SMD Luncheon Lecture

Stephen M. Foiles, distinguished member of the technical staff at Sandia National Laboratories, posed the nontraditional questions about molecular dynamics (MD) during his Structural Materials Division (SMD) Luncheon lecture, "Molecular Dynamics: With Great Power Comes Great Responsibility," on Monday, March 11.

"We're going to predict stuff, but do we really believe it?" he asked, noting that people increasingly want to use MD to predict materials properties and fundamental atomicscale mechanisms, but that as a field, "we need to quantify how accurate our predictions are." Additionally, Foiles stated that the problem of quantification uncertainty within MD is a challenging one. "We need quantitative prediction with error bias," he said, recalling a simple, yet troubling question once asked of him-"what are the error bars on vour calculation?"

Foiles continued that if MD intends to become a predictive tool for making real impacts, not just a qualitative one, problems such as these need to be addressed. "It has always bugged me that as a field, we don't know how to answer those questions. And as we become more relevant to the engineering field, we need to answer those questions."

EPD/MPMD Luncheon Lecture

Toru Okabe, vice president of the University of Tokyo, delivered the talk "Recycling Precious Metals and Rare Metals from Scraps" at the TMS Extraction & Processing Division (EPD)/Materials Processing & Manufacturing Division (MPMD) Luncheon on Tuesday, March 12. In his talk, Okabe identified three bottlenecks to rare metal supplies: resource supply restrictions, technology restrictions, and environmental restrictions.

"Most people don't know that serious environmental destruction occurs when mining or smelting," said Okabe, who discussed the naturally occurring radioactive materials that can be produced in waste when extracting material from ore and the harmful byproducts produced when extracting useful elements, such as the arsenic that comes along with copper extraction.

Okabe is currently working on processes for recycling of rare earth metals, which don't generate these types of harmful wastes. "When you factor in the value of nature and the cost of dealing with waste, recycling is less expensive than mining new materials," said Okabe. "Harmful wastes generated from natural ore can be avoided by recycling."

LMD Luncheon Lecture

Kevin Anderson, senior technical fellow in the Brunswick Corporation in the Mercury Marine Division, presented the featured lecture, "Technological Advancements on the Secondary Aluminum Industry," during the Light Metals Division (LMD) Luncheon on Wednesday, March 13. During his talk, Anderson discussed the increasing role of secondary aluminum and reasons why it's valuable to the economy, such as, weight reduction, cost reduction, energy savings, and better, more sustainable products.

While covering global themes and advancing technologies in secondary aluminum production, Anderson noted that "the old stereotypes of secondary having poor compositional control, poor metal quality, and inferior mechanical properties...those days are gone." New technologies, he said, are being introduced to plants to eliminate the "old stereotypes" and produce aluminum that is "a highly recyclable, sustainable material with excellent properties."

Recyclability is key, Anderson concluded, noting that educating every part of the value chain is an important step in this effort. "When you start to think about the design of a product, you also have to think about end of life," he said. "It really all starts with design, and then everyone along the value chain has to pay attention."

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Posters by undergraduate students, graduate students, and young professionals were honored for excellence at the 2019 Technical Division Student Poster Competition and the 2019 Young Professional Poster Competition, both held at the TMS 2019 Annual Meeting & Exhibition (TMS2019), March 10-14, in San Antonio, Texas. A number of symposia at TMS2019 also provided opportunities for professional recognition through poster and presentation competitions. Congratulations to the award recipients recognized in the following pages.

Technical Division Student Poster Competition Winners

Extraction & Processing Division Award

Graduate: "Thermochemical and Electrochemical Properties of Nd-Bi Alloys by Electromotive Force and Complementary Measurements," Timothy Lichtenstein, Pennsylvania State University

Functional Materials Division Award

Undergraduate: "Electrodeposition of Tungsten Oxide Hydrates on 2D and 3D Substrates for High Power Electrochemical Energy Storage," Ellie Scott, North Carolina State University

Light Metals Division Awards

Graduate: "Conventional and Low Phosphorous Ceramic Foam Filters (CFFs) - Chemical Reactivity and Thermal Stability," Are Bergin, Norwegian University of Science and Technology & Hydro ASA

Undergraduate: "Aluminum-cerium Alloys Treated with Niobium Diboride Nanoparticles for Aerospace Applications," Julie Colon, University of Puerto Rico Mayaguez



Materials Processing & Manufacturing Division Awards

Graduate: "Predictive Finite Element Simulations of Grain Growth," Erdem Eren, University of California, Davis *Undergraduate:* "Alginate Particle Fabrication Using Vibration Assisted Drop Generation," Brandon Wells, Purdue University

Structural Materials Division Awards

Graduate: "Influence of $\gamma' - \gamma''$ Co-precipitation on the Mechanical Properties and Coarsening Kinetics of IN718 Variant Superalloys," Semanti Mukhopadhyay, The Ohio State University

Undergraduate: "Identifying Damage Initiation of Woven Fiberglass Composites Under Compression," Isabella Mendoza, Drexel University





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Student and Young Professional Poster Competition Winners



Timothy Lichtenstein, Pennsylvania State University



Ning Zhang, Colorado School of Mines



Brandon Wells, Purdue University



Semanti Mukhopadhyay, The Ohio State University



Are Bergin, Norwegian University of Science and Technology & Hydro ASA



Abby Cisko, U.S. Army Engineer Research and Development Center

Young Professional Poster Competition Winners

Light Metals Division Award

"Analysis and Interpretation about Evaluation and Atomic Vibration of New Raman Active Modes from CDW Phase in of Layered 2H-TaX2 (X=S, Se)," Sugata Chowdhury, National Institute of Standards and Technology

Materials Processing & Manufacturing Division Award

"Fatigue Characterization and Microstructure-sensitive Modeling of Extruded and Friction Stir Welded Aluminum Lithium Alloy 2099," Abby Cisko, U.S. Army Engineer Research and Development Center

 Babella Mendoza, Drexel

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Ellie Scott, North Carolina State University



Julie Colon, University of Puerto Rico Mayaguez



(Not pictured: Erdem Eren, University of California, Davis)

Structural Materials Division Award

"Flaw Tolerance of Shape Memory Yttria-stabilized Tetragonal Zirconia Polycrystals," Ning Zhang, Colorado School of Mines

Additive Manufacturing for Energy Applications Symposium Best Posters

First-Place Poster: "Fabrication of Cr Cladded Zr-alloys Using Solid State Powder Spray Additive Manufacturing Technology," Benjamin Maier, Hwasung Yeom, Greg Johnson, *Tyler Dabney*, and Kumar Sridharan, University of Wisconsin-Madison

Second-Place Poster: "Investigation of Manufacturing Oxide Dispersion Strengthened (ODS) Steel Fuel Cladding Tubes Using Cold Spray Technology," *Mia Lenling,* Hwasung Yeom, Benjamin Maier, Greg Johnson, and Kumar Sridharan, University of Wisconsin-Madison; Peter Hosemann and Jeff Graham, University of California, Berkeley; David Hoelzer, Oak Ridge National Laboratory; and Stuart Maloy, Los Alamos National Laboratory



Mia Lenling (left) and Tyler Dabney accept their best poster awards from the Additive Manufacturing for Energy Applications Symposium.

Advanced Real Time Imaging Symposium Awards

First-Place Oral Presentation: "In Situ

Characterization of Hot Cracking Using Dynamic X-ray Radiography," Po-Ju Chiang, Runbo Jiang, Ross Cunningham, and *Anthony Rollett*, Carnegie Mellon University; Niranjan Parab, Cang Zhao, Kamel Fezzaa, and Tao Sun, Argonne National Laboratory

Second-Place Oral Presentation: "High Resolution 4D X-ray Tomography of Dendrite Growth in Aluminum Alloys," *Tiberiu Stan,* Yue Sun, Kate Elder, and Peter Voorhees, Northwestern University; and Xianghui Xiao, Argonne National Laboratory

Second-Place Oral Presentation: "New Insights on Liquid Metal Breakup from High Speed Image Analysis during Close Coupled Gas Atomization," *Jordan Tiarks,* Trevor Riedemann, Emma White, and Iver Anderson, U.S. Department of Energy, Ames Laboratory

First-Place Oral Presentation (Student):

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"Characterization of Localized Plastic Deformation Behaviors Associated with Dynamic Strain Aging in Pipeline Steels Using Digital Image Correlation," *Taylor Jacobs*, Los Alamos National Laboratory; David Matlock and Kip Findley, Colorado School of Mines

Second-Place Oral Presentation (Student):

"Real-Time Deformation Mechanisms of Advanced Nanocomposites by High-Resolution In-situ Testing," Arvind Agarwal and *Pranjal Nautiyal*, Florida International University

Third-Place Oral Presentation (Student):

"Observation of the Reaction between Iron Ore and Metallurgical Fluxes for Improved Pre-reduction," *James Whiston*, Stephen Spooner, and Z. Li, WMG, University of Warwick; and K. Meijer, Tata Steel Europe

First-Place Manuscript/Conference Proceedings:

"Quantitative Thermal Analysis of Solidification in a High-Temperature Laser-Scanning Confocal Microscope," *Dasith Liyanag*, Suk-Chun Moon, Madeleine Du Toit, and Rian Dippenaar, University of Wollongong

Second-Place Manuscript/Conference

Proceedings: "High-Frequency Ultrasound Analysis in Both Experimental and Computation Level to Understand the Microstructural Change in Soft Tissues," Leila Ladani and *Koushik Paul*, University of Texas at Arlington; and Jeremy Stromer, University of Connecticut

Third-Place Manuscript/Conference Proceedings:

"Surface Tension of High Temperature Liquids Evaluation with a Thermal Imaging Furnace," Andrew Caldwell, Mindy Wu, and *Antoine Allanore*, Massachusetts Institute of Technology

Third-Place Manuscript/Conference Proceedings:

"In Situ Characterization of Hot Cracking Using Dynamic X-ray Radiography," Po-Ju Chiang, Runbo Jiang, Ross Cunningham, and *Anthony Rollett*, Carnegie Mellon University; Niranjan Parab, Cang Zhao, Kamel Fezzaa, and Tao Sun, Argonne National Laboratory





Alloys and Compounds for Thermoelectric and Solar Cell Applications VII Symposium Best Posters

First-Place Poster: "High Thermoelectric Performance in La-doped n-type Mg₃Sb_{1.5}Bi_{0.5}," *Kazuki Imasato,* Max Wood, and G. Jeffrey Snyder, Northwestern University

Second-Place Poster: "Thermoelectric Properties of Y_xAl_yB₁₄ Prepared by Reactive Spark Plasma Sintering," *Hyoung-Won Son*, Quansheng Guo, and Takao Mori, National Institute for Materials Science

Third-Place Poster: "Phase Diagrams of Material Systems with Quasicrystalline Phases," Pei-chia Lo, *Tse-Yang Huang*, Tzu-ning Kuo, Anbalagan Ramakrishnan, and Sinn-wen Chen, National Tsing Hua University

The winners of the Alloys and Compounds for Thermoelectric and Solar Cell Applications VII Symposium best poster competition are, from left to right: Tse-yang Huang, Kazuki Imasato, and Hyong-won Son.



Biological Materials Science Symposium Best Posters

First-Place Poster: "3D Printing Bioinspired Composite Materials with Ultrasound Directed Self-Assembly," *Paul Wadsworth,* Isaac Nelson, Taylor Ogden, and Steven Naleway, University of Utah

Second-Place Poster: "Structural Basis for the Damage Tolerance of the Low-Density Cellular Structure of Cuttlebone," *Ting Yang* and Ling Li, Virginia Polytechnic Institute and State University

Third-Place Poster: "Calcium Phosphate Microspheres: A Novel Approach to Calcium Phosphate Cements," *Jerry Howard,* Isaac Nelson, John Colombo, Steven Naleway, and Krista Carlson, University of Utah

Green Materials Engineering: An EPD Symposium in Honor of Sergio Monteiro Best Posters

First-Place Poster: "Charpy Impact Test of Polymeric Composites with Epoxy Resin Reinforced by Jute Fabric," *Carlos Vieira,* José Machado, Juliana Carvalho, Anna Carolina Neves, Felipe Lopes, and Sérgio Monteiro, State University Northern of Rio de Janeiro **Second-Place Poster:** "Performance of Natural Curaua Non-woven Fabric Composites as Stand-alone Targets against Standard 9 mm and 7.62 mm Projectiles," *Fabio Braga,* Faculty of the National Service of Industrial Apprenticeship (SENAI); Michelle Oliveira, Fabio Garcia Filho, Sergio Monteiro, and Édio Lima Jr., Military Institute of Engineering

Third-Place Poster: "Study of the Technological Properties of Multiple Mortar Use with Efficient Addition of Rock Waste," Micaela Nicolite, *Lucas Amaral*, Geovana Carla Delaqua, Markssuel Marvila, Jonas Alexandre, and Carlos Maurício Vieira, State University of Northern Rio de Janeiro; and Sérgio Neves, Military Engineering Institute

Mechanical Behavior Related to Interface Physics III Symposium Best Posters

First-Place Poster: "Mechanical Behavior of Nanotwinned Metals under Micropillar Compression: An In Situ Study," *Jin Li*, Tongjun Niu, Jie Ding, Jaehun Cho, Sichuang Xue, Zhe Fan, Yifan Zhang, Haiyan Wang, and Xinghang Zhang, Purdue University

Second-Place Poster: "Application of Small Scale Mechanical Testing to Link Interface Properties to Macroscopic Hysteresis Behavior of SiC/SiC Composites," *Joseph Kabel,* Darren Parkison, and Peter Hosemann, University of California, Berkeley; Christian Deck, General Atomics; and Yutai Katoh, Oak Ridge National Laboratory

Third-Place Poster: "Tuning the Mechanical Behaviour of Nanocrystalline Austenitic Steel by Proton Irradiation," *Markus Alfreider* and Daniel Kiener, University of Leoben; and Peter Hosemann, University of California, Berkeley

REWAS 2019 Symposium Best Posters

First-Place Poster: "Distribution and Chemical Species of Chromium in the EAF Dust from Stainless Steel Plant," Zhi Li, *Guojun Ma*, and Xiang Zhang, Wuhan University of Science and Technology

First-Place Poster (Student): "Waste Tire Rubber Powders Based Composite Materials," *Carlos Revelo*, Mauricio Andres Correa, and Henry Colorado, Universidad de Antioquia; and Claudio Aguilar, Universidad Técnica Federico Santa María

Carlos Revelo takes first place in the student poster contest sponsored by the REWAS 2019





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THE 2019 BLADESMITHING COMPETITION: WHERE SCIENCE AND CRAFT COME TOGETHER

Ashley-Anne Bohnert

Attendees at the TMS 2019 Annual Meeting & Exhibition (TMS2019) in San Antonio, Texas, were treated to an extraordinary spectacle of technical skill and craftsmanship as the third iteration of the TMS Bladesmithing Competition showcased 33 forged blades from student teams around the world.

Every two years, university students are challenged to bring metallurgical concepts to life by creating their own blade through hand hammering or trip hammer forging. The competition sparks a passion for the science behind bladesmithing and fires a healthy collaborative spirit among team members. Above all, it is a chance for students to reinforce their materials knowledge while demonstrating their creativity, resourcefulness, and determination. Completing an entry is no small feat, as noted by 2018 TMS President Kevin Hemker in a speech during the Bladesmithing Awards Ceremony. "The competition marries physical skill and academic rigor as each entry is judged on a cumulative score for the blade, report, poster, and video submissions," Hemker said, praising each student team for rising to the challenge of completing an entry.

Jeffrey Wadsworth, retired president and CEO

Bohnert

of Battelle, was on hand at the awards ceremony to announce the recipients of the TMS Wadsworth-Sherby Bladesmithing Grand Prize, named in honor of his late mentor, Oleg D. Sherby of Stanford University. This year's competition also included an exciting new highlight: the addition of special citations to acknowledge blades that showed outstanding performance in individual categories such as beauty, hands-on process, or historical accuracy.

In the competition's off years, a Bladesmithing Symposium is held during the TMS Annual Meeting to give past and future contestants a chance to share their experiences and ideas for preparing entries, while also focusing on bladesmithing processes and procedures. Abstracts for the TMS2020 Baldesmithing Symposium are being accepted at www.tms.org/TMS2020. Additionally, new details for the next TMS Bladesmithing Competition, to be held at TMS2021 in Orlando, Florida, will be posted soon. Check the Bladesmithing website at

www.tms.org/Bladesmithing for news and updates. Continue reading this article for a presentation of this year's award and special citation recipients, as well as all 2019 competitors. To find out more about what it takes to complete an entry, you can view team videos at www.YouTube.com/ChannelTMS/Playlists under the Bladesmithing Competition 2019 playlist.

TMS-WADSWORTH-SHERBY GRAND PRIZE

University of Florida: "DECAPIGATOR"

Award includes \$2,000 Cash Prize, TMS-Wadsworth-Sherby Bladesmithing Grand Prize Medal, and Commemorative Volume of Wadsworth-Sherby Collected Works on Damascus Steels & Related Topics.

Michelle Thackeray, Alex Aviles, Brandon Capellini, Stephon Dean, Jacob Gusewelle, Evyatar Hashmonay, Jonah Hopton, Emily Huntley, Caroline Kelly, Chris Nacea, Jakub Pepas, Karina Pilo-Ricci, Devin Ritter, Natalie Starr, Troy Stringfellow, Nicole Trometer, Nadine Ulmer, Mikki Von Schaumburg, and Kellen Wise





Full-length blade featured on previous page.



The 2019 Bladesmithing Competition: Where Science and Craft Come Together

THIRD PLACE

Colorado School of Mines: "Rain Drop Pattern Chef Knife"

SECOND PLACE

Award includes \$500 Cash Prize and Certificate

Stuart Shirley, Itamar Brill, Tyler Mertens, Ty Porter, and Matt Zappulla





McMaster University: "The Mighty Gladius"

Award includes \$250 Cash Prize and Certificate

Paul Tallon, Yoel Emun, Dan Osoriod, Youssef Salib, Eric Tenutta, Adam Tyedmers, and Joe Wu





HONORABLE MENTION

University of Idaho: **"The Fire Creek Forge Bowie Knife"** Award includes \$100 Cash Prize and Certificate

Brandon Day, Paul Adisa, Mohammed Alqahtani, Vanessa Beasley, Mark Currier, Jadzia Graves, Arnab Kundu, Jackson Mitchell, Lily Mortensen, Paul Riebe, Anumat Sittino, Kendra Wallace, and Elijah Williams





LEARNING FROM AN EXPERT

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Many of the special citations awarded in the 2019 Bladesmithing Competition were selected by guest judge J. Alex Ruiz, program coordinator of the Wesley Foundation of San Antonio and owner of Volundr Forge. Ruiz is a Texas-based blacksmith and bladesmith best known for his appearance on the popular History Channel series *Forged in Fire* where he was declared champion for his entry, "The Horseman's Axe."

Since beginning his work as a blacksmith in 2015 Ruiz has taught and demonstrated across Texas. He was also featured in *Blade Magazine*'s 2017 Knifemaker's Showcase. Ruiz currently teaches at the South Texas Assocation of Bladesmiths Headquarters, and is a Lone Star Member of the Texas Knifemakers' Guild and a member of the American Bladesmith Society, the Balcones Forge Central Texas Blacksmiths, and the Artist Blacksmith Association of North America.

Ruiz has dedicated much of his personal and professional life to humanitarian and philanthropic work and his role as a volunteer judge is in many ways an extension of this passion. "I love that it's college students doing this, and I love that an organization is giving its members and students an opportunity to work with their hands," Ruiz noted. "In an age of technology we often dissociate ourselves from menial labor or hand-crafted work...Bladesmithing is a labor-intensive process, even for a professional. It's hot, it's tough, you're going to have blisters like you wouldn't believe, and if you're not paying attention you're going to catch fire."

According to Ruiz, those very challenges are what

makes encouraging students to learn crafts such as bladesmithing so invaluable. "Nothing's more humbling than finding faults in your work—but if there's one thing I've learned it's to take notes, not offense," he reflected. "I think that lesson applies to every field. Bladesmithing, or any craft, will teach you not how lacking you are or how good you are, but how much better you can be."

Ruiz's passion for the art of metalworking is evident in conversation. When asked about the challenging process of creating entries for the competition he observed: "They went through all of the trials and tribulations I did when I first started. There's a certain amount of hands-on practice you just have to do to get a product out there that's aesthetically appealing, fully functional, and that someone else is going to want. Looking at these submissions...I see knives that I want in my kitchen, I see blades that I want on my wall, and it's amazing to know that some of these students didn't have a background in bladesmithing before this competition."

And for those interested in learning more about bladesmithing? Ruiz advises them to begin with the fundamentals of blacksmithing by reaching out to local smiths or clubs and, above all, he notes, "Have fun. Learn. Go in with open ears and open eyes. Engross yourself in the culture and history of smithing because there's so much that we wouldn't have today if not for the advancements of metallurgy and blacksmithing working together—science and craft working together."



J. Alex Ruiz examines competition entries in the TMS 2019 Bladesmithing Competition exhibit before final judging takes place.



The 2019 Bladesmithing Competition: Where Science and Craft Come Together

SPECIAL CITATIONS

BEAUTY

University of Tennessee, Knoxville: "Volsung"

Cullen Pearson, Scott Bennet, John David Codevilla, Brionna Cooper-Momillan, Jonah David Duran, Brandt N. Fox, Mattheus Edward Fry, Gabriel A. Goenaga, Cameron Russell Hale, Eric Heikkenen, Zachary Alexander Herron, Samantha Rose Maness, Joshua James McCoy, Colin Moore, Max Lestat Neveau, Collin Matthew Pekol, Hunter Potter, Craig Thomas Replogle, Bradley Straka, Benjamin S. Terry, Caden Webb, Chris Wetteland, Deshon and Michael Young





HISTORICAL ACCURACY

Norwegian University of Science and Technology: "T13727 Viking Sword Reproduction"

David Dominikus Eide Brennhaugen, Emilie Bjønnes, Nikolai Skogen Ditlefsen, Inger-Emma Nylund, Erik Dobloug Roede, Sigurd Grydeland Schawlann, and Tore Andre Søgnen





CREATIVE USE OF MATERIALS

South Dakota School of Mines & Technology: "Crucible Steel Dagger"

Aaron Fortier, George Bernard, Isaac Hammer, Daniel Nagel, Meghan Strawniak, and Peter Vik





HANDS-ON PROCESS

Indian Institute of Technology, Bombay: "Talwar"

Gaurav Raj Singh and Nikhil Gotawala







Bohnert

SPECIAL CITATIONS

RESOURCEFULNESS

University of Utah: "Damascus Steel Swept Rapier"

Jano Farah, Hawken Knight, Olivia Pratt, and Alexander Wikstrom

OUTSTANDING POSTER

University of Texas at Austin: "Alpha Blade"

Emily Brady and Katherine Rader









BRINGING BLADESMITHING TO THE CLASSROOM

From its inception in 2015, the TMS Bladesmithing Competition has sparked excitement among participants. Gerald Bourne, professor of metallurgical and materials engineering at Colorado School of Mines (Mines), channeled that excitement into a bladesmithing course, photo left, that complements the university president's focus on "creating unique and hands-on student experiences at Mines."

The class, created by Bourne and students Ty Porter, Stuart Shirley, and Matt Zappulla, takes a safetyfirst approach, both in terms of lab equipment and common sense in handling edged tools. It also covers concepts such as profiling, bevel grinding, heat treating, sharpening, and ferrous metallurgy focused mostly on tool steels for knife making.

The course has been an incredible success filling each semester with students from multiple departments. I hear students who are not in our department and who I have never met discussing the course," noted Bourne. "Once enrolled in the course, excitement is a very significant motivator. Students go above and beyond expectations on their projects. I also feel the creative outlet gives the students a break from studying, and they are proud of the work that they put into the projects and the final outcome."

Students from Virginia Polytechnic Institute and State University (Virginia Tech), photo right, have found an





ingenious way to provide a safe outlet for forging on campus by offering the first ever bladesmithing class in 2020. Developing a formal class gives students the opportunity to practice bladesmithing within the context of a syllabus that covers a basic introduction to forging science and techniques.

Harrison Jones, bladesmithing team lead at Virginia Tech, credited the TMS Bladesmithing Competition with introducing the majority of his team to the art of forging. "The spur of interest in this type of material processing through our department prompted students and faculty to work together to provide an outlet for the general student body to learn more." According to Jones, "the students benefit from the hands-on experience of physically working on the metal and conducting research into the material's properties. Being able to see the results of our work reinforces what we're learning in the classroom."



The 2019 Bladesmithing Competition: Where Science and Craft Come Together

CONGRATULATIONS TO ALL THE 2019 TMS BLADESMITHING TEAMS



Drexel University "Occam's Razor"



Michigan Technological University: "**MTU Kukri**"

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Friederich-Schiller-University Jena "Hugin"



Missouri University of Science and Technology: **"Stahlzahn"**



Illinois Institute of Technology, Armour College of Engineering "**Kunai**"



Montana Technological University: "Renaissance Dagger"



Indian Institute of Technology, Madras "Indian Wootz"



Montanuniversität Leoben: "Historically Inspired Broken Back Seax"



Institut Teknologi Sepuluh Nopember "The Karambit, Indigenous Martial Arts Weapon of Indonesia"



Michigan State University "An Agricultural Tool, and Then Some"



New Mexico Institute of Mining and Technology: **"Second Heat"**

Oregon Institute of Technology: **"Viking's Little Helper**"

na Technological

1938



Oregon State University: "Raindrop San Mai Damascus Bowie"



University of Minnesota Twin-Cities: **"Seax Blade"**



Universidad Nacional Autónoma de México: **"Iztactepostli"**



University of North Texas: "Anglo-Saxon Broken-Back Seax"



Universidad San Francisco de Quito: **"Dragon Dagger"**



University of Pittsburgh, Team #1: "PittSmiths"



University of Alberta: "Double-edged Sword"



University of Pittsburgh, Team #2: "It's a Wonderful Knife"



University of California, Berkeley: **"Ax L. Rose"**



Virginia Polytechnic Institute and State University: **"World War I Trench Knife Replica**"



University of California, Irvine: "Utilitarian Kitchen Chopper"



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TMS officially released its newest technical study, Metamorphic Manufacturing: Shaping the Future of On-Demand Components, at the TMS 2019 Annual Meeting & Exhibition (TMS2019), held in San Antonio, Texas, March 10-14. The study, which was supported by the U.S. Office of Naval Research (ONR) and the Lightweight Innovations for Tomorrow (LIFT) Manufacturing Institute, is focused on defining metamorphic manufacturing (MM), identifying foundational elements of MM, outlining specific technical challenges preventing full development and adoption, and offering recommendations and action plans on how to jump-start this new manufacturing technology.

According to the report, metamorphic manufacturing combines the incremental thermomechanical deformation of a blacksmith with the

T**MO Re**leases Report on Potentially Disruptive Technology

Owen Daly



Glenn Daehn, Metamorphic Manufacturing study team lead, reviews the impact that this technology could have on the future of manufacturing during an information session held at TMS2019 with study team members and meeting attendees.

TMS Studies Available for Free Download

Metamorphic Manufacturing: Shaping the Future of On-Demand Components: www.tms.org/MetamorphicManufacturing

Verification and Validation of Computational Models Associated with the Mechanics of Materials: www.tms.org/VerificationandValidation

Additional TMS Studies

The entire suite of TMS studies is available at: www.tms.org/Studies

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Figure 1. A visual synopsis of the five fundamental elements of metamorphic (Metamorphic Manufacturing: Shaping the Future of On-Demand Components, 2019, p. xxiv.)

"This is extending open die forging, which is a large industry already... we are adding another layer of sophistication onto that, which should take open die forging to the next level."

—Glenn Daehn, Metamorphic Manufacturing study team lead



precision and control of intelligent machines and robotic systems. Glenn Daehn, study team lead and the Fontana Professor of Metallurgical Engineering at The Ohio State University, describes this novel manufacturing approach as the "third wave of digital manufacturing," following subtractive or computer numeric control (CNC) machining and additive manufacturing (AM). Daehn noted that metamorphic manufacturing's "impact could be every bit as great as the impact of additive manufacturing." He further explained that MM improves upon both CNC machining and AM by reducing the amount of raw material loss and enabling the ability to tailor material properties through locally controlled deformation. With recent advances in the field of integrated computational

materials engineering (ICME), "fully realized metamorphic manufacturing would span the materials engineering process, from material discovery and development to commercial component creation," said Daehn.

Jian Cao, study team member and Cardiss Collins Professor at Northwestern University, sees the integration of computational tools and processes such as MM into the metal forming industry as a revolutionizing opportunity. Of this integration, she said that "metal forming was often considered old and dirty, but now we actually have the opportunity to bring digital technology and robotics into the industry." Similarly, Daehn said, "this is extending open die forging, which is a large industry already...we are adding another layer of sophistication onto that, which should take open die forging to the next level." He noted a particularly impactful trait of MM is the ability to adapt the same system to create many different types of parts, eliminating the high material and energy cost of creating a new die for each new component and dramatically reducing time to market.

As outlined in the study, metamorphic manufacturing could provide a more economically and environmentally friendly method for advanced manufacturing as compared, for instance, to some powder metal AM methods. Likewise, the potential to create complex-shaped components without milling away material indicates that MM could offer similar benefits

Figure 2. This graph provides rough estimates and comparisons of the Electricity Usage vs. Process Rate for various additive and other manufacturing processes (blue) compared to metamorphic manufacturing (red). Acronym definitions: SLS = Selective Laser Sintering, SLM = Selective Laser Melting, FDM = Fused Deposition Modeling, BAAM = Big Area Additive Manufacturing. (*Metamorphic Manufacturing: Shaping the Future of On-Demand Components*, 2019, p. 9. Graph produced based on inputs from Glenn Daehn and Gutowski et al., "Note on the Rate and Energy Efficiency Limits for Additive Manufacturing," *J. Ind. Ecol.* 21, S69 [2017].)



over methods such as manufacturing through machining.

TMS Releases Report on Potentially Disruptive Technology

While the study characterizes MM as disruptive, it also identifies and addresses a number of barriers to the full realization of the technology's benefits. To this point, Daehn believes that the most valuable aspect of the report is the action plans that it offers of "things that we can do as a community to actually start developing" this technology. He also commented that the report "is designed so that readers of various sorts can jump in and start taking actions."

Daehn said he was excited for the report to be released because of "the opportunity to bring a completely new technology to the United States." While the report describes what could be a fully realized MM technology, Daehn noted that this technology could even be advanced beyond that. "I don't see this as something with a clear end point and beginning point, but as part of the technology continuum," he said. "I encourage everyone from students



and academic/industry researchers to government agency employees to download the report and start taking action." Those who are interested in helping usher in this technology can download the report for free at www.tms.org/MetamorphicManufacturing.

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Fig. 3. A conceptual metamorphic manufacturing suite. (*Metamorphic Manufacturing: Shaping the Future of On-Demand Components*, 2019, p. xxviii.)

Implementing Verification and Validation Practices in the Mechanics of Materials Community

Another new TMS technical report released at TMS2019 was *Verification* and *Validation of Computational Models Associated with the Mechanics of Materials*, developed with the support of the U.S. National Science Foundation. The report is an examination on the current state of verification and validation (V&V) of computational models in the mechanics of materials (MOM) community. In this context, verification refers to confirming that the mathematical equations that serve as the basis of computational models are accurate, and validation refers to confirming that the results of the predictive models properly represent the physical world, via comparison to experimental results. While V&V has been developed more fully in other disciplines, its widespread development and adoption within the MOM community has been seriously lagging, and is critically important for unlocking the great potential of such models in reducing the time and cost of developing new materials and manufacturing processes.

To address this issue, the report outlines a number of challenges to the development and adoption of V&V in the MOM community that were identified during a workshop of invited researchers and thought leaders on the topic. Once these were determined, the workshop team identified opportunity areas and recommendations for overcoming these challenges, encompassing technical, cultural, and policy-related challenges. Those who are interested in aiding the development and adoption of V&V approaches within the MOM community are encouraged to download the report, at no cost, at www.tms.org/VerificationandValidation.







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TMS meeting headlines

View all upcoming meetings online at www.tms.org/Meetings.

Other Meetings of Note

The 10th Pacific Rim International Conference on Advanced Materials and Processing August 18–22, 2019 Xi'an, China

2019 Liquid Metal Processing & Casting Conference (LMPC 2019) September 8–11, 2019 Birmingham, United Kingdom

TMS Anode Technology for the Aluminum Industry Course (Anode 19) September 9–13, 2019 Årdal, Norway

Materials Science & Technology 2019 (MS&T19) September 29– October, 3, 2019 Portland, Oregon, USA

ANS/TMS Materials in Nuclear Energy Systems (MiNES 2019) October 6–10, 2019 Baltimore, Maryland, USA

TMS Industrial Aluminum Electrolysis Course (IAE 19) November 10–14, 2019 Askar, Kingdom of Bahrain

ICTP 2020: The 13th International Conference on the Technology of Plasticity July 26–31, 2020 Columbus, Ohio, USA



July 21–25, 2019 JW Marriott Indianapolis Indianapolis, Indiana, USA www.tms.org/ICME2019

• Book your room at the congress location, the JW Marriott Indianapolis, by June 28, 2019, to receive the group rate for attendees.



August 14–17, 2019 TMS Headquarters Office Pittsburgh, Pennsylvania, USA Discount Registration Deadline: July 8, 2019

www.tms.org/PEReview2019

• There's still time to register for the TMS Metallurgical and Materials Engineering Professional Engineer (PE) Licensing Exam Review Course before rates increase on July 8, 2019. Make your plans to attend and register today.



August 20–23, 2019 DoubleTree by Hilton Hotel Dearborn, Michigan, USA Discount Registration Deadline: July 8, 2019

www.tms.org/MetFoam2019

• Plenary speakers for the conference include: Kamel Hooman, *The University* of Queensland; Haydn N.G. Wadley, University of Virginia; Christopher B. Williams, Virginia Polytechnic Institute and State University; and Ulrike Wegst, Dartmouth College. For more information on plenary presentations, visit the Technical Program page of the conference website.

THE WORLD COMES HERE **TMS** 2020 149th Annual Meeting & Exhibition February 23–27, 2020 San Diego Convention Center and Marriott Marquis & Marina San Diego, California, USA Abstract Submission Deadline: July 1, 2019

www.tms.org/TMS2020

- Plan now to participate in the TMS 2020 Annual Meeting & Exhibition (TMS2020). Submit your abstract in one of the more than 80 symposia planned for this comprehensive, cross-disciplinary conference.
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September 13–17, 2020 Seven Springs Mountain Resort Seven Springs, Pennsylvania, USA Abstract Submission Deadline: July 31, 2019

www.tms.org/Superalloys2020

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call for papers

JOM is seeking contributions on the following topics for 2019 and 2020. For the full Editorial Calendar, along with author instructions, visit www.tms.org/EditorialCalendar.



December 2019: Manuscript Deadline: July 1, 2019

Topic: Advances in Surface Engineering

Scope: This special topic aims to capture recent advances in processing, characterization, simulation/ modeling, and applications related to surface engineering of materials. Areas of interest include surface protection from wear and corrosion, surface characterization techniques, surface alloying, and nanostructured surfaces.

Guest Editors: Tushar Borkar, Rajeev Gupta, Sandip Harimkar, and Mary Lyn Lim

Sponsor: Surface Engineering Committee

Topic: Aluminum: Shape Casting and Forming

Scope: This topic covers processes and manufacturing technologies to produce final shapes for aluminum applications.

Guest Editor: Dmitry Eskin

Sponsors: Aluminum Committee and Shaping and Forming Committee

Topic: Extraction and Recycling of Battery Materials

Scope: This topic covers the fundamentals and latest developments in battery recycling including lead acid, nickel-cadmium, nickel-metal-hydride, and lithium ion batteries. Papers discussing applications of primary processes for the treatment of battery materials are also welcome.

Guest Editors: Xiaofei Guan, Camille Fleuriault, and Joseph Grogan

Sponsors: Pyrometallurgy Committee and Recycling and Environmental Technologies Committee

Topic: Functional Nanomaterials for Energy Applications

Scope: The scope of this topic will address nanomaterials for energy harvesting on a flexible substrate. Specifically, recent advances in the fabrication, characterization, and synthesis of energy harvesting nanomaterials, including piezoelectric nanowires, nanofibers, and thin film, for flexible substrate will be covered.

Guest Editors: Jiyong Chang and Chang-Yong Nam Sponsor: Nanomaterials Committee

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THE WORLD COMES HERE TMS 2019 148th Annual Meeting & Exhibition

TMS would like to thank the following exhibitors for their participation in the TMS 2019 Annual Meeting & Exhibition (TMS2019) in San Antonio, Texas:

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Don't miss your opportunity to be an exhibitor or sponsor of the TMS 2020 Annual Meeting & Exhibition, scheduled for February 23–27, in San Diego, California. For more information, visit www.tms.org/TMS2020 or contact Gavin McAuliffe, TMS2020 Exhibit Manager, at gavin@corcexpo.com, or Mary Michalik, TMS2020 Sponsorship Manager, at mary@corcexpo.com.

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