JOM

OCTOBER 2020

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An official publication of The Minerals, Metals & Materials Society

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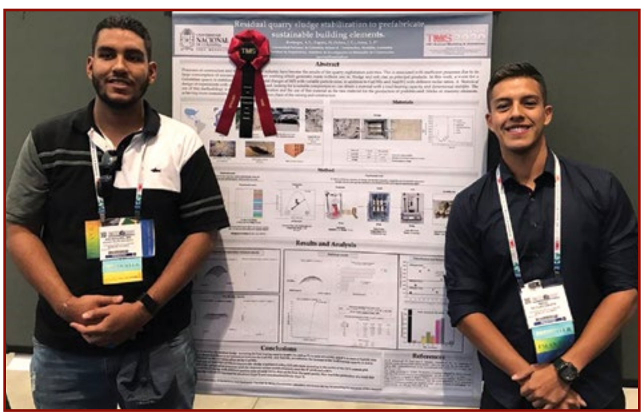

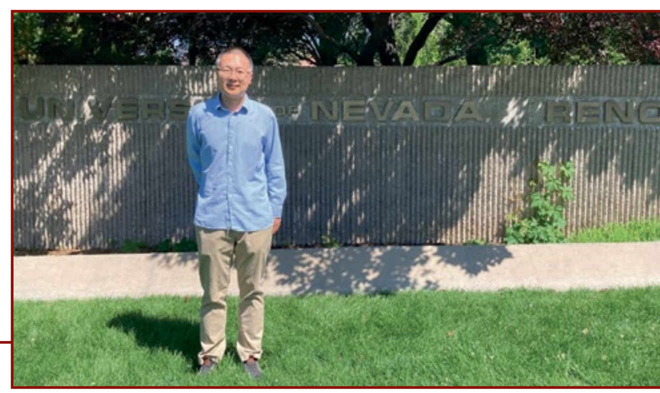

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About the Cover

Shown is aluminum scrap being charged into a remelting furnace. Remelting is a core step in the recycling of aluminum, a process that uses around only 5% of the energy required to make primary aluminum. A detailed study of the charging of compacted, used aluminum beverage cans can be found in the article "Dross Formation in Aluminum Melts During the Charging of Beverage Can Scrap Bales with Different Densities using Various Thermal Pretreatments" by Jan Steglich, Bernd Friedrich, and Marcel Rosefort in this issue.

October 2020 Guest Editors

Aluminum: Recycling and Carbon / Environmental Footprint
Aluminum Committee; Recycling and Environmental Technologies Committee
David S. Wong, Consultant
Anne Kvithyld, SINTEF
Hong Peng, University of Queensland

High Temperature Processing of Complex Ores
Pyrometallurgy Committee
Leili Tafaghodi, University of British Columbia
Camille Fleuriault, Gopher Resource
Joseph Grogan, Gopher Resource

Interfacial Stability in Multi-component Systems
Alloy Phases Committee
Chao-hong Wang, National Chung Chung University
Shih-Kang Lin, National Cheng Kung University

Practical Research in Processing Science
Titanium Committee; Shaping and Forming Committee; ICME Committee
Adam Pilchak, Johns Hopkins University
Edward Herderick, Ohio State University
John Rotella, Purdue University

Solidification Behavior in the Presence of External Fields
Solidification Committee
Lang Yuan, University of South Carolina
Andrew Kao, University of Greenwich

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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in the final analysis

JOM
Volume 72
Number 10
October 2020

"It takes humility to seek feedback. It takes wisdom to understand it, analyze it, and appropriately act on it."

—Stephen Covey

James J. Robinson
Executive Director
@JJRofTMS

Back in COVID-19's "Before Times," when I traveled for business with too-frequent-flyer frequency, there was one absolute that I could count upon while waiting in any airport: The Ubiquitous Stephens. In every concourse newsstand, a traveler could reliably predict finding plentiful volumes by Stephen King of horrifying-literature fame and Stephen Covey of don't-be-a-horrifying-business-person fame. The former is imprinted on culture as the author of *The Shining* and *It.* The latter produced such self-improvement management guides as *The 7 Habits of Highly Effective People.* All three titles are shelved within arm's reach as I sit here typing in my home office and one is the inspiration for this month's editorial. . . .but which one? Oh, the suspense! Will it be haunted hotels, demonic clowns, or earnest self-improvement?

With apologies to Overlook and Pennywise fans, today's focus is on self-improvement and the "humility to seek feedback."

Humbly or not, TMS conducts a survey of the professional membership every other year. Our goal is to find out how members view the Society and how the Society might improve its support of members. As the members are the owners of the Society, this is an essential activity. About 13% of professional members participated. Even in the Year of Coronavirus, that's a respectable sample size, with members from 57 countries responding. We're still digging for nuggets, but impatient me is always looking for immediate takeaways. For example:

- Most professional members were introduced to TMS by a professor or advisor. Second most common pathway: A colleague.
- Which aspect of TMS is of most value? Almost a tie between "connection with peers and professionals in my field" and "access to technical information."
- The most common form of participation in TMS activities? Presenter of technical presentations. Second most common? Member of a technical committee.
- What TMS activity helps members best address professional challenges? "Networking with other professionals," closely followed by "attending conferences and events."
- The form of participation that provides the greatest value? Serving as a symposium organizer.
- Type of event in which respondents would be most likely to participate in the future? "Large conferences for the entire materials community." Second: "Virtual events."

Beyond the checkbox feedback, there are also many passionate comments to consider. With a survey, is this not where the greatest value is often found? We have a lot of members who love the camaraderie and tradition of the Society, the events, the access to new or emergent technologies, the opportunities to give back through volunteering, . . . the affirming list goes on. The list is also long for opportunities to improve: We clearly have work to do on better engaging new members in Society activities, on addressing the bulkiness of *JOM* while finding a way to add more general interest articles, on encouraging greater industrial participation, and on integrating our international members to the levels of our North American constituents. There are plenty of nuggets to sift through and sift we will. Determining how best to apply the guidance that we have so generously been provided is the biggest challenge and opportunity. We will be working on that between now and the next survey, when the process begins anew.

To those who participated this year, thank you. To those who couldn't participate, an opinion offered to a TMS leader is welcome at any time. And to the member who wrote, "Inertia, after 50+ years, it seems a shame to quit while I'm still alive," I say, 50 years of membership is a great start!

"TMS conducts a survey of the professional membership every other year. Our goal is to find out how members view the Society and how the Society might improve its support of members."

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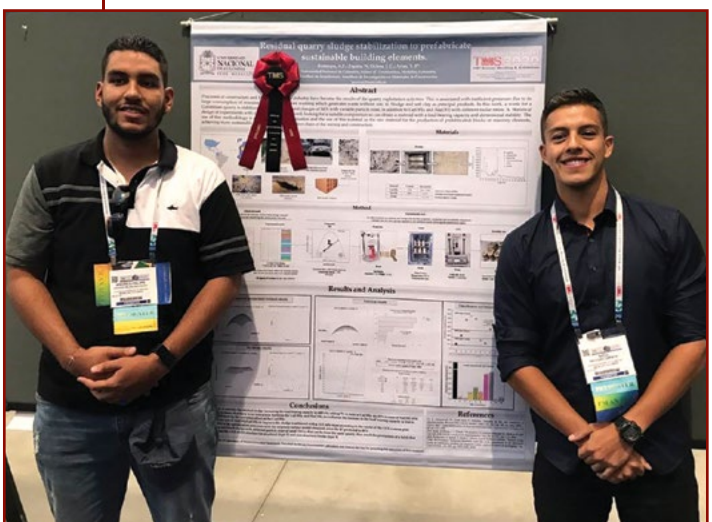
JOM themagazine

Congratulations to Poster Contest Winners; TMS Member Named ANS Fellow

Poster Awards from TMS2020

JOM would like to recognize and congratulate poster award recipients from the Recycling of Secondary, Byproduct Materials, and Energy Poster Session held at the TMS 2020 Annual Meeting & Exhibition (TMS2020) in San Diego, California, in March 2020. The session was sponsored by the TMS Extraction & Processing Division (EPD) and the Recycling and Environmental Technologies Committee. The awardees are:



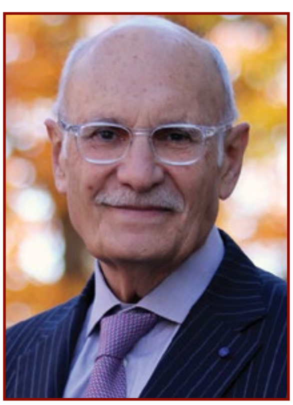
Andres Felipe Restrepo Ramirez (left) and Nicolas Zapata Perez (right), Universidad Nacional de Colombia, with their award-winning poster from the EPD/LMD Recycling and Environmental Technologies – Best Poster – Undergraduate Contest held at TMS2020.

EPD/Light Metals Division (LMD) Recycling and Environmental Technologies – Best Poster

Undergraduate: "Residual Quarry Sludge Stabilization to Prefabricate Sustainable Building Elements," Andres Felippe Restrepo Ramirez, Nicolas Zapata Perez, Yhan Paul Arias Jaramillo, and Juan Carlos Ochoa Botero, Universidad Nacional de Colombia

Graduate: "Characterization of Wasted LEDs from Tubular Lamps Focused on Recycling Process by Hydrometallurgy," Rafeal Oliveira, Amilton Botelho Júnior, and Denise Espinosa, University of São Paulo

Diran Apelian and ACRC Move to UCI



Diran Apelian

Diran Apelian joined the University of California, Irvine, as the Distinguished Professor of Materials Science and Engineering in July 2019. He was previously the Alcoa Howmet Professor of Mechanical Engineering at Worcester Polytechnic Institute (WPI) for more than 30 years. The Advanced Casting Research Center (ACRC), an industry-university alliance initially founded to advance the use of light metals, followed Apelian to UCI in July 2020. According to UCI, the ACRC's relocation under Apelian's leadership, as founding director, aims to "expand the consortium to meet the needs of manufacturing industries on the west coast—aerospace and major DOD OEMs."

In addition to his service to the TMS as 2008 President, Apelian is a 2006 TMS Fellow and recipient of the 2006 Bruce Chalmers Award. He was also a founding editor of the *Journal of Sustainable Metallrugy* from 2015 to 2017.

The University of California, Irvine, campus, new home to the ACRC.

member news

Share the good news about your professional accomplishments! Contact Kaitlin Calva, JOM Magazine Managing Editor, at kcalva@tms.org. Please note that only news submitted by current TMS members will be considered.

TMS Member Receives ANS Fellow Award

TMS member Kumar Sridharan, a professor in the Engineering Physics and Materials Science and Engineering Departments at the University of Wisconsin–Madison, was elected as a Fellow of the American Nuclear Society (ANS). He was awarded the honor during the 2020 ANS Virtual Annual Meeting in June along with eight other recipients. The distinction of Fellow is the highest membership grade honored by ANS. His citation reads, "for major research contributions in materials corrosion and degradation processes in nuclear energy systems, and for impact on the nuclear industry through the development of improved fuel cladding concepts as well as education and mentorship of undergraduate and graduate students."

Sridharan has authored more than 300 publications and has been a reserach mentor to more than 100 undergraduate and graduate students and postdoctoral reasearch assistants.

Kumar Sridharan

TMS Welcomes New Members

The TMS Board of Directors approved professional membership for the following individuals at its July 2020 meeting. Please join us in congratulating and welcoming them to all the privileges and benefits of TMS membership.

Abiodun, Yetunde; University of Lagos, Nigeria, Nigeria

Aghadavoudi Jolfaei, Mohsen; University of Warwick, United Kingdom

Allen, Stuart Keith; Mechatherm International Ltd., United Kingdom

Anand, Mohan; Warwick Manufacturing Group, United Kingdom

Anderson, Steve; Wagstaff Inc., United States

Awasthi, Shikha; Indian Institute of Science Bangalore, India

Barbosa, Isabella Tereza Ferro; Senac University Center, Brazil

Bennett, Tyler P.; Turbocam International, United States

Berg, Mike; Bruker Nano, United States

Bhandari, Geetanj; Rtec-Instruments Inc., United States

Bhargava, Parag; Indian Institute of Technology Bombay, India

Bhat Panemangalore, Devadas; National Institute of Technology Karnataka, India

Bibhanshu, Nitish; Oak Ridge National Laboratory, United States

Biener, Monika; United States

Boster, Connor; United States

Bowers, Mark; United Kingdom

Breguet, Jean-Marc; Alemnis AG, Switzerland

Bryan, Craig C.; Allied High Tech Products Inc., United States

Buswell, Deborah Jane; Australia

Cade, Austin; EAG Laboratories, United States

Carvalho Silva, Cleiton; UFC Campus Do Pici, Brazil

Chen, Shuonan; University of California, Riverside, United States

Claveau, Simon; STAS Inc., Canada

Cubillas Martinez, Fernando; Universidad de Sonora, Mexico

Dada, Modupeola; South Africa

Dahanayake, Vidumin; Anton Paar USA, United States

Drake, Robert; PROTO, United States

Du, Hui; MSE Supplies LLC, United States

Duque, Ramon; Altek LLC, United States

Essa, Khamis; University of Birmingham, United Kingdom

Ewasiuk, Rhonda J.; McSwain Engineering, United States

Farokhzadeh, Khorameh; Bruker, United States

Fernandez, Jorge; Altek LLC, United States

Friberg, Irma; United States

Ganguly, Partha; Baker Hughes, United States

Ghosh, Udayan; United States

Grauerholz, Blake; Fritsch Milling & Sizing, Inc., United States

Greenwood, Anna; United Kingdom

Griessmann, Gunda; RHI Magnesita GmbH, Austria

Guo, Xiaofeng; Washington State University, United States

Haertling, Carol; Los Alamos National Laboratory, United States

Hall, Steve; TA Instruments, United States

Hamilton, Bob; Precimeter Inc., United States

Heffernan, Michael; United Kingdom

Hernandez-Negrete, Ofelia; Universidad De Sonora, Mexico

Heslin, Edel; Taylor Francis Group, United Kingdom

Hetrick, Rob; Claudius Peters Projects GmbH, United States

Hill, Tina; Bruker, United States

Hirsch, Edward A., Allied High Tech Products, United States

Hoover, Malini; Advanced Optical Technologies, United States

Hostettler, Simon; Synton Mdp AG, Switzerland

Jackson, Daniel; Pyrotek Inc., United States

Jahangiri, Negin; Leica Microsystems, United States

Jencks, Danielle E.; Pratt & Whitney, United States

Jetten, Peter; Pyrotek Inc., United States

Jiang, Xiaoping; MTI Corporation, United States

Johanns, Kurt; KLA Corporation, United States

Khosla, Tushar; Rtec-Instruments, Inc., United States

Kulkarni, Ajit; IIT Bombay, India

Lamar, Rick; Goodfellow Corp., United States

Lang, Melanie; Formalloy, United States

Lanza, Mark S.; Pacific Northwest National Laboratory, United States

Lau, Siu Chung; Hong Kong

Lavanya, S.; Indira Gandhi Center for Atomic Research, India

Lecroy, James; RCS, United States

Leosson, Kristjan; DT Equipment, Iceland

Leverette, Bobby; Pace Technologies, United States

Liddell, Keith; United Kingdom

Liu, Jian; Polaronyx Inc., United States

Lok, Jonathan; United States

Lopez Rodrigues, Isbelis; United Kingdom

Loukus, Josh; REL Inc., United States

Mahajanam, Sudhakar; Stress Engineering Services Inc., United States

Masi, Luca; Granta Design/Ansys Inc., United Kingdom

Mason, John; Solar Turbines Incorporated, United States

Mehta, Subal; Almex USA Inc., United States

Morel, Pierre; Rtec-Instruments,Inc., United States

Mouginot, Roman; Femtotools AG, Switzerland

Mu, Yunpeng; CIMM Group Co. Ltd., China

Muntwyler, Simon; Femtotools AG, Switzerland

Nair, Chandrasekharan; Intel Corporation, United States

Nalwa, Kanwar S.; Indian Institute of Technology Kanpur, India

Nedeljkovic, Dragutin; American University of the Middle East, Kuwait

Nisar, Ambreen; Florida International University, United States

Norris, Adam; Glama, Germany

Obali, Akin; Sistem Teknik Industrial Furnaces Ltd., Turkey

Olszta, Matt; Pacific Northwest National Laboratory, United States

Ortiz-Zavaleta, Gerardo; Innofacturing Solutions, United States

Parkes, Ken; Wagstaff Inc., United States

Pasini, Kellie; United States

Patel, Jitendra K.; United Kingdom

Patel, Chetan; United States

Pegg, Elise; United Kingdom

Potter, Megan; SCR Technologies, United States

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Rasovic, Ilija; United Kingdom

Reali, Jon C.; Magnitude 7 Metals, United States

Regmi, Abiral; United States

Rice, Christian; Nanovea, United States

Rui, Gao; Massachusetts Institute of Technology, United States

Schultz, Benjamin F.; Matsys Inc., United States

Seaman, Elyn; Hitachi High Technologies America Inc., United States

Shea, Ryan J.; Howmet Aerospace, United States

Shin, Dongwoon; University of Utah, United States

Shojaee, S. Ali; Thermo Fisher Scientific, United States

Singh, Sukhjinder; IPS Ceramics USA, United States

Sleep, Kyle; Limpact International Limited, Canada

Soellner, Wolfgang; Airbus Defence and Space, Germany

Stauffer, Terry E.; Microtrac, United States

Stiller, Adrian; Abo Akademi University, Finland

St-Onge, Dominic; Tekna, Canada

Szeszko, Justyna; Femtotools AG, Switzerland

Thompson, Taylor; Proto, United States

Tilak, Ravidra; Almex USA, United States

Tourountzis, Konstantinos; Alumil, Greece

Uguccioni, Paul; International Magnesium Association, United States

Valdis, Patrick; Nanovea, United States

Vichos, Peter; Netzsch Instruments, United States

Wagstaff Parkes, Barbara; Wagstaff Inc., United States

Walsh, Thomas; Tenova Inc., United States

Wang, Shuo; University of Maryland, College Park, United States

Wang, Yan; Georgia Institute of Technology, United States

Xiao, Jun; Rtec-Instruments Inc., United States

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***Membership grade recommendations are based on a review of credentials provided by the individuals. These credentials are taken on the honor system and not independently verified except by exception.**

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JOM the magazine

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

Toyota Lightens Third-Row Seat

Wyandotte, Michigan, USA: BASF Corporation and Toyota Motor North America Research and Development achieved lightweighting success with the new 2021 Toyota Sienna. The third-row seat, which was previously made of 15 steel pieces, was redesigned to be a free-standing, two-occupant injection molded back-frame with no molded reinforcement, which reduced weight by 30%, lowered costs by 15%, and increased safety performance. For the seat components, BASF used its unique 35% glass-reinforced and impact-modified polyamide PA6 grade Ultramid® B3ZG7 CR and its proprietary computer-aided engineering tool ULTRASIM®.

GR Silver Extends Plomosas Project

Vancouver, Canada: GR Silver Mining Ltd. has reported successful 50-meter step-out drilling at its Plomosas silver project in Sinaloa, Mexico. High-grade silver mineralized zones were intersected to confirm that the system has a continuity of at least 500 meters along the strike. Drilling extended the continuity of both mineralization styles: silver-gold low sulphidation epithermal veins and polymetallic high-grade silver-lead-zinc hydrothermal breccias, up to 700 meters down dip below surface.

Gary, Indiana, USA: United States Steel Corporation (U.S. Steel) restarted two blast furnaces in August 2020 that had been idled in April. The Gary Works in Indiana is U.S. Steel's largest mill and produces sheet, strip mill, and tin products. The two revived blast furnaces at Gary Works have capacities of 1.07 million short tons and 1.23 million short tons. The company aims to restore capacity for key customers in the auto industry with the reopening of Gary Works, which will additionally support a continued demand from the appliances, packaging, and construction industries. (Photo courtesy of U.S. Steel.)

Canada Nickel Launches NetZero Metals

Toronto, Canada: Canada Nickel Company Inc. created a wholly owned subsidiary, NetZero Metals, to begin research and development for a processing facility that would be located in Timmins, Ontario, with the goal of utilizing existing technologies to produce zero-carbon nickel, cobalt, and iron products. According to Canada Nickel, its potential to develop zero-carbon products for the mining sector is a result of advantages like its Crawford Nickel-Cobalt Sulphide project, comprised mostly of serpentine rock, which naturally absorbs carbon dioxide when exposed to air.

Lordstown Motors Agrees to Merger, Going Public

Detroit, Michigan, USA: Electric vehicle startup Lordstown Motors Corporation and DiamondPeak Holdings Corporation agreed to a $1.6 billion merger agreement that will result in Lordstown becoming publicly listed in the fourth quarter of 2020. Lordstown's merger with the special purpose acquisition company is expected to aid in the development of Lordstown's all-electric pickup truck, the Endurance. In the first year, Lordstown expects to be able to produce at least 20,000 trucks.

Partnership Forms in Magnesium Alloy Research

Dayton, Ohio, USA: Allite Inc. has agreed to support a five-year, multi-million-dollar partnership in magnesium alloy research with top material science professors at Xi'an Jiaotong University. The partnership will focus on advancing Allite's proprietary Super Magnesium™ alloys used in a variety of industries and applications, including consumer electronics, lightweight electric vehicles, and outdoor sports. The areas of development will be ultra-high strength magnesium alloys, machine learning-assisted design of high-performance magnesium alloys, high-dampening magnesium alloys, and the design and production of high-performance magnesium alloys.

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JOM the magazine

Qi An Brings Passion and Focus to Electronic and Atomistic Modeling

Ann Ritchie

young professional technical notes

This occasional feature highlights the scientific interests and professional accomplishments of a young TMS member who has contributed to the technical content of the current issue of *JOM* as an author, advisor, or guest editor. The development of this feature is a special project of the TMS Young Professionals Committee. For additional information contact Kaitlin Calva, *JOM* Magazine Managing Editor, at kcalva@tms.org.

"Three lessons have been important for me to learn in my career: Be passionate about your research; focus on the most important problems in your field; and think about how your scientific research benefits society," said Qi An, assistant professor in the Department of Chemical and Materials Engineering at the University of Nevada, Reno (UNR). An's recent contributions to the field include co-authoring the September 2020 *JOM* paper, "Modified Failure Mechanism of Silicon through Excess Electrons and Holes," on quantum materials for energy efficient computing.

"The *JOM* paper illustrates that the electron and hole carriers have a significant influence on the mechanical properties of silicon, a semiconductor material. This study suggests that the strength and ductility of inorganic semiconductors may be tuned through electron and hole carriers," An said.

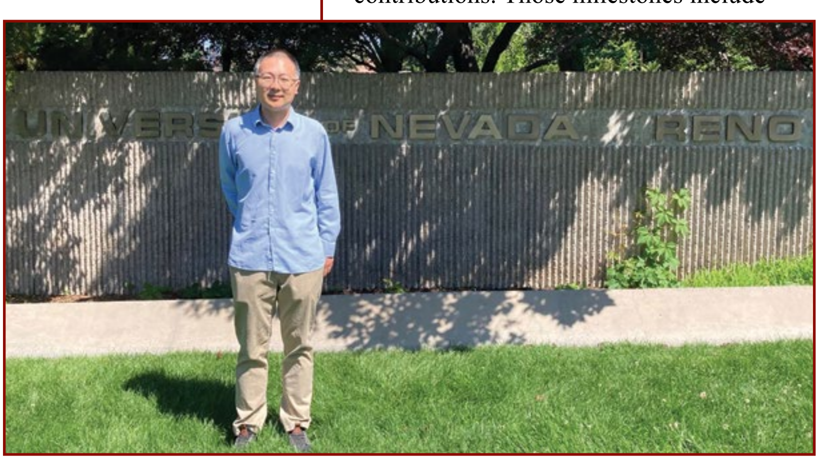
Since 2016, An has taught at UNR, where he conducts research and advises students interested in electronic and atomic modeling. He is focused on computational materials design, structure-properties relationships of materials using electronic and atomistic modeling approaches.

With a devotion to problem-solving and bringing benefits to society through his research, An marks the milestones along his career path based on his research contributions. Those milestones include three achievements that are distinct in his mind: finding that electron-hole pair excitation plays an important role in determining the dislocation or twinning deformation mechanism of covalent and ionic semiconductors; exploring how the abnormal brittle failure of boron carbide and related superhard ceramics arises from the higher density amorphous shear bands; and determining the catalytic reaction mechanism of the Haber–Bosch process on iron catalysts and developing a hierarchical high-throughput catalyst screening approach to single out silicon as the most promising dopant to improve the efficiency of iron-based catalyst.

An completed doctoral studies at California Institute of Technology (Caltech), where he earned a Ph.D. in materials science in 2012, and then continued research as a postdoctoral scholar in the Division of Chemistry and Chemical Engineering. At Caltech, he especially valued the opportunity to be mentored by William A. Goddard III, who directs the Materials and Process Simulation Center at Caltech. An credits Goddard as having the greatest influence on his career, not only as his Ph.D. advisor but also because he provided "enthusiasm, inspiration, and focus on scientific research."

Through TMS, other mentors and colleagues have helped An along the way. He appreciates being able to expand his networking opportunities with other talented scientists, engineers, and researchers. "TMS provides an excellent opportunity to share my research outcomes with the community, as well as to encourage interactions with experts in my research field," An said.

An is a strong member of the research community and benefits from his own advice to be passionate, stay focused on important problems, and make a societal impact. As An continues to develop and deepen his expertise in computational materials science, his list of contributions to the field only continues to grow.



Qi An teaches and researches at the University of Nevada, Reno.

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Standing Together While We Stay Apart: Your 2021 TMS Membership

Tom Battle

Tom Battle

In the past year, our global professional community—and indeed the entire world—has been grappling with hard questions. Perhaps central among these, at least professionally speaking, is this: How do we keep science and technology advances moving forward when we're so far apart?

Connecting with colleagues is an essential aspect of our careers as scientists and engineers. We gather with teams of co-workers to solve difficult problems. We work side-by-side in laboratories to test new ideas. We meet at conferences and events to share insights and gather inspiration for our own work. Our careers and our individual projects thrive on this kind of interaction. So how do we keep our momentum going in time of pandemic?

While there are no easy answers to these questions, there is one important thing that all of us can do. We can stand together (figuratively speaking!) as a community. Our TMS community has always been a place that brings together scientists with engineers, industry employees with government lab workers, academic professionals, and students. ***We have long been the Society that connects individuals working throughout the world to move the minerals, metals, and materials science and engineering fields forward. And we continue to do so today.***

One of the easiest ways to show solidarity and to stay connected with your community is to renew your membership in The Minerals, Metals & Materials Society for the coming year. It doesn't sound like much, but when you renew your membership, your dues help to cover costs associated with the services provided to TMS members, as well as the services we are able to provide to the larger community.

When you renew for 2021, you also help to grow our Society's network of professionals and students, making it easier for individuals to share new ideas, inspire new research directions, and forge new professional relationships. When you renew for 2021, you help to enable all of these connections and interactions to continue happening and you help keep the field moving forward, for both yourself and your colleagues.

For our part, we are working to do all we can to provide additional support to the TMS community during this challenging time. A few examples:

- We have launched a new series of webinars, led by TMS volunteers with a wealth of expertise and experience, on topics of current interest. Log in to www.tms.org/WebinarLibrary to view past webinars for free and to register for upcoming events.
- We've introduced a new Economic Hardship member category for any member who may be dealing with a temporary setback in their career, such as job loss, employer funding cuts, or reduced working hours. You can contact Bryn Simpson, TMS Membership and Volunteerism Program Manager, at bsimpson@tms.org to request this free membership until you are back on your feet.
- We launched a COVID-19 Resource Portal (www.tms.org/COVID-19) that consolidates many resources that members can use as they work from home. This includes the TMS COVID-19 Materials Needs Exchange, which connects organizations and programs on the front lines of the COVID-19 pandemic with TMS members who can render materials or manufacturing assistance, resources, and/or expertise. More than 2,000 users have accessed these resources since April 2020.
- We offered a virtual version of the Metallurgical and Materials Engineering Professional Engineer (PE) Licensing Exam Review Course this year, which helped individuals to continue their preparations for this important test remotely.
- We have also continued to publish high-quality journals that disseminate advances in our field to readers throughout the world. (And it's worth noting just how impactful these journals are—see the article "Impact Factors and Other Key Metrics Released for All Six TMS Journals" in the September issue of *JOM*.) Log in to www.tms.org/Journals to read any of these journals or to learn how to submit your work.

TMS will continue to seek new ways to reach out and connect members with one another, as we all strive to stand together, even as we stay apart. I encourage you to take a few moments of your day to renew your membership, so that you can continue to stand with us.

P.S.: I know it's been a year of changes for many of you, so if you have switched jobs, relocated, or added new technical interests, please be sure to update your member profile information during the renewal process. You can also update this information at any time through the Member Tools section of members.tms.org.

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Workforce Development Survey Results: Industry, Government Laboratories, Academia, and Recent Graduates

Simona E. Hunyadi Murph, Ashish Singh, and Kester Clarke

Simona E. Hunyadi Murph

Ashish Singh

Kester Clarke

The TMS Education Committee designated a subcommittee on Workforce Development to survey professionals in industry (I), government laboratories (G), academia (A), and recent graduates (RG) to gain insights into the alignment of materials science curricula with workforce needs. The survey project began with a charter to explore any disconnects that might exist between university materials curriculum and workforce knowledge, skills, and ability needs for materials science and engineering (MSE)-related careers, and also highlight critical areas of excellence that should be preserved. Focused surveys for each category were developed and more than 150 responses were received, including 83 responses from industry/government, 40 responses from recent graduates, and 29 responses from academia. The primary survey questions are summarized below, with choices for answers given in Table I.

- Which of the following knowledge or

Table I. Specific skills listed in the survey, of which the top five were selected

Mathematical Foundations	Materials Physics	Mechanical Behavior of Solids	Structure of Materials	Materials Design Fundamentals
Materials Processing	Statistical Process Control and Design of Experiments	Modeling and Simulation Tools	Computational Approaches	Data Science
Failure Analysis	Effective Communication	Working Across Interdisciplinary Teams		

Other (summary of responses received):

Academia (A) – mechanical engineering

Industry (I) and Government Laboratories (G) – proposal writing, chemistry, critical thinking, awareness of fields (e.g., nuclear), programming, basic computer skills, industrial work habits, deadlines, accuracy, communication (phone vs. e-mail vs. text)

Recent Graduates (RG) – Six Sigma principles, project engineering, industry best practices

Table I. The variety of skills listed for survey participants to choose from, as well as a summary of additional responses received from each group.

“Workforce Development Survey Results: Industry, Government Laboratories, Academia, and Recent Graduates” was developed as a special project of the TMS Education Committee to identify potential gaps between university curricula and workforce skills and needs, as related to materials science and engineering. For additional information, contact Kaitlin Calva, *JOM* Magazine Managing Editor, at kcalva@tms.org.

skills have not been acquired by new hires?

- Which of the following knowledge or skills have been acquired by new hires?

The results of the category surveys are summarized in the following sections, highlighting noteworthy categories and comments.

Results

The results of the surveys are presented in three parts, starting with industry and government, followed by perspectives from new graduates themselves, and finally insights from academia.

Response from industry and government professionals involved in hiring and training new hires:

Experienced professionals from industry and government participated in this survey, including representatives from aerospace, automotive, energy, primary materials, sustainable materials, and suppliers. Specifically, the surveys were limited to professionals who participate in the new hire process and workforce training, with a focus in the area of materials science and metallurgy. A total of 83 responses were received for the survey, out of which 57% were from industry, 36% were from the government agencies, and the other 7% were from other organizations, including safety regulators and trade associations. Most responses were received from professionals who identified with the energy sector (30%), followed by aerospace (14%), primary material production (11%), and the automotive industry (6%). A combined 25% of the responses received were from other sectors including medical devices, defense, simulations, materials informatics, electronics, and the semiconductor industry. Overall, these employers indicated that they hire materials engineers from all three university degrees: bachelor's (B.S.), master's (M.S.), and doctorate (Ph.D.). Generally, industry indicated the hiring of more B.S.-level graduates, with government laboratories hiring more M.S.- and Ph.D.-level graduates. Figure 1 presents results from the surveys summarizing the skill sets that recently hired new graduates do (Figure 1a) and do not (Figure 1b) possess.

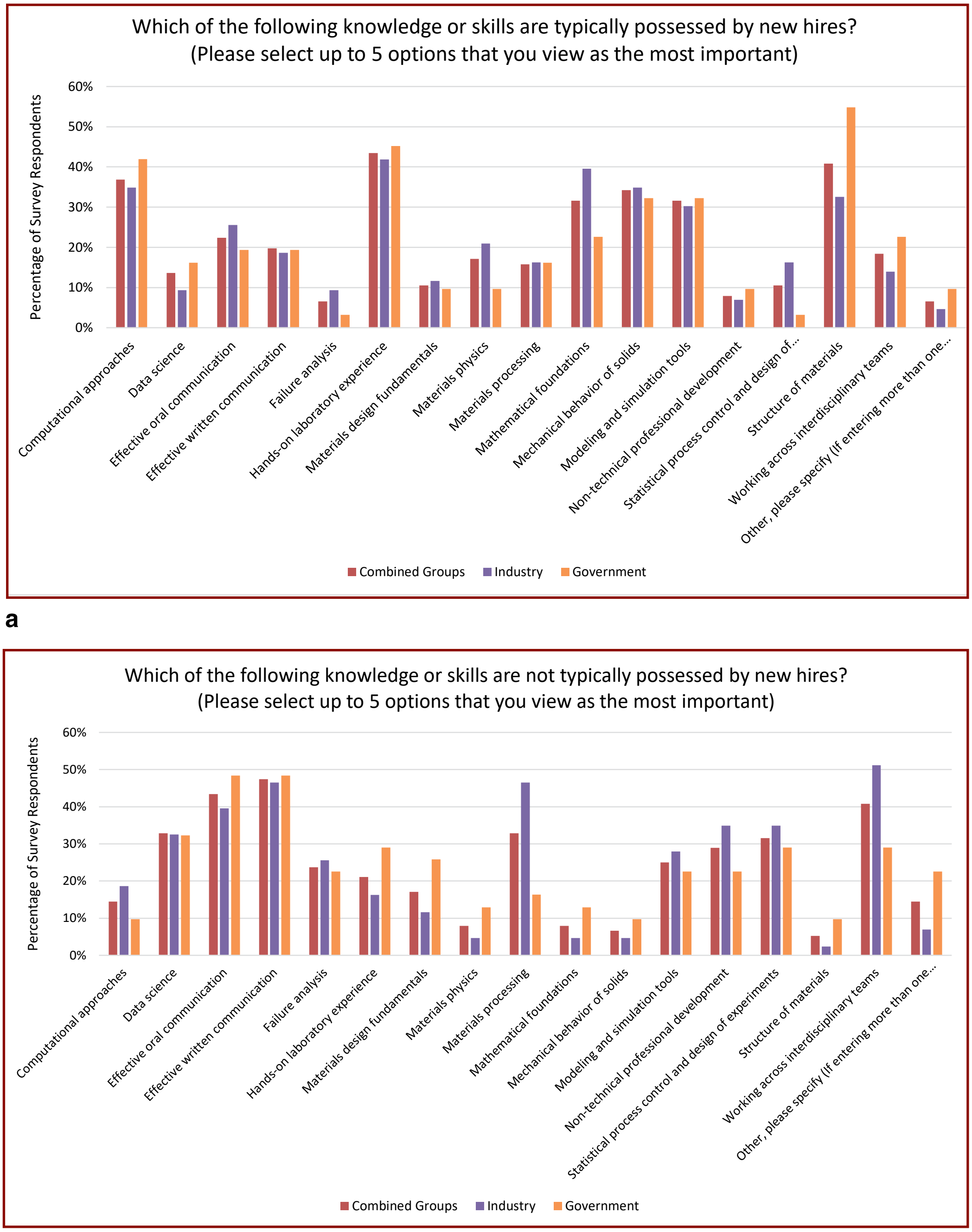


Figure 1. Percentage of survey respondents indicating the skillsets that are (a) and are not (b) possessed by new hires.

The four areas where responses indicated new graduates have sufficient skill development included hands-on laboratory experience (42%), structure of materials (41%), computational approaches (37%), and mechanical behavior of solids (34%). Industry and government responses were similar, with the exception of structure of materials, which was indicated significantly more by government professionals, and mathematical foundations and statistical process control and design of experiments, which were indicated significantly more by industry professionals. Similarity between industry and government in this case also indicates comparable outcomes for B.S., M.S., and Ph.D. graduates, based on general hiring practices mentioned previously, where industry tends to hire more toward the B.S. end of the spectrum and government tends to hire more Ph.D. graduates.

Generally, it appears that materials curricula address most of the polled categories, with the only categories below 10% respondents consisting of failure analysis, non-technical professional development, and "other." In the "other" category, basic computer skills were listed by one respondent, and one added a comment that most B.S. graduates have learned to learn, but inevitably require further training wherever their career immediately takes them.

About 40% of both industry and the government professionals identified two major skills that are not adequately mastered by recent graduates, including effective oral (43%) and written (47%) communication. Typically, both undergraduate and graduate programs build these skills through oral presentations and report writing assignments in various courses during their studies. However, in order to create a qualified workforce, universities should provide courses that focus more on teaching foundational skills in professional writing and speaking needed for professional success. Additionally, data science, materials processing, statistical process control, and working across interdisciplinary teams were identified by >30% of respondents. Industry professionals also considered materials processing (47%) as an important skill for new individual graduates to possess.

The survey shows that hands-on laboratory experiences, materials design fundamentals, working across interdisciplinary teams, and statistical process control and design of experiments (SPC/DOE) are skills highly desired by government employers. Both government and industry professionals expressed that working in an interdisciplinary team environment is a major skill needed to be developed in the new hires (41%). Energy, automotive, and aerospace-based professionals identified that failure analysis (24%) and statistical process control and design of experiments (32%) were critical skills for new hires. It is to be noted that the above-mentioned industries not only perform failure analysis for parts/products in-service but also during the manufacturing of products to resolve process-related issues. Statistical process control and product testing are key for many industries and assist management in the decision-making process. In the "other" category, specific skill areas listed included proposal writing, chemistry, economics, computer programming skills, and hands-on industrial work habits; general skill areas included accuracy and deadlines, awareness of various materials areas (nuclear was noted), critical thinking, and understanding of which communication methods are commonly used (i.e., phone vs. e-mail vs. text, etc.—perhaps generational issues).

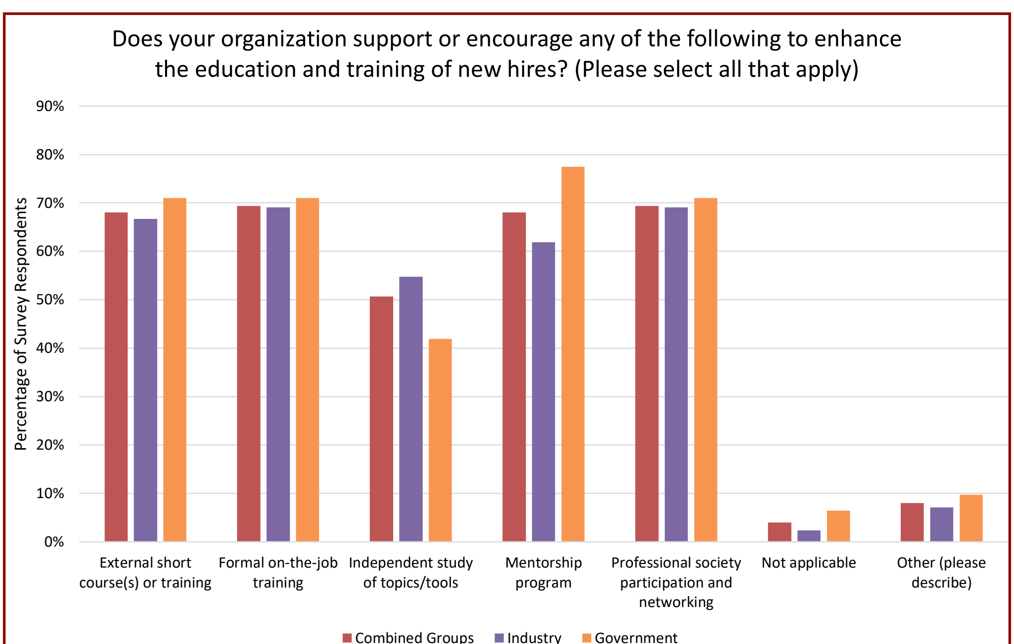
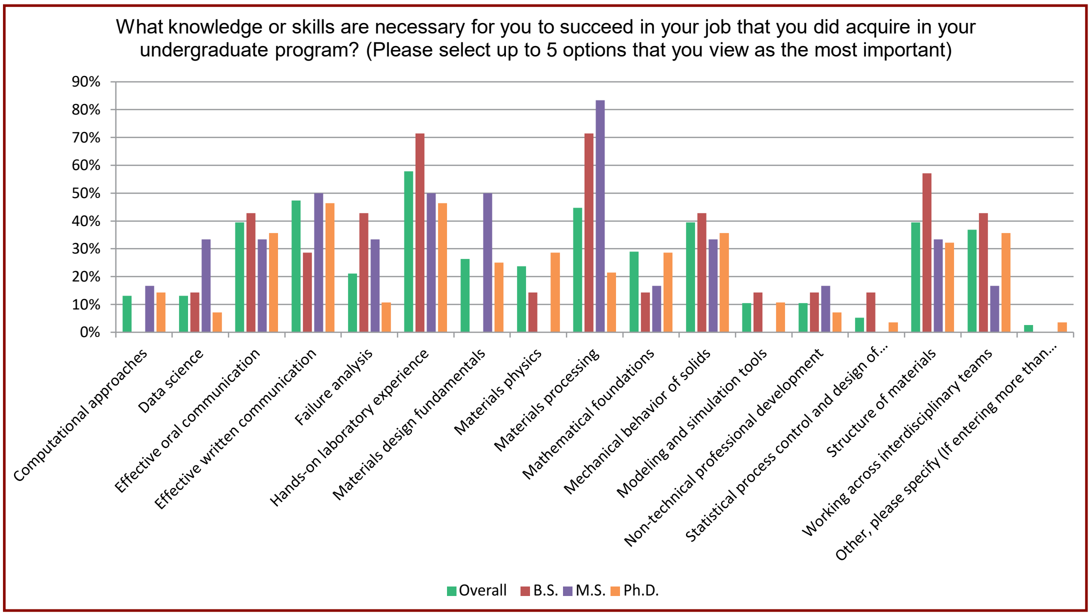


Figure 2. Percentage of survey respondents indicating organizational support and encouragement for the indicated continuing education opportunities.

Professionals from both industry and government agencies expressed that, once on the job, their organizations support and encourage the new hire's continuous education and training through a number of professional development programs, as seen in Figure 2. These training programs include external short courses, formal job training, mentorship programs, professional society participation, and networking. These activities accounted for >60% of the major ways of supporting new hires and their on-the-job engagement. The independent study of various topics and tools were voted by 50% of the survey respondents as important for a successful career path. Several respondents also indicated that internal training courses are available and some organizations offer rotational programs to expose new graduates to the breadth of organizational activities. Continuing formal education in the form of an advanced degree from local colleges or universities was also included in possible avenues for advancement, but at least one respondent indicated that these activities might not result in advancement at their current organization.

General comments provide interesting insight into the responses outlined above, particularly with regard to communication skills. One respondent from a government entity indicated that communication skills were not entirely absent during the academic training, but perhaps do not fully encompass the daily activities of a practicing engineer, including reading and reviewing technical reports, writing requests for proposals (RFPs), evaluating proposals, writing technical reports, and delivering formal and informal presentations. Another respondent from industry indicated that the ability to capture all relevant details in a concise, succinct, and thorough manner in a report is rarely seen in new graduates. These responses suggest that it is likely that not much time is spent in undergraduate programs developing writing skills for the breadth of document types and audiences that young engineers will encounter.

An interesting comment from an industry respondent was that their organization does not generally hire materials engineers but focuses on engineers from other disciplines. Although the reasons behind the decision were not indicated, this may be due to a lack of resources to have focused materials engineers in their organization and may indicate today's engineers need to have broader skillsets than may have been required in the past.



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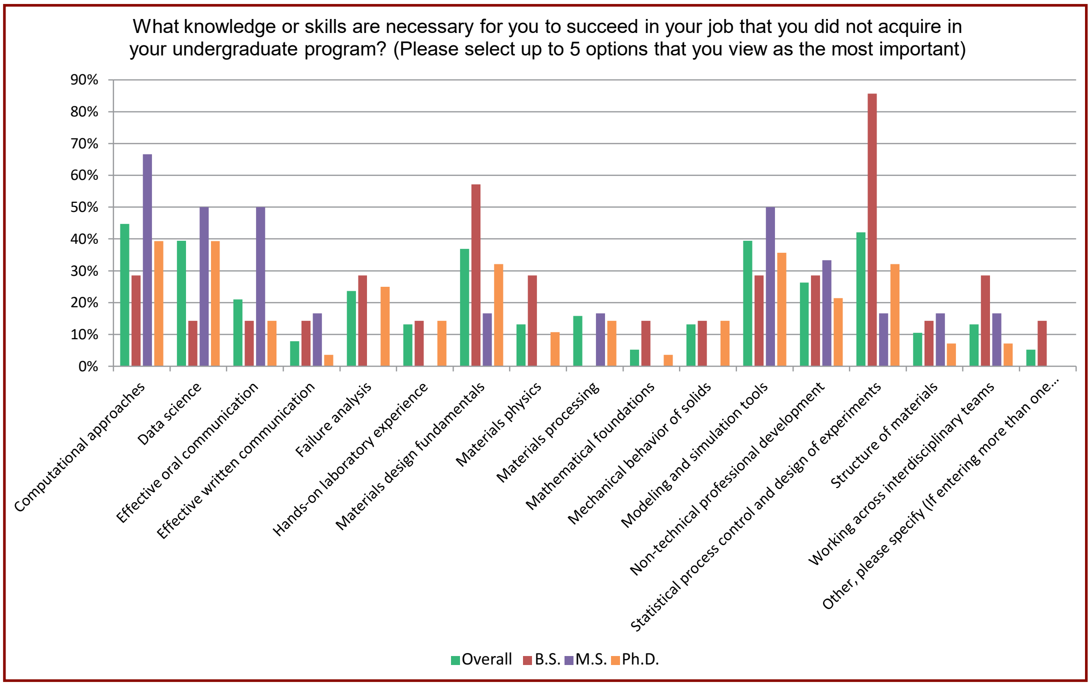

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Figure 3. The percentage of new graduate survey respondents indicating the skillsets that they did (a) and did not (b) posses after graduation.

Diversity was also mentioned as a big challenge, as a lack of a diverse pipeline from universities results in challenges for organizations to hire a diverse workforce. This suggests that further efforts are needed to improve diversity when recruiting students to university education programs.

Response from recent graduates who have entered the workforce within the past three years:

A similar survey was taken by recent graduates to identify their learning experiences in the materials science/metallurgy programs. Forty-one (41) recent graduates participated in the survey. Among them, 68% had Ph.D.'s, 15% M.S.'s, and 17% B.S.'s. These graduates identified with various economic sectors, including energy (20%), primary materials (15%), automotive (10%), and aerospace (10%). The vast majority of the new hires were now in academia (15%) or industry segments and government agencies (30%). The remaining 45% indicated "other" areas that were not specifically listed on the survey choices, including defense, minerals processing, medical/pharma, and government research. The responses were separated into highest degree achieved. Figure 3 on the previous page presents results from the surveys summarizing the skill sets that recently hired new graduates do (Figure 3a) and do not (Figure 3b) acquire.

The top areas where recent graduates felt their degree program gave them the skills necessary to succeed in their career were hands-on laboratory experience, effective written communication, materials processing, effective oral communication, mechanical behavior of solids, and structure of materials. Responses were generally similar regardless of highest degree achieved, particularly considering the relatively low number of respondents whose highest degrees were a B.S. or M.S. Surprisingly, the new hires generally expressed that they possessed adequate oral and written communication skills to perform their new jobs which completely contradicts the impressions of the experienced professionals (managers, executives, directors, etc.) that hired them, see Figure 1.

Generally, it appears that materials curricula address most of the skill categories that were listed on the survey, with very few indicating "other." In fact, the only respondent including another category here was a Ph.D. graduate suggesting that some more specific knowledge in their specific discipline would be helpful. The categories with the lowest response levels were SPC/DOE, modeling and simulation tools, non-technical professional development, computational approaches, and data science.

Recent graduates expressed the importance of having additional information on technology/computational technical skills that allow them to pursue a successful career path in government, industry, or academia. The skill deficits identified by these recent graduates included computational approaches (45%), data science (39%), and modeling and simulation tools (39%). In alignment with experienced professionals, 42% of the recent graduates responded that statistical process control and design of experiments should be more emphasized in undergraduate programs.

Approximately 70% of recent graduates responded that independent study topics/tools were helpful supplements to their undergraduate studies, Figure 4. Recent graduates also responded that informal discussions with colleagues (60%), formal job training (51%), and external short courses and training (49%) were activities that helped them improve their new job performance. Around 30% of the recent graduates also noted that professional society participation and networking provides good supplemental education and training.

Additional anecdotal comments from recent graduate respondents may be useful in providing some context to the data in Figure 4. One respondent indicated

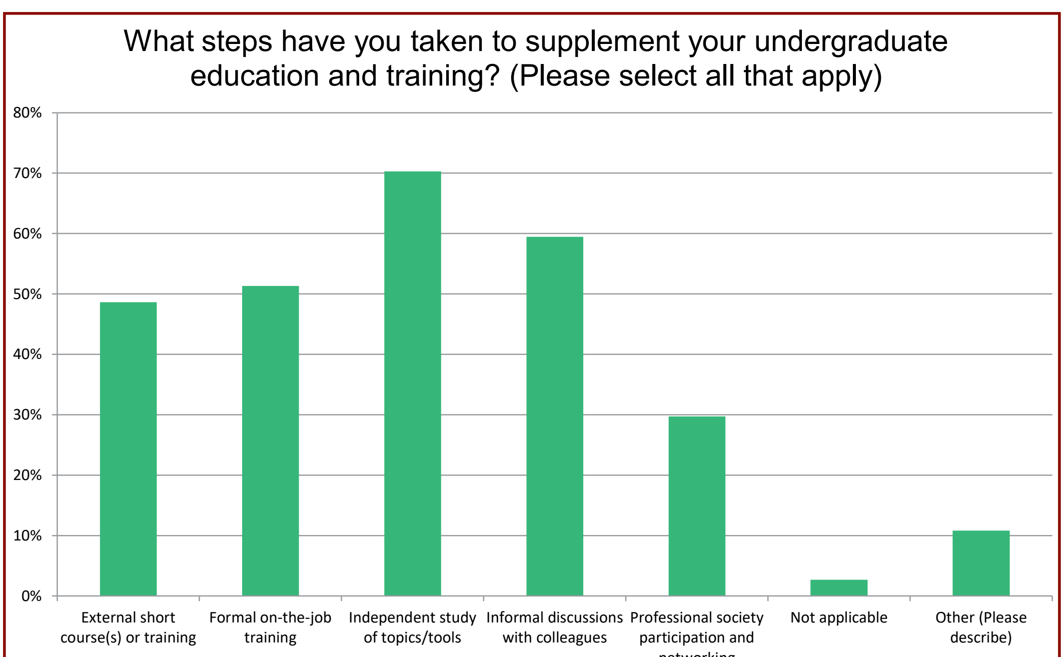
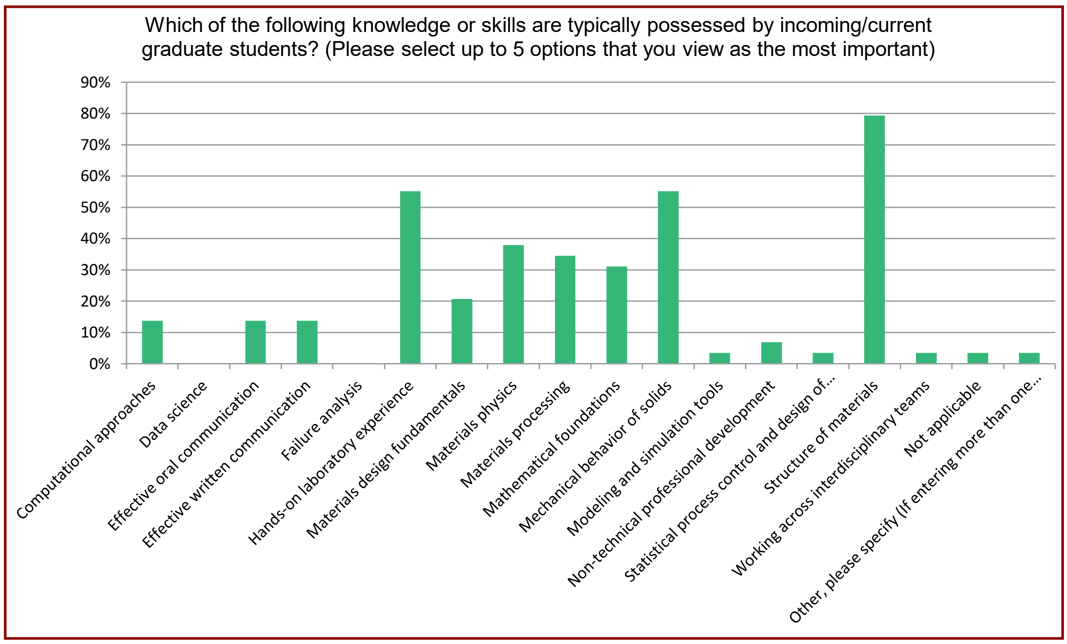


Figure 4. Percentage of recent graduate respondents indicating they have supplemented their undergraduate education with the listed continuing educational opportunities. The "other" category response was graduate school in all cases.

that, for themselves and other recent hires they have known, there are educational gaps in new techniques being developed in industry, including computational engineering, modeling, and simulation, and that just a few of their fellow new hires had formal introductions to these important topics. Statistical process control and design of experiments was also an area specifically mentioned by a respondent in the additional comments, particularly for those seeking industry careers, and another suggested that their undergraduate program did not necessarily focus on some of the skills that were useful in industry, but instead on skills for those who subsequently pursue advanced degrees.

The experiential components of an undergraduate education were highlighted in one comment, suggesting that participation in undergraduate research opportunities not only allowed them to gain experience, but also provided a better view of which aspects of the field the student found interesting and engaging. Others found that the professional development opportunities in their undergraduate program were limited and resulted in most graduates accepting positions at the same employers that supported the program, year after year.

For those entering graduate programs, materials engineering programs might benefit from some type of "bridge" from undergraduate engineering to maximize opportunities for recruitment, as one respondent noted the challenges associated with pursuing an advanced degree in one area after completing a B.S. in another area. They found that substantial independent study helped them overcome the "imposter syndrome" they initially felt, and also indicated that their most salient competency was not knowledge or skill-based, but rooted in the critical thinking abilities they developed during their undergraduate experience. Finally, a respondent indicated that knowledge in materials engineering is important, but additional skillsets in management of people would have been quite beneficial in their career.



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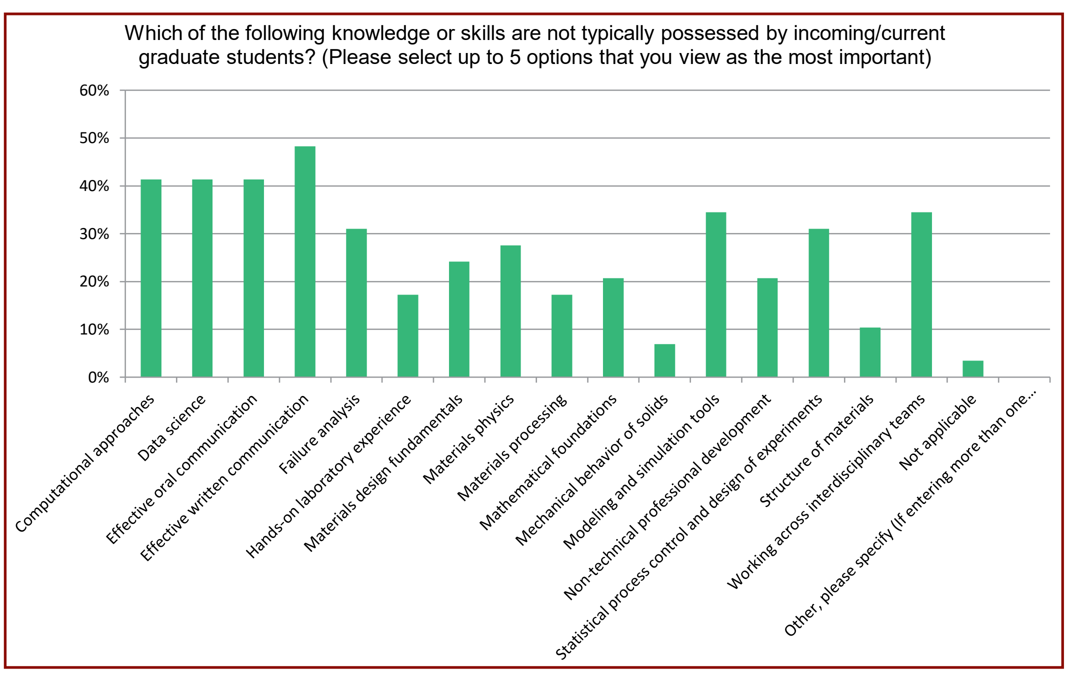

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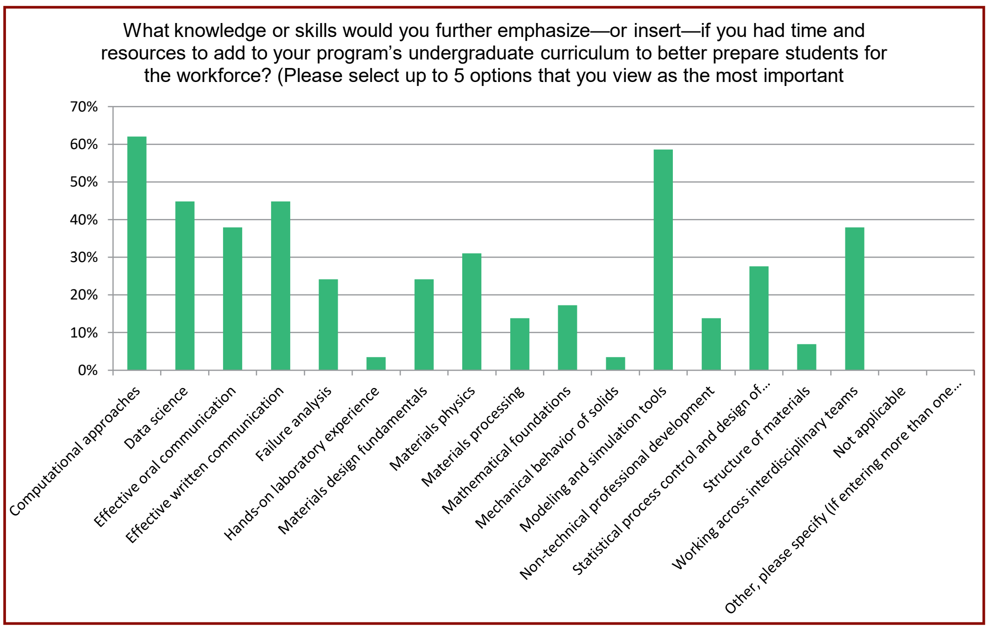
Figure 5. Percentage of academic professional survey respondents indicating skillsets that are (a) or are not (b) possessed by incoming and/or current graduate students.

Response from academic professionals involved in hiring and training new hires:

The respondents to the academic survey indicated they are generally (64%) highly engaged in curriculum development for the materials science or materials engineering program at their university and represented over 16 materials programs from U.S. universities. When considering their own program, most respondents indicated structure of materials, hands-on laboratory experience, and mechanical behavior of materials were skills that incoming graduate students possess, and that effective written communication, effective oral communication, data science, and computational approaches could benefit from further development (see Figures 5a and 5b on the previous page). Importantly, the areas indicated in both of these charts are generally in alignment, suggesting that the greatest opportunities for augmenting materials engineering programs lie in the computational and data science areas, which is further corroborated by Figure 6a, which suggests the areas that faculty would insert or further emphasize in curricula, given the opportunity. Given the indications from industry, government, recent graduates, and academia that computational and data science need further attention in materials engineering curricula, the primary challenge seems to be how to manage this while maintaining the current strengths in curricula.

The final survey question to academia posed which changes occurring in materials engineering departments will affect faculty ability to address preparation of future materials workforce, Figure 6b. Unsurprisingly, the impacts of the current global pandemic garnered the most responses, but the availability of funding, the increase in student populations, and limitations in laboratory space each garnered a significant number of responses. Several interesting "other" responses included (1) growing faculty and institutional focus on research limits dedication to pedagogy and educational development; (2) competition with disciplines such as computer science may challenge smaller disciplines such as materials engineering; (3) declining faculty numbers may be a challenge to overcome; and (4) priority differences among faculty and visions for the future workforce may dilute materials education.



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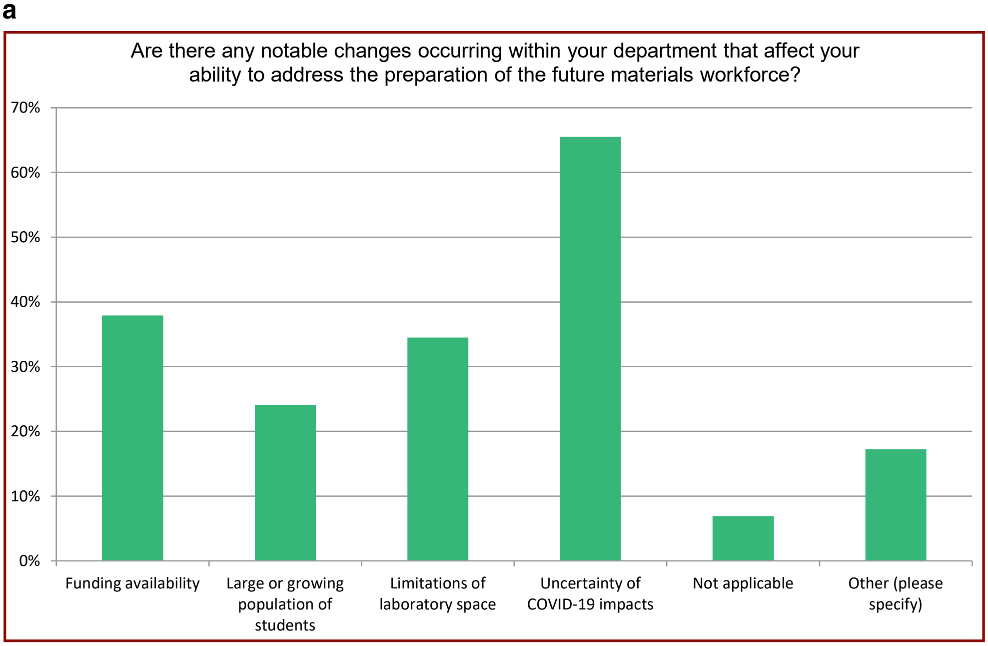

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Figure 6. Percentage of academic professional survey respondents indicating skills that would be inserted or further emphasized in undergraduate curricula, if given the opportunity (a), and departmental changes and challenges that prohibit their ability to address materials workforce preparation (b).

Two general comments from academia respondents also provided some further context. First, one challenge in educating the materials engineering workforce is that career paths are bimodal, where some graduates go on to an industrial (largely manufacturing) environment and subsequently proceed on a managerial track, whereas others go on the graduate school path and end up in dedicated research roles at national laboratories or in academia. It was noted that the skillsets required for these two paths are quite different. Some comfort may be taken from the results of this survey regarding this concern, as nearly all respondents from all employment categories identified communication and computational/ data science as the main areas that need to be enhanced in materials engineering curricula. Second, echoed from above, is that materials faculty tend to lean toward research-intensive careers and that research in specialized areas or faculty that are less interested in undergraduate education both undermine efforts to provide undergraduates with a strong materials engineering foundation that is sufficiently broad to allow career flexibility.

Summary

The survey results presented here suggest that current university materials engineering curricula are successfully training the workforce in many areas, including hands-on laboratory experiences, structure of materials, mechanical behavior of solids, and some computational and modeling/simulation competencies. However, the primary areas identified in this survey where materials engineering curricula could be further enhanced include communication and computational/ data science skills. The ability to think critically was also acknowledged as a skill that enabled individuals to add flexibility to their career choices, as adapting to a new area becomes much easier with these skills. A significant highlight of materials engineering curricula coupled with hands-on laboratory experiences often translate to real-world successful careers, but there is concern that laboratory practices at the university level are in some way behind in the precision, documentation, and safety considerations that have become standard in industry and government facilities.

The feedback from industry and government professionals regarding a general lack of adequate communication skills in recent graduates is quite interesting, as the graduates' feedback contradicts this assessment and they believe that they are proficient. This apparent discrepancy may not be that surprising, however, when considering that the bulk of communication assignments in undergraduate courses are focused on laboratory reports (laboratory courses) and project presentations (senior design/ capstone), whereas the breadth of communication routes and audiences significantly increases upon entering

"The survey results presented here suggest that current university materials engineering curricula are successfully training the workforce in many areas…"

industry, government laboratories, or even graduate school. It may be worth considering new strategies and assessments on how to incorporate more diverse writing assignments for various audiences into undergraduate courses. Some suggestions have been included above but should not be considered comprehensive. A specific challenge in enhancing the undergraduate curriculum with respect to communication is that the general trend of teaching larger class sizes results in limited individual interactions and limited detailed critiques of student communications by faculty or even graduate students. That is, the larger the class, the more communication is evaluated based on rigid metrics and practices, which may hinder a student's ability to perfect and grow their communication skills.

It is currently rare that undergraduates critique the communication style of their peers or are requested to evaluate professional publications. One solution might be to ask undergraduates to regularly assess the writing and oral communications of themselves and others. With teleworking activities being more prevalent these days, students could also record themselves and asses their skills. This may give further perspective on effective communication and how to appropriately adjust communications practices for a given medium or audience. This approach may be more effective as class sizes increase. Finally, it could be beneficial to teach writing and oral communication in a manner that suggests these are areas that can and should be continuously developed and reshaped throughout a given career.

An area of significant concern expressed by recent graduates was that they did not have a clear understanding of career options and opportunities. Although many undergraduate curricula include discussions of career options and universities are equipped with career centers, it appears that additional connections are needed between scholarly activities and career paths in industry, government, and academia. Further discussion of career options or internship opportunities seems necessary, and perhaps communications and experiences of what to expect from a job in industry, at a national laboratory, or at a university. Better communication of these opportunities, including how to apply for a professional position or graduate school, would be beneficial, including further discussion on engineering graduate school norms (such as stipend, tuition, health insurance paid). Materials is a field that isn't introduced until after high school, and students may be overwhelmed with the various areas of opportunity. TMS has five divisions—Extractive & Processing, Functional, Light Metals, Materials Processing & Manufacturing, and Structural Materials—and within them 34 technical committees focusing on various materials areas. Undergraduate students are unlikely to really understand the details of these areas. However, programs such as Material Advantage can go a long way toward exposing undergraduates to a wide range of industry and government professionals through local interactions and seminars, and the ability to attend conferences such as the TMS Annual Meeting & Exhibition, which provides broad exposure to the materials community. More information on Material Advantage can be found at www.tms.org/MaterialAdvantage.

TMS also offers many opportunities for recent graduates and early-career professionals, ages 40 and under, including the Young Professionals Committee, the Emerging Leaders Alliance program, the Young Leaders Professional Development Awards, the Young Leaders International Scholar program, and the Early Career Faculty Fellow Award. For details on these opportunities, visit www.tms.org/YoungProfessionals. In addition, there are many resources that can expand an individual's knowledge of the materials field, including TMS meetings and events, the TMS Webinar Library, professional registration, the professional engineering (PE) exam study guide, volunteer opportunities, and the *JOM* job board. Access these and other resume-enhancing resources at www.tms.org/PD.

TMS is also dedicated to being a highly inclusive Society where all materials students and professionals feel welcome and diversity is celebrated, suggesting that participation by students, professionals, and academic faculty could help address some diversity challenges. The TMS Diversity, Equity, and Inclusion committee is active, growing, and enthusiastically welcoming new volunteers. Additionally, the Fourth Summit on Diversity in the Minerals, Metals, and Materials Professions (DMMM4) will be co-located with the TMS 2021 Annual Meeting & Exhibition (TMS2021). Programming and additional opportunities for both events are still being developed; find the most up-to-date information at www.tms.org/TMS2021.

TMS recently published the study *Creating the Next-Generation Materials Genome Initiative Workforce*. The current independent and more general workforce study reinforces the MGI study findings that the foundational pillars of data, computation, and experiments require key competencies in data science, modeling and simulation, and advanced experimental tools. Action plans from the MGI study include modernizing academic curricula and developing tools for continuous learning and workforce education. *Creating the Next-Generation Materials Genome Initiative Workforce* is available for free download at www.tms.org/MGIWorkforce.

Acknowledgements

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Kester Clarke an assistant professor and the Forging Industry Educational and Research Foundation professor in the Metallurgical and Materials Engineering Department at Colorado School of Mines. As a TMS member, he has served as chair of the Shaping and Forming Committee, is currently vice-chair of the Education and Steels Committees, and is involved in several other TMS committees.

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A Roundtable Discussion:

Challenges for a Sustainable Aluminum Industry and Advice for the Next Generation

Anne Kvithyld, David S. Wong, and Ed Herderick

Editor's Note: This article corresponds with the Aluminum: Recycling and Carbon/Environmental Footprint technical topic published in the October 2020 issue of *JOM*: The Journal. For additional insight on this topic, browse papers in this issue or log in to your TMS member account at tms.org to read articles on Springer.

Five well-known specialists in the aluminum industry were invited to participate in a *JOM* panel discussion and comment on the most critical challenges our industry is facing, how we might face them, and what they would have liked to know when they started their careers. Whilst we had many enjoyable and meaningful discussions, here we summarise some of the highlights from our experts.

Meet the Panelists

Chris Bayliss is deputy secretary general at the International Aluminium Institute (U.K.) and has almost two decades' experience in the sustainability of the aluminium industry. He is involved in all aspects of the Institute's activities, from data collection and analysis to communication, and has played a leading role in collaborative projects to develop the industry's greenhouse gas accounting protocols, occupational health performance measurement tools, the global aluminum mass flow model, and "The Aluminium Story" (www.thealuminiumstory.com).

Gao Binliang is a professor at Northeastern University (China) and has been working in molten salt electrochemistry, especially in aluminum reduction, for over 20 years. His work mainly focuses on the theory of molten salts electrolysis, as well as electrochemical preparation of Al-based alloys in high-temperature and room-temperature molten salts. He has authored more than 100 scientific and technical papers, as well as two books on molten salts.

Don Doutre is senior principal scientist, molten metal processing and recycling at Novelis Inc. (Canada), and has developed the LiMCA™, AlScan™, and PoDFA$_f$™ technologies used daily throughout the aluminium industry. He is active in the preparation, casting, and properties of metal matrix composites, as well as in automotive casting and semi-solid forming, and more recently in quality, recovery, and environmental issues relating to aluminium recycling. He has 14 U.S. patents and has been a TMS member since 1985.

Stephen Lindsay is smelting specialist consultant at HATCH (USA) and previously served in technical and managerial capacities at Alcoa for almost 40 years, with responsibilities spanning anode, cathode, reduction, and emission control technologies. He has patents related to emissions control and alumina handling and has authored dozens of articles in *Light Metals*, *JOM*, and the Australasian Smelting Technology Conferences and Alumina Quality Workshops. He was editor of *Light Metals* in 2011, and an instructor for TMS courses on Industrial Electrolysis, Anode Technology, and Potline Scrubbers and Emissions.

Ray Peterson is director, technology at Real Alloy (USA) and has served in many areas of TMS, including as chair of the Recycling and Aluminum Committees, Light Metals Division Chair, and President in 2009. He has five U.S. patents and authored numerous papers and presentations in aluminium, including: primary production, recycling, dross processing, and molten metal treatment and handling. He is a Fellow of TMS and one of the instructors in the TMS Aluminium Cast Shop Workshop.

Q. From the perspective of your industry, what is the most critical sustainability challenge that we as a materials community need to answer?

PETERSON: Focusing on the recycling side [of aluminum], I see a societal issue around efficient collection of post-consumer scrap that needs to be addressed. Too much aluminum escapes the recycle loop. In particular, we have, at least in the U.S., a big problem with used beverage containers escaping the recycle loop. A more materials-related challenge is the minimization or reuse of our waste products, whether it is carbon dioxide, red mud, or salty recycling by-products.

DOUTRE: Sustainability includes not only quantifiable technical aspects such as energy intensity, greenhouse gas (GHG) emissions, water usage, etc., but also economic and social factors including financial performance, employee development, and community involvement. From a materials industry perspective—aluminum specifically—it will come as no surprise that CO_2 emissions represent the single biggest sustainability challenge. To appreciate the magnitude of this issue, it is worth noting that CO_2 emissions for flat rolled products are in units of tonnes CO_2e/tonne product shipped, in contrast to solid waste to landfill (perceived as a huge problem, and it is) which is expressed in kg/tonne.

BAYLISS: Yes, so I'll quote a report released [recently] by the World Bank. Looking at the material requirements for future energy systems (solar, wind, new renewables) by 2050, you'd need six million tonnes of aluminum, just for that segment. In general, achievement of the U.N. Sustainable Development Goals will require more material and energy resources, and not just a bit more. For aluminum, the [International Aluminum Institute] sees growth in demand of around 50% by 2050, requiring an increase in primary production of 25–30 million tonnes on today's 65 million tonnes level. Even with improved (>95% post-consumer) scrap collection rates, an additional 15–20 million tonnes of primary aluminum will be required. Ninety-five million tonnes of primary aluminum means an annual bauxite requirement of 500 million tonnes, an annual generation of 250 million tonnes bauxite residue, and, based on today's technology and energy mix, around 1.6 billion tonnes of CO_2e emissions. Today, the industry emits around 1.1 billion tonnes, 2% of global emissions. How to achieve this—while minimizing environmental impact during the production process—is our greatest challenge.

LINDSAY: Reduction of carbon-based emissions spanning the consumption of electrical energy and CO_2 emissions, to the industry's significant contributions of CF_4 and C_2F_6 to the atmosphere. The historical pathway has been through incremental improvements. However, some innovative approaches that allow [smelters] to be able to operate in concert with renewable forms of energy or to operate with inert anodes have the potential to be game changers. Major producers and even the LME are involved in a rush to market low CO_2 equivalent forms of aluminum—but they're basically badging the capacity that they're fortunate enough to have linked up with hydro power. I wonder if we shouldn't have some metrics, beyond CO_2 equivalence? What about the enabling of new renewable sources of energy—solar, wind power, or others—beyond traditional hydro capacity? TRIMET in Germany are doing a lot of the ground-breaking work with their "virtual battery" project. They should have called it "integrating the primary aluminum industry with the infrastructure and social needs of Germany," but that's just too long of a name. It aptly describes what they are doing—identifying social and countrywide goals, where they can actually fit in primary aluminum production and energy management into a bigger scheme of things.

GAO: Life cycle analysis of aluminum production in China shows the biggest GHGs are due to electricity production; emissions from smelters using coal are five times those using renewable power, e.g., hydro. At present in China, 90% of primary aluminum uses coal-generated electricity [and this] contributes 60% of total GHG emissions in aluminum production. Therefore, I think the most critical challenge for sustainability is how to use renewable power—especially wind, solar, and hydro power—as much as possible and decrease the share of the coal. We need to build a scientific basis for aluminum smelting technology for this. Other challenges are the quality of Chinese alumina, which is rich in lithium and potassium impurities, and thus, how to recycle the [resulting] spent electrolyte; how to recycle spent pot lining; and how to reduce the fluoride and sulfur emissions. All these problems, I think, are challenges to the future of our Chinese industry.

A ZOOM-based roundtable discussion with our expert panelists and *JOM* organizers.

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Q. How can we solve these *big challenges*?

BAYLISS: It's all about time. We need the solutions quickly—in 10, 20, 30 years—in order to avoid some of these environmental impacts that are being discussed. So, time is critical here. What has happened over the last 10, 20, 30 years? Well, Elysis [inert anode technology] is coming to market. We've seen China now operating mostly on 400+ kA [reduction cell technologies], up to 600+ kA, and specific energy [consumption] come down. We've seen significant changes happen, but for these big questions, solutions need to happen quickly. Sometimes it can be [mistaken] that, "a bit of tweaking here" and "a bit of creep, and we'll get there."

PETERSON: I think we're going to have some sort of outside driving force [perhaps on a COVID-19 scale]. A company by itself is not going to take that risk or be able to make these changes. It's going to have to be a collaboration between governments, companies, and research organizations.

LINDSAY: I agree with Ray, it's going to need some bigger driving force, either at a governmental level or perhaps even at the world level. I do believe the future for the industry can be fit well into the development of smarter grids and use [of] more renewable sources of energy, [with] lower CO_2. As Chris has pointed out, "chasing small scale creep projects and incremental change" is not going to get the industry where it needs to be.

DOUTRE: You know, it's bigger than the aluminum industry, this is worldwide. You can pick concrete, shipping, air traffic—I concur with the others here—it's a tough one. It can't be dealt with at just the company level. But at the individual level, there are choices we can make, things we can do—as people, as organizations—in terms of "chipping away at the edges," but the bigger underlying question is still out there.

GAO: Yes [in China], we [direct] a lot of money to focus on the big problems, [through] our government. For example, in recent years, our government has funded a heavy focus on environmental issues, and I think, maybe 10, 20 years later, we can develop many good solutions for the aluminum industry. So, I'm optimistic for the future, for both the Chinese and the [global] aluminum industry.

Q. Do you have any advice for the next generation of young people entering this community now? What would you have liked someone to tell you when you started in the industry?

PETERSON: There's a lot of things I wish people had told me when I first started my career, but I think one of the biggest ones is make it a point to network every chance you get. You never know when you might meet someone with whom you can collaborate or learn new ideas and facts. As a young professional, you may feel intimidated by more senior members, but most of them love to talk about their work and enjoy helping out younger members of the community. Understand that it may take several contacts to establish a relationship.

BAYLISS: I think Ray's point was great, to find mentors and people who can teach you the craft, and that takes time. But for me, [there] was a point where I realized that "you are eminently replaceable!" You bring a unique perspective and collection of skills, experiences, and knowledge that will need to be mobilized and drawn on to bring about positive change. But that change can only happen in concert with the skills, experiences, and knowledge of others. So, see yourself as a positive agent for change, but don't think it needs to be you to make it happen—don't let it weigh you down. Like a species occupying an ecological niche, your "fitness" depends on those around you, but if you are taken out of that niche, something or someone will fill the gap. That's humbling, but it's also empowering—for each new niche you occupy, you have an opportunity to learn and adapt.

DOUTRE: Pick up the phone and start a two-way dialogue. The problem with e-mail, Jabber, or texting is that it's agonizingly slow and you tend to stay on topic. Whereas if you pick up the phone, there's a personal relationship there. It's, "What's on your mind? What's going on?" Recognize that humans are, by nature, a very social species. We intrinsically prefer to connect and communicate in real time. Again, this is about making connections and broadening your exposure to different perspectives (production, sales, procurement, and technical all can have different points of view). The [other] advice is to recognize that everything we know is built upon knowledge accumulated from past generations—the industry is 132 years old—and there is now an enormous body of technical documents, most of it available electronically. Read, search, read some more, and repeat. You'll be amazed by what's already out there.

LINDSAY: I agree with what's already been said, especially what Ray started off with, that networking is really important. By growing some of your expertise and also having a bigger network, you can make more of an impact. But part of that also has to be taking advantage of every training opportunity. When you enter the aluminum industry, it should not be the end of your education. In fact, it should be the beginning.

GAO: I've collected some opinions from three eminent co-workers. Their hope for young people is that they would not only be satisfied with finishing assigned work, but they would become inventors, creators of new processes and technologies. They should devote their lives to providing answers to the [big] problems and transform the process into one more friendly, cleaner, and energy efficient. The demand for interdisciplinary talents is also increasing. I believe in the next two decades, the future aluminum smelting process will be quite different from the current process. There is a large room for the [next generation] to impact the development of new technology.

A Final Word

As our panelists have highlighted, our industry's challenges are great. Tackling them is perhaps a journey requiring all to come together, each adding contributions, with efforts coordinated.

Aluminum at TMS

TMS has a long history of engagement with the aluminum industry. From offering symposia and special events at the annual meeting, to notable publications, to unique networking opportunities, TMS has established itself as a leader in providing resources and information to support and benefit professionals who are working in this field. Discover all that TMS has to offer today!

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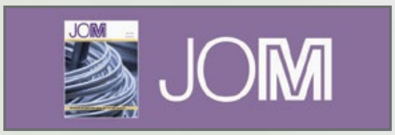

Check out upcoming technical topics related to your technical interests and learn how to submit a manuscript for a future issue at **www.tms.org/EditorialCalendar**. Search the Editorial Calendar by keyword to find topics in your field. TMS members can also access the *JOM* Archive at jom.tms.org to read articles in aluminum-related topics published in the journal since 1949.

EXPLORE *LIGHT METALS*

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More than 2,500 papers from TMS's signature *Light Metals* proceedings are available in TMS's Light Metals Digital Library. Considered an essential publication of the aluminum industry, *Light Metals* will celebrate its 50th anniversary in 2021. Search the collection by author, title, keyword, or year for access to individual papers, even those from the very first publication in 1971, online at **www.tms.org/LightMetalsLibrary**.

CONNECT WITH COLLEAGUES

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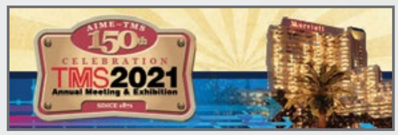
JOIN A TECHNICAL COMMITTEE

For many, joining a technical committee is the starting point for their involvement in the Society. Participation is also a valuable networking opportunity and provides the chance to contribute new ideas to your profession in a meaningful way. Visit **www.tms.org/Committees** to see all 34 technical committees—like the Aluminum Committee, Magnesium Committee, or Recycling and Environmental Technologies Committee—within the five divisions of TMS and learn how to join.

TMS ANNUAL MEETING



One of the most well-attended technical tracks year after year at the TMS Annual Meeting & Exhibition focuses on light metals and features a number of symposia focused on more specific aspects of the field. Other special events, such as the Light Metals Keynote and Light Metals Division Luncheon, are great places for attendees to network and exchange ideas with peers in a relaxed setting. The cross-disciplinary nature of every TMS Annual Meeting provides the added benefit of presenting opportunities to develop connections outside of your field or specialty. Learn more about programming for the next annual meeting at **www.tms.org/TMS2021**.

NOMINATE A COLLEAGUE

The TMS Awards program gives you the opportunity to advance your career through respected professional recognition, or the ability to honor a mentor or esteemed colleague. View a list of Light Metals Division-sponsored awards, as well as awards from other TMS divisions or Society-level awards and nominate a colleague to showcase deserving work in your field at **www.tms.org/Awards**.

WATCH A WEBINAR

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The newly redesigned TMS Webinar Library features a variety of topics, from fundamentals and overviews, to developing business and leadership skills, to recent advancements and current issues impacting the breadth of materials science and engineering. As an exclusive benefit, TMS members can access live or recorded content for free at **www.tms.org/WebinarLibrary**. Don't see content that fits your interests and needs? Click the "What New Content Do You Need?" button on the Webinar Library page to provide new ideas for webinars.

Anne Kvithyld and David Wong are guest editors for *JOM* from the Aluminum Committee of the TMS Light Metals Division. Ed Herderick is the industrial editor for *JOM*.

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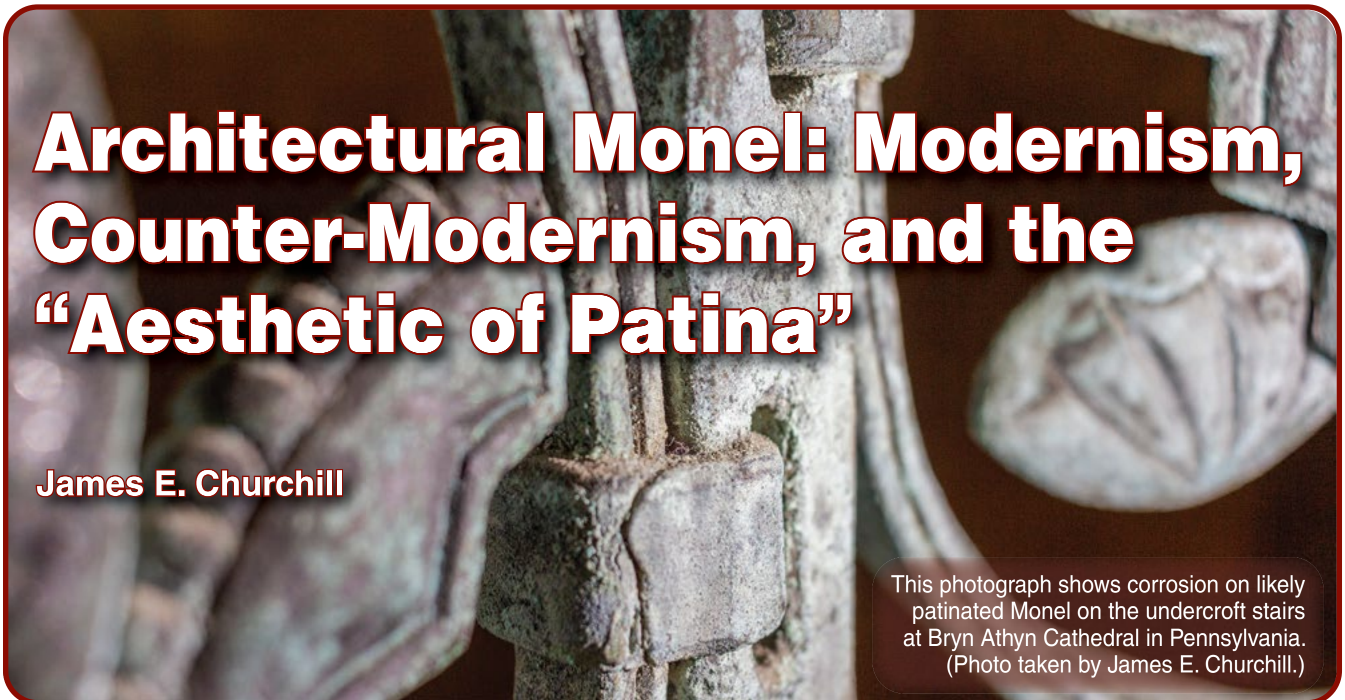
Architectural Monel: Modernism, Counter-Modernism, and the "Aesthetic of Patina"

James E. Churchill



This photograph shows corrosion on likely patinated Monel on the undercroft stairs at Bryn Athyn Cathedral in Pennsylvania. (Photo taken by James E. Churchill.)

James E. Churchill

Do You Have a Perspective to Share?

JOM: The Magazine is seeking case studies, member perspectives, and non-technical project overviews with strong industrial applications. To suggest an article idea, contact Kaitlin Calva, JOM Magazine Managing Editor, at kcalva@tms.org.

Introduction

Monel® 400 is rapidly vanishing from the architectural canon of decorative metals. A silvery alloy of approximately two-thirds nickel and one-third copper, it was fashioned into the epitome of modern American design after its founding in 1905 by metallurgist and, later, president of the International Nickel Company, Robert C. Stanley. Within three decades, however, its first mover advantage was eroded, while internally a management shift saw investment into new-fangled alloys in the chase to space. By the late 1940s, Monel began to settle into its new role of specialized anonymity.

Present Day

Writers point to the high cost and restricted supply of nickel during the war for the proverbial downfall of the alloy, but the reasoning appears more convoluted and includes an inherent coloring issue that the company ignored, or was not aware of, until it was too late. Today, Monel is all but forgotten by the American architect. A lack of guidance from the conservation authority, the National Park Service, results in a hodge-podge of treatment that favors the preservation of "patina," or more accurately, weathering, which may sustain damage, and yields an entirely different design aesthetic.

Monel and Sudbury

Discovered after research by a trio of International Nickel Company metallurgists, the alloy was reduced by Stanley in an attempt to bypass expensive refining methods to make nickel silver.[1] The 2.3:1 nickel to copper ore content that defined the alloy had come naturally from the Creighton mine of Sudbury, Ontario. This vast open pit dominated production for the company from 1901-1920 due to its rich nickel ratio. Refined without the expensive need for elemental separation, its properties yielded many attractive potential uses.

Early Years

Monel's discovery was fortuitous. Born into an insatiable arming campaign as World War I inched closer, the alloy was recognized for acid and alkali resistance, performance in seawater, and impressive strength. Initially, demand remained subdued due to difficult workability and forced the opening of in-house casting, but early gains dramatically shrunk after the disarmament treaties of 1919.[2] Stanley, the devoted parent, recognized the need to explore new markets. Building a refining factory in West Virginia, he invested significant sums in research and marketing. By 1925, Monel products had diversified into 16 different industries and by 1930 they were servicing over 20.

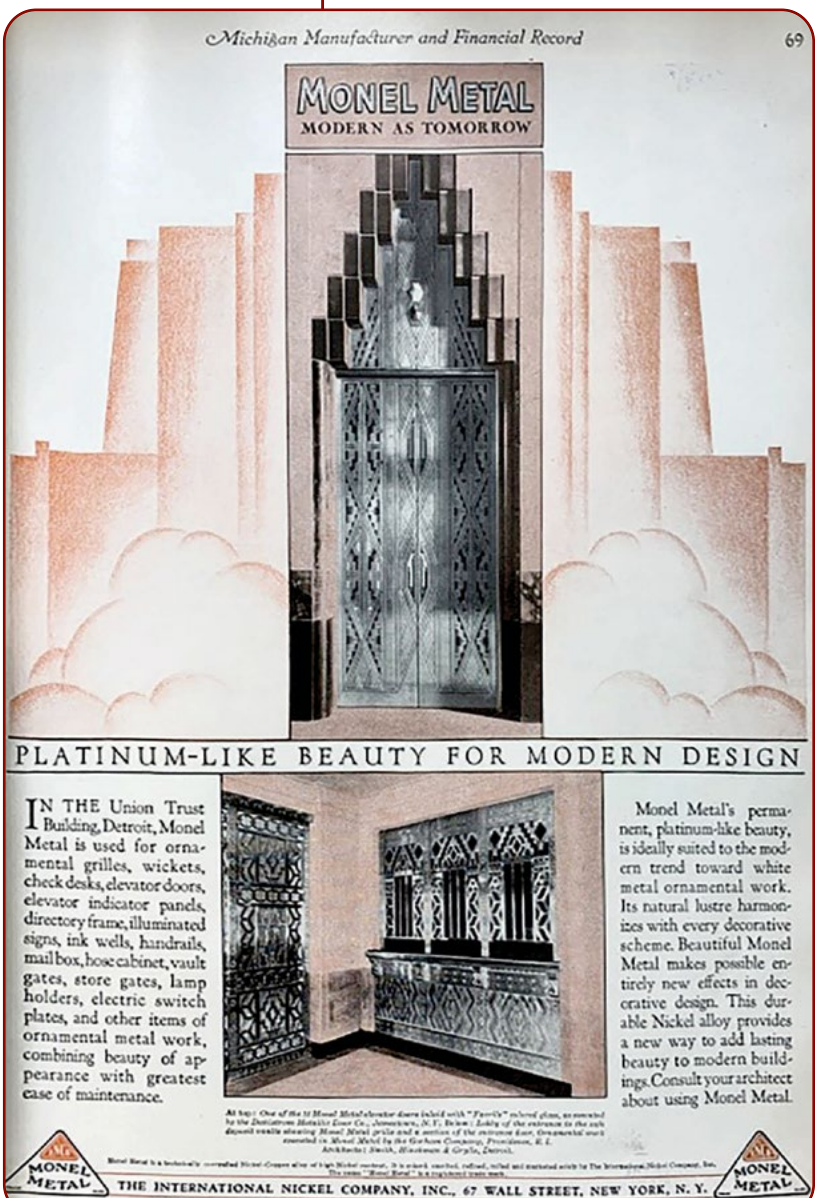


Figure 1. This 1929 advertisement for the Union Trust Building (now Guardian), Detroit, tied Monel to modernism and the expensive platinum group metals that the company also refined.[4]

Branding

The International Nickel Company took the unusual gamble to sell and research Monel concurrently. Positioned as a "white metal," David H. Browne, a colleague of Stanley's in the early years, stated Monel was "silver white and takes a brilliant finish, which it retains indefinitely."[3] As advertising ramped up, the company referenced other precious metals: silver used in hygienic household or food products and platinum for more grandiose projects such as the opening of the Union Trust Building (now Guardian) in 1929. Proclaiming "a metal that never looks old," Monel was aligned with modernism, popular after the famed art-deco exposition in Paris in 1925. Sales expanded rapidly as the world pivoted away from stodgy, patinated bronzes.

Architectural Use

By the 1920s, Monel had caught the eye of a wealthy elite who demanded decorative items made of this "shiny" and "indestructible" alloy. As the economy boomed, metal craft in the Northeast was buoyed by Samuel Yellin, a European immigrant with tremendous aptitude for wrought work. Yellin adopted Monel early, receiving his first order for church gates at St. James the Lesser in Philadelphia in 1920. Logs reveal lanterns, grilles, and other ornament until the year of his death, 1940. His teaching and stature in society disseminated the alloy to the likes of the principal metal design artist at Bryn Athyn Historic District, Parke Edwards, and others.

Research

Scientific research was, however, starting to catch up to the advertising machine. By 1924, the seminal corrosion engineer, W.H.J. Vernon, discovered nickel was prone to "fogging." In a summary written some years later, he concluded sulfur dioxide reacted to create a white film on the surface.[5] Dulling the metal, it became permanent if left unchecked and could only be removed through abrasion. Archival research revealed the Straus mausoleum decorative gates by Yellin at Woodlawn Cemetery turned surprisingly white within a year of installation and were subsequently ordered to be polished.[6] In a compelling report by the head of corrosion engineering at the International Nickel Company some 30 years later, fogging was stated as the primary reason behind nickel's lack of use for architectural or decorative applications.[7]

Weathering

By 1931, the International Nickel Company conceded that Monel could, in inaccessible areas, acquire a "grayish-green patina, eventually darkening to a mottled green, brown, and black."[8] The cat was out of the bag. The booklet, fashioned with a skyscraper-like silvery design, linked the alloy to modernist architecture, yet paradoxically featured no exterior architectural work at all. Stanley had watched as two symbols of the modern age, the Chrysler Building and the Empire State Building, were constructed of aluminum and stainless steel. The publishing of *Aluminum in Architecture* a year later showed the direction markets were taking; the inside cover sported an inventory of 24 buildings and counting.

Conservation

Despite its depiction of permanence, architectural metal, like any other building material, is subject to soiling and corrosion. Artistic unity can become compromised. In metals conservation, stabilization is integral, but work predicated on "restoration" is often viewed suspiciously out of a reaction to severe cases in the 19th century. Professionals tend to favor age-value over design. Today's "patina aesthetic" repairs often see the merger of green-induced cupric nitrate stainless steel with nonionic detergent cleaned Monel as a result. In America, the appetite towards green coloring is documented, but it presents an ethical dilemma that subjectively permits corrosion irrespective of the original design intent.[9]

Aesthetic Intent

Exhaustive archival research points to ignorance on the part of fabricators towards the green and brown hues that could result in Monel. Archives held at Yale University Library revealed that Yellin expected the alloy to have "a sort of dull pewterish look and gradually darken up a little, but will always look like metal."[10] Extant watercolors by Edwards are gray or black, the latter a factor of oxidation when forged, not through weathering. None of his work ever displays a green or brown patina that is now widely seen and maintained.

Corrosion

While conservation literature has in general indicated Monel's copper content

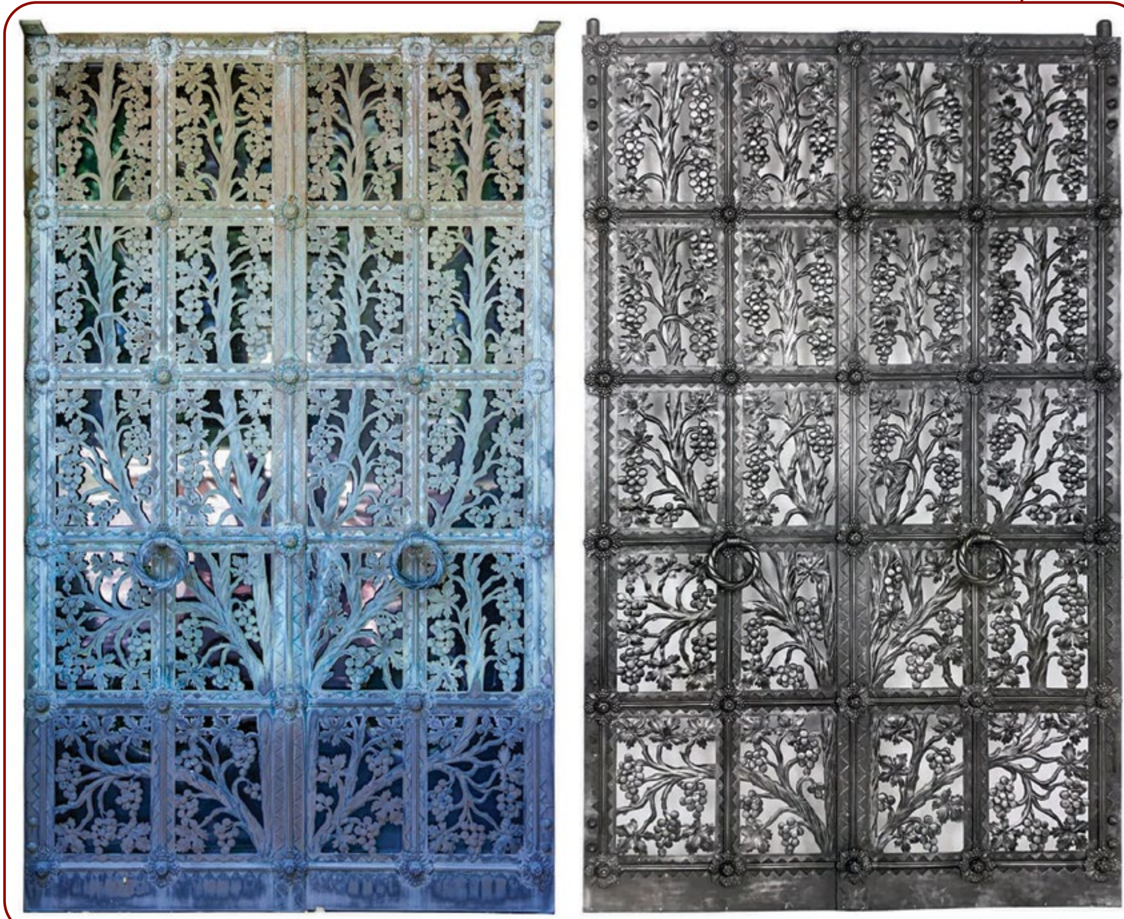


Figure 2. The Jesse I. Straus Monel gate by Samuel Yellin at Woodlawn Cemetery has weathered considerably and has lost highlights and relief as a result. Should the "patina aesthetic" be maintained?[11]

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> *"Preservation must evaluate each situation separately on its own decorative merit."*
> —James E. Churchill

as responsible for the green weathering in sheltered areas, laboratory and in-field research discovered nickel hydroxy and hydrated sulfates and nickel oxides are also impacting the rich tapestry of color during atmospheric corrosion. Conservation literature remains sorely lacking on cleaning methods for nickel minerals, namely Bunsenite and Retgersite, but the discovery of Brochantite and Cuprite, common bronze minerals, do open avenues to attempt well-documented methods alongside new alternatives based on the chemistry.

The Future

Preservation must evaluate each situation separately on its own decorative merit. While the "patina aesthetic" was first advanced by the British Man of Letters, John Ruskin, the concept was later codified as age-value by Alois Riegl. By the mid-twentieth century however, Cesare Brandi questioned this now dogmatic approach and suggested more fluid concepts that furthered art and the "oneness of the image."[12] Restoration is not the dirty word it once was. As David W. Look noted, the oxidation of Monel is protective, yet "not attractive, and detracts from the overall appearance"—a far cry from the adjectives to advertise the metal in the early twentieth century.[13] This research offers background and scientific data to consider an alternative treatment for one of the first modern and homegrown North American alloys.

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JOM the magazine

TMS meeting headlines

Meeting dates and locations are current as of August 14.
For the most up-to-date list of TMS-sponsored events, visit www.tms.org/Meetings.

Other Meetings of Note

The 11th International Conference on Molten Slags, Fluxes and Salts (MOLTEN 2021)
February 21–25, 2021
Seoul, South Korea

TMS Materials Innovation Briefings: Focus on Pittsburgh
May 12, 2021
Pittsburgh, Pennsylvania, USA

Solidification Course 2021
May 30–June 4, 2021
Villars-sur-Ollon, Switzerland

The 12th International Conference on Magnesium Alloys and their Applications (Mg 2021)
June 15–18, 2021
Montreal, Canada

The 13th International Conference on the Technology of Plasticity (ICTP 2021)
July 25–30, 2021
Columbus, Ohio, USA

Liquid Metal Processing & Casting Conference (LMPC 2021)
September 19–22, 2021
Philadelphia, Pennsylvania, USA

World Congress on High Entropy Alloys (HEA 2021)
November 14–17, 2021
Charlotte, North Carolina, USA

TMS 2022 Annual Meeting & Exhibition (TMS2022)
February 27–March 3, 2022
Anaheim, California, USA

TMS2021

150th Annual Meeting & Exhibition

March 14–18, 2021
Orlando World Center Marriott
Orlando, Florida, USA
Registration Opens Soon!
www.tms.org/TMS2021

- Book housing at the Orlando World Center Marriott—the convenient, self-contained resort where all TMS 2021 Annual Meeting & Exhibition (TMS2021) technical programming, exhibit hall, committee meetings, and social functions will be located.
- View topic tracks planned for the Fourth Summit on Diversity in the Minerals, Metals, and Materials Professions (DMMM4), co-located with TMS2021. More details on this signature event can be found at www.tms.org/TMS2021/DMMM4.

SUPERALLOYS 2021

September 12–16, 2021
Seven Springs Mountain Resort
Seven Springs, Pennsylvania, USA
Proceedings Are Available Now!
www.tms.org/Superalloys2021

- All accepted manuscripts are published in the *Superalloys 2020* proceedings. The proceedings access will be included in the registration fee.
- Learn about new technologies for lifecycle improvement of superalloys. Explore improvements in the processing and performance of existing materials and the development of new alloys.
- Register today and join the community for the longest-running symposium dedicated to superalloys.

MiNES

MATERIALS IN NUCLEAR ENERGY SYSTEMS

September 19–23, 2021
Pittsburgh, Pennsylvania, USA
Abstract Deadline: April 2, 2021
www.tms.org/MiNES2021

- Materials in Nuclear Energy Systems (MiNES) 2021 will build on its highly successful inaugural 2019 conference to serve as the professional destination for the fission reactor materials community to share the latest research and developments specific to the field.
- Submit your abstract to the following topics: Fundamental Irradiation Damage; Evolution of Material Properties; Integrated Phenomena in Reactor Materials; Advanced/Novel Materials; Fuels and Actinide Materials; and Nuclear Fuel Cycles.

TMS ICME

MANUFACTURING DESIGN MATERIALS

April 18–22, 2021
Lake Tahoe, Nevada, USA
Discount Registration Deadline: March 5, 2021
www.tms.org/ICME2021

- Join your colleagues in submitting an abstract to the 6th World Congress on Integrated Computational Materials Engineering (ICME 2021). This congress convenes leading researchers and practitioners to share the latest knowledge and advances in the discipline.
- Exhibitor and sponsorship opportunities are available! Showcase your products and services among software developers and process engineers along the entire production chain, as well as for materials scientists and engineers developing new materials. Visit the ICME 2021 website to learn more.

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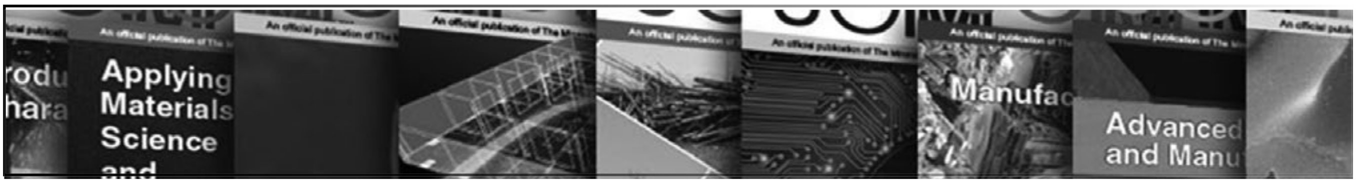
call for papers

JOM is seeking contributions on the following topics for 2021. For the full Editorial Calendar, along with author instructions, visit www.tms.org/EditorialCalendar.



April 2021
Manuscript Deadline: November 1, 2020

Topic: Advances in Process Metallurgy

Scope: Over the past several decades, extensive research and developmental activities have led to the emergence of new methods, processes, and engineering flowsheets in hydro(bio)-, pyro-, and electrometallurgy. Incorporation of new modifications into conventional techniques has shown promise in many metallurgical practices. Authors are requested to contribute manuscripts in the areas of materials electrochemistry, chemical metallurgy of secondary resources and strategic (waste) materials, recovery of critical elements, and separation science and technology.
Editors: Hong (Marco) Peng and Kerstin Forsberg
Sponsor: Hydrometallurgy and Electrometallurgy Committee

Topic: Aluminum and Magnesium Alloys for Automotive Applications

Scope: This topic covers the development of aluminum and magnesium alloys specifically for application in the automotive industry. This may include new alloys designed for engines, enclosures, and structural components of vehicles. Also covered is the adaptation of existing alloys for uses in automotive applications and specialized joining techniques. Papers should contain essentially new scientific and practical data underpinned by advanced characterization and testing and in-depth analysis of the mechanisms. All submissions should be relevant to automotive applications.
Editor: Dmitry Eskin
Sponsor: Aluminum Committee

Topic: Developments in the Production of Magnesium Alloy Flat Products

Scope: Magnesium alloys are considered to be potential candidates for lightweighting in the transportation sector for improved performance and fuel economy. One of the "holy grail" applications is automotive body panels, which require scalable, low-cost, formable sheet production. Substantial research has been conducted in recent decades and this special topic invites the submission of reviews on advances made, as well as on emerging research avenues e.g., friction stir processing, dynamic cutting extrusion, and twin-roll casting.
Editors: Jishnu J. Bhattacharyya and Aeriel Murphy-Leonard
Sponsor: Magnesium Committee

Topic: Materials Recovery Considerations for Design of Next-Generation Functional Materials

Scope: There is an urgent need to find smart practices to enhance the sustainability of energy conversion, storage, and manufacturing practices, such as additive manufacturing and green manufacturing by incorporating novel design. This special topic invites industry leaders, as well as scientists, academics, and students to publish their best practices in industry and frontier research in sustainability.
Editors: Surojit Gupta, Lan (Samantha) Li, and Manoj Kumar Mahapatra
Sponsor: Energy Conversion and Storage Committee

May 2021
Manuscript Deadline: December 1, 2020

Topic: 8th European Conference on Renewable Energy Systems (By Invitation Only)

Scope: This special topic will publish invited papers presented at the 8th European Conference on Renewable Energy Systems. The areas of coverage will include energy materials, optoelectronic materials, semiconducting, compounds, alloys, and composites of potential use in energy applications. In addition, submissions related to synthesis and characterization of materials for energy conversion, solar energy, wind energy, fuel cells, and energy storage materials are included.
Editors: Shadia Ikhmayies and Hilal Kurt
Sponsor: Invited

Topic: Adaptive Metallurgical Processing Technologies for Strategic Metal Recycling

Scope: The demand for strategic metals has enabled many new technologies for recycling of complex materials. In the meantime, traditional metallurgical processes also need to be adapted to address techno-economic barriers. This special topic is open to researchers from both industry and academia in areas of strategic metal recycling. Papers providing perspective on technical challenges or broader materials science challenges toward sustainability are also welcome.

Editor: Mingming Zhang

Sponsor: Recycling and Environmental Technologies Committee

Topic: Microstructure Characterization: Descriptors, Data-Intensive Techniques, and Uncertainty Quantification (By Invitation Only)

Scope: Advancements in computational processing power, instrument and detector capabilities, and multi-scale modeling techniques are generating increasingly large three-dimensional microstructural datasets that have facilitated the discovery of quantitative descriptors linking processing parameters to material properties. This special topic will focus on theoretical and computational developments of novel descriptors to characterize microstructural features. Papers that apply advanced statistical techniques, such as machine learning and uncertainty quantification, for collecting, analyzing, and reconstructing experimental microstructural datasets are also invited.

Editors: Srikanth Patala, Shawn Coleman, Jacob Bair, and Houlong Zhuang

Sponsors: Materials Characterization Committee, Computational Materials Science and Engineering Committee, and ICME Committee

Topic: Thermodynamic Considerations for Improved Renewable Energy Production

Scope: Municipal and industrial wastes are increasingly becoming important sources of renewable energy. However, fouling, slagging, and corrosion associated with the combustion processes of these resources are costly and threaten the long-term operation of power plants. Papers focusing on the thermodynamic modeling of problematic sulfates and chlorides in waste combustion processes are welcome. Research papers on emission control pertaining to the renewable energy industries are considered. Manuscripts intended for a broad readership are especially encouraged.

Editors: Fiseha Tesfaye

Sponsors: Process Technology and Modeling Committee and Recycling and Environmental Technologies Committee

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June 2021
Manuscript Deadline: January 1, 2021

Topic: 100 Years of the Griffith Fracture Criteria (By Invitation Only)

Scope: While today's materials scientists know the impact of the Griffith criteria, many may not be aware of how little effect it initially had on basic and applied research. It was not until the "Space Race" in the 1950s that basic research was able to take advantage of the Griffith methodology and establish the ASTM-E-24 fracture toughness standard. This special topic will showcase the reach of the Griffith fracture criteria throughout the world today.

Editors: Megan Cordill and Jennifer Carter

Sponsors: Nanomechanical Materials Behavior Committee and Mechanical Behavior of Materials Committee

Topic: Multiscale Experiments and Modeling in Biomaterials and Biological Materials

Scope: Manuscripts are solicited in all areas of research that use multiscale experimental or computational methods to explore biological materials (at the molecular, cellular, or tissue levels) and biomaterials (those materials which are designed to mimic or replace biological materials).

Editors: Jing Du, Dinesh Katti, and Hendrik Heinz

Sponsor: Biomaterials Committee

Topic: Processing-Microstructure-Property Relationships in Additive Manufacturing of Ti Alloys

Scope: This topic seeks to highlight recent advances to create a process–microstructure–property knowledge base for additive manufacturing (AM) of titanium (Ti) alloys. We also welcome developments in new feedstock materials (beyond Ti-6Al-4V and Ti-5553) that are better suited to take advantage of AM processes and their parameters, as well as the application of advanced characterization techniques in AM Ti-alloys. Both experimental and modeling submissions are encouraged, especially where modeling or theory is applied and validated experimentally.

Editors: Rongpei Shi, Michael Gram, and Yufeng Zheng

Sponsor: Titanium Committee

Topic: Pyrometallurgical Processing of Secondary Resources

Scope: With the decrease of high-quality primary metal resources around the world, effective processing of secondary resources has become vital. This special topic focuses on pyrometallurgical approaches to the processing of secondary resources. The secondary resources in this context include low-grade ores, urban ores (electronic wastes, battery wastes, photovoltaic materials, and other end-of-life products), industrial byproducts and wastes, construction wastes, medical wastes, and organic resources and wastes.

Editors: M. Akbar Rhamdhani and Stuart Nicol

Sponsor: Pyrometallurgy Committee