JANUARY 2025
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JOM THE MAGAZINE

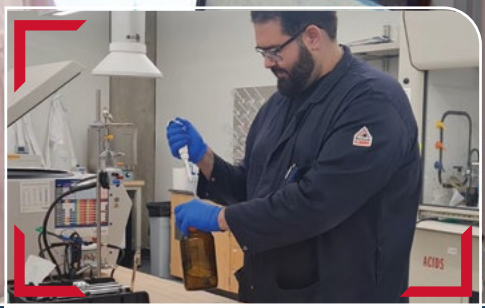
News and insights about TMS, its members, and the professions it serves

MELTING BEFORE OUR EYES: A MATERIALS ART MYSTERY

TMS Springer

Showcase Your Materials Science Passion!

Do you work on an exciting materials science or engineering project? Here's your chance to shine!



What's Happening?

TMS is spotlighting the most captivating video submissions from materials scientists. We want to showcase the incredible work you're doing and highlight the amazing world of materials science!

Why Participate?

- **Gain Exposure:** Your work will be featured across TMS's social media platforms.
- **Inspire Others:** Show how exciting and impactful materials science can be.
- **Get Recognized:** Highlight your achievements and innovations.

How to Participate:

1. **Create a Video** Capture the unique and interesting aspects of your materials science work.
2. **Submit Your Video** Fill out the submission form and send us your video! You do not need to provide a finished video—simply submit your raw footage, and TMS staff will handle the editing.

Tips for Shooting Your Video:

- **Use Your Smartphone:** Most smartphones shoot high-quality footage.
- **Shoot in Portrait Mode:** The portrait aspect ratio is 9:16 (standard Smartphone portrait).
- **Audio is Acceptable:** Feel free to talk about your process and what makes your project special.
- **Do Not Use Zoom:** Keep the focus sharp without zooming.
- **Limit Length:** Keep your video to 30 seconds.
- **Limit File Size:** Keep the file size under 30MB.
- **File Formats:** Submit videos in .MP4 or .MOV format.
- **Be Authentic:** Let your personality and passion shine through!

Submit your video today!

TMS | MEMBER MADE

JOM THE MAGAZINE
News and insights about TMS, its members, and the professions it serves

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// ABOUT THE COVER

Our cover story this month, "Melting Before Our Eyes: A Materials Art Mystery," looks at conservation efforts underway at The Andy Warhol Museum in Pittsburgh, Pennsylvania, to preserve works in Warhol's *Oxidation* painting series. The cover image shows Rikke Foulke (right), associate conservator of paintings at The Warhol, and Travis Olds (left), assistant curator of minerals at The Carnegie Museum of Natural History, examining one of the paintings. Photo by Bryan Conley. Cover designed by David Rasel, TMS Senior Manager, Brand and Digital Assets.

About *JOM: The Magazine*:

This print publication is excerpted from the publication of record, *JOM*, which includes both The Magazine and The Journal sections. *JOM: The Magazine* includes news and insights about TMS, its members, and the professions it serves. To access the publication of record, visit www.tms.org/JOM.

About TMS:

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

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TABLE OF CONTENTS

JOM Volume 77 Number 1 January 2025

FEATURES

DEPARTMENTS

SPECIAL INSERT

Photo: Bryan Conley

JOM: The Magazine, Vol. 77, No. 1, 2025
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IN THE FINAL ANALYSIS

JOM THE MAGAZINE

"Lately it occurs to me, what a long, strange trip it's been."
—"Truckin'," the Grateful Dead

It's a new year, so this first editorial of 2025 appropriately consists of a reflection, and that reflection is premised on a declaration and a confession. . . . Don't worry, this column is not as pompous or as dreary as that opening sentence portends. For proof, the next paragraph is about high-life counterculture touchstones, the Grateful Dead.

Intrigued? Okay, here's the promised declaration: The Grateful Dead get my vote as the world's all-time most overrated classic "rock" band. Not that Deadheads care, but my enjoyment of the Dead's endless jamming and psychedelia is nil. Now for the confession: While I have no Grateful Dead tunes in my playlists and none of their albums on my shelves, I think often of the "long strange trip" lyric. Rightfully, it has become a modern aphorism that is endlessly applicable to countless how-did-I-get-here situations.

Speaking of how did we get here, we've effectively reached the five-year anniversary of the pandemic. Has there been a longer, stranger trip than this half-decade? Not in my 40 years of TMS experience. With a fair amount of meticulousness and frankness over those years, I've used this column to comment on how the pandemic affected TMS. There was candor on the difficulties of virtualizing meetings. I grumped about the inflexibility of contract-holding hotels being unwilling to acknowledge that the pandemic made it impossible for us to conduct events as travelers could not travel. I whined about hotel attrition (the penalty for not satisfying sleeping room commitments). I reflected on the Great Resignation as so many organizations, including TMS, lost staff to the hiring boom that followed the pandemic shutdowns. I worried about the glacial recovery in TMS business models as a wary professional community started to—slowly, slowly—re-embrace in-person event attendance. I especially lamented the financial challenges faced and addressed by the Society, particularly in 2022 and 2023 when operating expenses exceeded operating revenues by roughly $2 million and $200,000, respectively. Such levels of red ink were an unknown frontier for the Society, and we took many actions, some quite difficult, to return to black-ink operation.

Several readers told me that they appreciated me pulling back the curtain on the TMS business enterprise. No problem. Members literally own the Society, so reflecting on the good and the bad is necessary transparency in my opinion. Plus, as I was obsessed with addressing these issues, the writing came easily and may have been therapeutic. Will I continue to pull back the curtain with these editorials? Sure; disclosure is in my grain structure.

While I generally prefer to write about things other than money, I can't quite avoid it this month as I have financial news to report. It's good.

I write this column two months before the close of our 2024 operating year. So, our results are not completely finalized, but 2024 is projecting to go into the books as a year with a surplus rather than a deficit. The surplus should be around 1%, which is our goal by Society policy when building a budget. That is a celebratory differential after the long, strange years since 2019 and the negative net revenue years of 2022 and 2023. Our return to surplus operation during 2024 should not be a one off as our 2025 operating budget is built to deliver similar returns. That's the kind of performance that TMS demonstrated year over year before the pandemic, and I believe that we are firmly reestablishing our traditional virtuous cycle of ongoing non-deficit operation.

That is a long and far-from-strange trip that I am eager to continue helping members, volunteers, staff, and the greater materials community take together.

James J. Robinson
Executive Director

James Robinson

"While I generally prefer to write about things other than money, I can't quite avoid it this month as I have financial news to report. It's good."

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JOM TECHNICAL TOPICS

JOM THE MAGAZINE

Find peer-reviewed technical articles covering the full range of minerals, metals, and materials science and engineering in the January issue of *JOM:* The Journal. Each issue features several technical topics presenting a series of related articles compiled by guest editors. A preview of January technical topics and articles are listed below. TMS members can log in to www.tms.org/Journals for full access to technical articles from *JOM:* The Journal and additional TMS journals.

Below is a sample of articles that will appear in the January issue, based on information available at press time. For the most up-to-date article listing, visit www.tms.org/JOM.

// JANUARY 2025

Applications of Machine Learning in Materials Development and Manufacturing

Editor: **Victoria Miller,** University of Florida

"Materials Informatics Driven Designing Mg Alloys for Biodegradable Short-Term Implants Using Machine Learning," **Rahul Mukherjee,** et al.

"Prediction Model of Material Dynamic Mechanical Properties Embedded with Physical Mechanism Neural Network," **Houchao Wang,** et al.

"Prediction of Copper Matte Grade Based on DN-GAN Stacking Algorithm," **Tiangui Li,** et al.

"Study on High-Performance Gear Fatigue Life Prediction Method Based on Deep Learning Theories," **Xingbin Chen,** et al.

"Modeling and Prediction Method for Young's Moduli of Ti Alloys based on Residual Muti-layer Perceptron," **Hua Yan,** et al.

"Flexible Cooling Strategy for Hot-Rolled Steel Based on Physical Theories Coupled with Machine Learning," **Yang Cao,** et al.

"A Review on the Application of Superalloys Composition, Microstructure, Processing, and Performance via Machine Learning," **Junhui Zhang,** et al.

Cutting Edge In Situ Characterization Techniques

Editors: **Zhiwei Peng,** Central South University; **Jian Li,** CanmetMATERIALS

"Production and Properties of Novel CrB_2 Reinforced Copper Matrix Composites by In Situ Processing," **Alina Igorevna Trunova,** et al.

"Preheating Characteristics of Magnetite Pellets Under Microwave Irradiation," **Ran Tian,** et al.

"Exploring Mechanism of H_2 Adsorption on Surfaces of Iron Oxides by Density Functional Theory Calculation," **Jianzhi Zhang,** et al.

Contribute Your Work

View the *JOM* Editorial Calendar to see upcoming topics and learn how to submit your own article for *JOM*: The Journal. Visit **www.tms.org/EditorialCalendar.**

View More Technical Articles

JOM regularly publishes additional articles that fit within the scope of the journal, but not within the scope of a particular technical topic. Read these in the "Technical Articles" section of *JOM* on Springer.

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NAVIGATE YOUR TMS MEMBERSHIP WITH NEW VIDEO ORIENTATION SERIES

Kelly Zappas

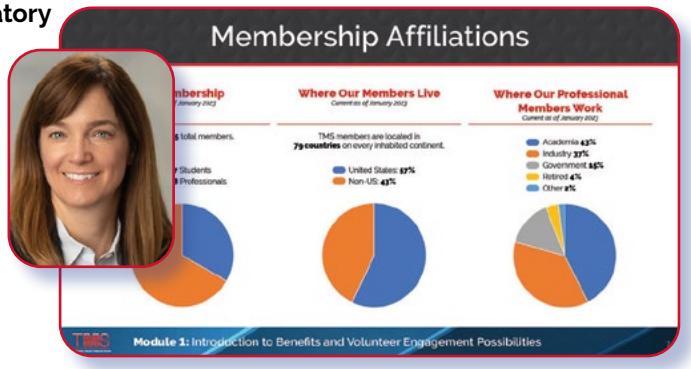
What's your professional new year's resolution? To advance your career? To give back to your profession? To put your Society membership to good use? Whatever your professional goals are for the year ahead, TMS can help—and a new resource is now available to get you started.

The **Navigating Your TMS Membership** video series shows new and existing members how to use their memberships for maximum, long-term impact on their careers. The series consists of six video modules (approximately ten minutes each) that can be watched individually (to help you learn about a particular aspect of the Society) or all together (to gain a comprehensive understanding of all your TMS membership options). Presented here is a sample of what you can expect from the series and a few key tips drawn from the presentations.

Module 1: Introduction to Benefits and Volunteer Engagement Possibilities

Presented by Ellen Cerreta, Los Alamos National Laboratory

"I personally have enjoyed the benefits of membership, and I am eager to share that with you," says Cerreta, a former president of the Society and a TMS member for almost 30 years, in this introductory module. Ideal for someone new to TMS, this video provides a big-picture view of the Society—what it stands for, how it accomplishes its mission, and how individual members contribute to the organization's work. It also previews the broad range of benefits and opportunities available to members.



Module 2: TMS Conferences and Meetings

Presented by Alexandra (Allie) Anderson, RHI Magnesita

This module breaks down the different types of conference experiences offered by TMS and offers advice for making the most of these events. She offers a number of tips for anyone attending the TMS Annual Meeting or Materials Science & Technology conference, including this one: "Make a plan. I always download the conference app prior to my arrival. This allows me to build a personalized schedule with the technical sessions and social events I want to make sure I attend."

Module 3: TMS Technical Committees and Divisions

Presented by Paul Mason, Thermo-Calc Software Inc.

"The best way to get involved as a volunteer within TMS is to start with the technical committee that is most aligned with your interests," said Mason, who introduces the Society's 35 technical committees (housed within five technical divisions) and describes how and why to join them. "Many members who have joined committees have made and retained lifelong, beneficial professional relationships and friendships by working with committee members and attending meetings for years or even decades."

Module 4: TMS Functional Committees

Presented by Jonathan Madison

"TMS Functional Committees are organizational units within TMS's infrastructure that address issues that have an impact on our professional life as well as the future of our field and the future of TMS." Madison introduces the concept of TMS Functional Committees, before describing how to join one, focusing on three specific committees that are open to all TMS members. "If you want to become involved in a TMS Functional Committee that is *not* open, have a conversation with the chair, the co-chair, or the staff liaison and they may be able to advise you on when an opportunity may be available," he counsels.

Module 5: Pathways to Volunteer Leadership Positions

Presented by Christina Meskers, SINTEF

"There are lots of opportunities within TMS to take on a volunteer role," Meskers says, explaining how, once you get involved, you can progress through the leadership ranks at TMS. She identifies two main paths that members typically follow to serving on the TMS Board of Directors: by becoming a technical division chair or by becoming the chair of a Board-level Functional Committee. However, she says, it's not an either-or approach. "Many people have served on functional committees as well as technical committees and used the different opportunities that these committees provide to serve TMS as a Society and to develop themselves."

Module 6: Publications

Presented by Tresa Pollock, University of California, Santa Barbara

Pollock introduces the six journals published by TMS, which all members receive access to as part of their memberships, as well as proceedings, studies, and online libraries offered by the Society. (She recommends the TMS Member Library, which, she says, has been a beneficial resource for her own research.) In addition to providing instructions for accessing these publications, she shares information on how to submit articles and become involved in editorial roles.

Watch Now

Take the time this month to learn more about how your Society works and how you can make the most of your TMS membership. View the whole series in order or select the topics of most interest to you. Set aside approximately ten minutes to watch each video.

www.tms.org/NavigatingYourTMSMembership

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TMS Members Gain Valuable Experience at 2024 Emerging Leaders Alliance Program

Kaitlin Calva

Five TMS members took the opportunity to develop their leadership styles and hone their managerial skills at the Emerging Leaders Alliance (ELA) Conference, September 22–25, in Pittsburgh, Pennsylvania. TMS is one of seven partner societies sponsoring this unique program for the science and engineering community. Registration for up to seven individuals each year is supported by the TMS Foundation.

The curriculum allows early-career professionals to strengthen their nontechnical skills in a setting that allows them to interact across disciplines and obtain foundational, executive-level knowledge. Furthermore, the ELA program gives attendees access to training modules and experiences that their employers might not have the resources to provide.

The event kicked off with a networking reception and followed with three days of presentations and working groups led by a team of experts. Sessions covered a variety of topics, ranging from conflict resolution to negotiation to collaboration. "The conference was phenomenal," said one attendee in a post-event survey. "I felt that every session was extremely tailored to my experience, and it was a fantastic opportunity to meet like-minded engineers."

Pictured are the ELA participants from TMS, from left to right: **Deborah Hixon**, TMS; **Matthew Dantin**, Naval Surface Warfare Center; **Irina Iachina**, Massachusetts Institute of Technology/ University of Southern Denmark; **Alexander Cruz**, Baker Hughes; **Kyle Schneider**, Core Power Magnetics; and **Brianna Musico**, Los Alamos National Laboratory.

The ELA strives to equip the next generation of leaders in the scientific and engineering fields with the skills they need to tackle current and future challenges facing mankind, and the interactive nature of the program is an essential piece of the puzzle. "I liked the networking opportunities and small group work. It helped to put what we just heard into practice," one attendee commented. Another colleague agreed, mentioning that while they liked the presentations and their content, they "especially liked the engagement and activities."

Those who are interested in participating in the next ELA conference, scheduled for September 15–17, 2025, in Pittsburgh, Pennsylvania, can now apply for a seat through TMS. Applicants must be TMS members, typically between ages 25–40, with rising or current leadership positions within their organizations. Interested members should send a letter of interest, one or two letters of recommendation, and a resume or curriculum vitae to Deborah Hixon, TMS Awards Program Manager, at **hixon@tms.org**. The deadline to apply is **May 15, 2025**.

More established TMS members can support future leaders of the professions by donating to the TMS Foundation, which funds the ELA program and other initiatives for students and early-career professionals. Visit **www.TMSFoundation.org** to learn more and make a donation.

Kaitlin Calva is an independent contributor and past Editor of *JOM: The Magazine*.

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JOM Talks with IRINA IACHINA of Biomimica

Irina Iachina is the chief executive officer and co-founder of Biomimica, a company founded in 2022 that is working to replace environmentally harmful materials in clothing and other applications with artificial spider silk. Iachina was one of five early-career professionals selected by TMS to participate in the Emerging Leaders Alliance Conference in Pittsburgh, Pennsylvania, in September 2024. (You can learn more about this program in the article "TMS Members Gain Valuable Experience at 2024 Emerging Leaders Alliance Program" in this January issue of *JOM*.) She is also a postdoc fellow at the Massachusetts Institute of Technology and a member of the TMS Biomaterials Committee.

JOM: Could you provide a brief description of your company?

Iachina: Biomimica is a company on a mission to revolutionize traditional environmentally harmful materials through the development of artificial spider silk: an eco-friendly super-material designed to disrupt multiple industries while accelerating our journey to a sustainable future. Our proprietary spinning platform mimics a spider's natural silk production processes, allowing us to create game-changing materials that not only set new industry standards but also contribute meaningfully to a healthier planet. At Biomimica, we aim to not only redefine industry standards but also to make a significant contribution to environmental sustainability.

JOM: When did you first start studying spider silk?

Iachina: My journey with spider silk began in 2016, when I was searching for a topic for my master's thesis. While watching a show on the Discovery Channel called *Bug Wars,* I was fascinated by how spiders used their silk to capture prey and construct intricate structures. This incredible material piqued my interest, and I approached a professor at the University of Southern Denmark to propose a master's project focused on characterizing spider silk.

This lab set-up shows the production of artificial spider silk at Biomimica.

This article is part of a *JOM* interview series featuring industry leaders and start-up founders discussing new developments and current issues in their fields. To suggest a candidate for a future issue, contact Kelly Zappas, *JOM: The Magazine* editor, at kzappas@tms.org.

Throughout that project, I came to realize that spider silk is incredibly tough, elastic, and environmentally friendly. Motivated by the potential of this material, I pursued a PhD on the development of artificial spider silk.

JOM: Why did you decide to start your own company?

Iachina: A key driver in my work has always been the belief that my research could have a meaningful, positive impact on the world. To bring this research beyond the lab and into everyday life, I founded Biomimica with the vision of creating sustainable solutions for a better future.

JOM: What are some of the potential applications for your technology?

Iachina: Just as a spider produces various types of silk for different purposes, our artificial spider silk holds nearly limitless potential for future applications. Currently, we are focused on replacing the quite harmful plastic-based textile materials like elastane and polyester, as the clothing industry faces increasing pressure from both consumers and legislation to adopt more sustainable alternatives.

Looking ahead, the versatility of artificial spider silk extends beyond textiles, with promising uses in industries such as transportation, packaging, and even medicine. Our mission is to harness this extraordinary material to drive greener, more innovative solutions across a wide range of sectors.

JOM: How is Biomimica's product more environmentally friendly than alternatives?

Iachina: Biomimica's artificial spider silk is an environmentally friendly material because it's made entirely from proteins at room temperature and is fully biocompatible. In contrast, the textile industry heavily relies on plastic-based fabrics like polyester and elastane, which are responsible for over a third of all microplastics released into the environment.

What sets our material apart is its ability to serve as a sustainable alternative to elastic fibers like elastane. Current environmentally friendly fiber alternatives are not able to provide the comfort that elastic materials such as elastane provide. By producing high-performance, elastic spider silk fibers, the customer won't have to compromise on comfort, while we can help significantly reduce the release of microplastics and offer a greener solution for the textile industry.

JOM: Can you describe the current phase of your company's development?

Iachina: We are currently at a technological readiness level (TRL) 3, meaning we have an experimental proof of concept and can produce silk in small quantities in a lab. With more funding, we would be able to advance our TRL by hiring more people and moving out of the university lab.

JOM: What challenges have you faced in creating a start-up company?

Iachina: One of the key challenges we've faced is transitioning from a university-based research project to a commercial business. This shift required us to expand our mindset, particularly when seeking funding. While we had experience with research grants, it didn't easily translate to pitching to investors.

Another challenge has been securing direct funding for the company outside of the university framework. Our TRL is often considered too low for traditional investors, and at the same time, research funding tends to be a slow process, delaying our technological development.

What has kept us motivated throughout these challenges is our belief that our product has the potential to change the world

JOM: What's next for Biomimica?

Iachina: The next step for Biomimica is to secure funding to scale up our silk fiber production, allowing us to begin delivering our silk fibers to potential customers within the next year. In parallel, we are also expanding our research to explore how artificial spider silk can replace common plastic materials across industries, moving beyond just clothing.

JOM: Is there anything you'd like to add?

Iachina: To me, it is fascinating how nature has developed exceptional materials with properties that we seek in modern society. At Biomimica, we believe the future of materials must be inspired by or mimic nature, paving the way for sustainable innovation.

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Table of Contents

Above: Andy Warhol, *Oxidation*, 1978, © The Andy Warhol Foundation for the Visual Arts, Inc.

MELTING BEFORE OUR EYES: A MATERIALS ART MYSTERY

Kaitlin Calva

When you think of drip-style paintings or abstract expressionism, Andy Warhol is probably not the first name that comes to mind. Known better as a leader in the American Pop Art movement of the 1960s, the artist experimented with more abstract techniques in the last decade of his life. Far from the bright, glamorous, and often gimmicky portrayals of his commercial work and silkscreen prints, his foray into abstraction was much more methodical than the emotional, spontaneous techniques of contemporaries like Jackson Pollock. One of his first abstract works is *Oxidation*, a series of nearly 100 paintings created from 1977 to 1978. The largest canvas from this collection (pictured above), measuring 50 inches high by 200 inches wide, brings *JOM* into the intersection of science and art with a fascinating materials mystery.

WHAT HAPPENED: A PERFECT STORM

First, there was the June heat in Pittsburgh, Pennsylvania, home of The Andy Warhol Museum. Then, there was the reduced onsite staff due to COVID-19 restrictions. And finally, a short, albeit significant, failure in the museum's heating, ventilation, and air conditioning (HVAC) system. The combination led to the unthinkable: tiny puddles were discovered on the floor beneath the largest of the *Oxidation* canvases one week after the initial power outage. After ruling out other possible explanations, such as a leak, staff determined the puddles were from the painting. This unparalleled artwork seemed to be *melting*.

The culprit? Warhol himself—or, more appropriately, his choice of materials. With funding from a Bank of America Art Conservation Grant, associate conservator of paintings at The Warhol Rikke Foulke got to work finding out what happened to Andy Warhol's *Oxidation*.

Andy Warhol, *Oxidation* (detail), 1978, © The Andy Warhol Foundation for the Visual Arts, Inc.

TAKING A STEP BACK: THE CREATION OF OXIDATION

In order to understand why this work of art dripped in the wake of temperature fluctuations within the gallery, one must understand how it was created. It should be simple . . . pigments painted onto a canvas, right?

Not quite. There is so much more to the materials Warhol used than meets the eye, and so much more to investigate than pigment and canvas. Every scientist knows that the key to understanding an unexpected outcome often lies beneath the surface, within the characterization of the minerals and materials.

In December 1977, Warhol started his *Oxidation* series by fabricating his own paint using flaked brass and acrylic medium. Next, rabbit skin glue (RSG) was used during a process called sizing, by which a sealant is applied to tighten and stiffen cotton and linen fabrics. "Canvas needs to be sealed from the effects of the drying oils in oil paint and oil grounds because over time the oil will degrade the cloth fibres causing the canvas to darken and become brittle," according to art supplier Jackson's Art.[1] As a sealant, the RSG, made by rendering animal gelatine, can also help "prevent moisture from drawing up colour, acids, glues, etc. from the wood into . . . gesso."[1]

Subsequently, layers of an alkyd-based gesso were applied on top of the RSG sizing. In contrast to water-based paints like acrylic or latex, alkyds are made from polyhydric alcohol and polybasic acid, according to specialty raw materials supplier Van Horn, Metz & Co., and "modified by adding drying oils or fatty acids to the reaction mixture, which increases flexibility . . . and makes them a desired ingredient in coatings."[2] In the case of O*xidation*, titanium white pigment was used to achieve a brighter white gesso. Finally, the canvases were painted with Warhol's metallic mixture.

Pictured here are sample materials used by The Andy Warhol Museum staff to create mock-ups of *Oxidation* for testing. The container on the left of the image contains Venus Bronze Powder Pale Gold No. 13, one of several metallic powders Warhol would have used in creating his *Oxidation* paintings. (Photo: Bryan Conley)

Always one to push the envelope, Warhol then achieved the abstract splatter effect by adding urine to the canvases while the paint was still wet, juxtaposing the shimmering, rich copper-toned background with the cooler blotches of oxidized browns, blacks, and greens in the forefront. While Warhol's efforts resulted in seemingly random stains and patterns, his methodologies were anything but. "Creating paintings through chemical reactions takes dedicated study, intentionality, and experimentation," noted a *Carnegie Magazine* article on The Warhol's *Altered States* exhibit.[3] "Warhol took great care when creating the *Oxidation* paintings."[3]

In addition to the wall-sized *Oxidation* painting, The Andy Warhol Museum houses several smaller paintings from the same series, as shown here. And yet, when a power outage in June 2020 caused a temporary failure in the museum's HVAC system, only the largest canvas was damaged. "The other works are on a smaller scale and were framed years ago within climate control parcels to reduce the risk of change to fluctuations in temperature and humidity," explained Rikke Foulke, associate conservator of paintings at The Andy Warhol Museum. "The largest canvas measures 50" high by 200" wide and is too large to outfit with a climate-controlled system, therefore it was, and still is, susceptible to fluctuations in the environment." (Photo credit: The Andy Warhol Museum, Pittsburgh, 2023. Photo: Bryan Conley)

THE SCIENCE OF ART: WHY DID IT DRIP?

With a more comprehensive awareness of the organic and inorganic materials used in the artwork, the next piece in the puzzle meant reconstructing the art. Distinct from reproducing exact copies through Xerox or silkscreen, as Warhol was so fond of, this step involved creating new pieces to undergo testing and analysis. Fortunately, the vast archives of The Andy Warhol Museum include detailed notes, materials, and other records that aided in this step: "museum staff procured vintage metal powders identical to the originals in golden and copper-toned alloys and acrylic medium of the same manufacturer to replicate paint that Warhol would have used . . . in the late 1970s."[4] New canvases were painted, leaving one final step before the mock-ups could be truly considered accurate. "Preparation of the urine also followed Factory protocol by consuming Vitamin B, and it was applied to the mock-up canvas with a dropper."[4] The chemical reactions that occurred on the mock-ups, which were recorded in a time-lapse video available to watch on the museum website, shows what would have happened with the original art in 1978.

Mock-ups and small samples from the original canvas were then shared with two groups in the Pittsburgh area: the Carnegie Museum of Natural History, which has assisted The Warhol with previous art conservation projects, and the RJ Lee Group, an industrial forensics lab with expertise in scientific analysis and materials characterization. To properly analyze cross-sections of canvas, these investigative partners used SEM techniques to determine the characterization of the paint and accelerated aging processes to recreate atmospheric conditions of the gallery to better understand how aging affected the original works and how the HVAC failure contributed to the changes.

After months of research and testing, Foulke and the team working on this project finally had clarity. "Passages of corrosion we see on the *Oxidation* paintings are essentially the urine interacting with copper to make a complicated mixture of copper salts. These salts absorb water at different values of relative humidity until they soften and become a supersaturated solution in water," explained Foulke. The salt solution further interacts with the copper in the paints and other materials that Warhol used when they encounter one another. "Excess moisture carried in the supersaturated salt solution will reverse once the humidity returns to normal, which is then manifested by dripping. Again, salt mixtures release

Foulke creates a sample oxidation work for future testing. (Photo: Bryan Conley)

excess water at different points," she reiterated, "so the reaction may take some time to reverse."

The changes that occurred in 2020 were not limited to dripping; some areas of corrosion also changed in color. For this reaction, Foulke noted, "no pure materials could be identified in the complex mixtures of copper salts, despite our best efforts to identify verdigris or malachite." Historically, urine was considered "liquid gold" for a number of uses, including dyeing textiles.[5] Urine develops into ammonia when aged, acting as a mordant, "wrapping and binding dye molecules to cloth."[5] Foulke mentioned that recipes for such pigments date back to the first century A.D., when Pliny the Elder of the Roman Empire recorded them in his text, *Natural History*.

"The main goal of the conservation grant was to understand the cause of the *Oxidation* paintings dripping and ensure that it would not happen again," Foulke explained. With the former goal accomplished, The Warhol staff set out to achieve the latter. "Once the role of salt deliquescence was understood to be responsible for the change, minimal conservation measures were undertaken," she said.

One factor that played a role in determining exactly how to proceed with those measures was dust, as well as how much and where it had accumulated on the canvas. "The collection of dust in highly textured corrosion areas were hygroscopic, which means they can keep moisture in contact with the surface of a work of art for a longer period than an area free of dust." The dust-free sections were, as expected, easier to take care of. A simple dusting with a light brush guided the dust into a vacuum nozzle. For the areas with heavier dust accumulation, cleaning and conservation were more delicate processes. Foulke detailed the activity: "the painting was lightly dusted using the combination of a feather, held at a distance from the paint surface and 'fluttered' to disturb loose dust particles while the nozzle of a HEPA filter vacuum collected particles freed from the surface."

Here, Foulke can be seen taking a sample from the *Oxidation* painting to send to a lab for testing. (Photo: Bryan Conley)

Foulke visited with staff at the RJ Lee Group in August 2023 to drop off canvas samples as well as samples pulled from the original *Oxidation* painting. (Photo: Bryan Conley)

The innate uniqueness of Warhol's materials and methods with *Oxidation* are exactly why it posed such a challenge—there is nothing else like it. Chemical reactions of water, salt water, air, and even urine have been studied in relation to brass or bronze artifacts. "Although scientific articles address the corrosion of metals in moist atmospheres, there is no literature on the use of urine on canvas paintings made with copper alloys," Foulke said. "It took considerable effort to understand the chemistry and mechanics that were taking place on the surface of these *Oxidation* paintings."

CONSERVATION: WHAT'S NEXT FOR *OXIDATION*?

The journey that *Oxidation* has taken Foulke and her colleagues on has led to one very important conclusion. "The research confirmed for us the importance of rigid controls in the climate system for The Andy Warhol Museum to preserve the collection," Foulke commented. "The nature of the modern works in our collection, beyond the *Oxidation* paintings, are too sensitive to withstand relaxed standards."

The next dilemma for *Oxidation* is more philosophical than scientific. All materials degrade over time, but how much change is tolerable among priceless works of art? "A conservator's goal is to preserve the integrity and materials of an artist," said Foulke. Warhol himself noticed a change in *Oxidation* when the series first debuted at the Paris Art Fair FIAC in 1978. In an interview with art critic Benjamin H.D. Buchloh, Warhol shared his reaction to the chemical development: "Well, when I showed them in Paris, the hot lights made them melt again; it's very weird when they drip down. They looked like real drippy paintings; they never stopped dripping because the lights were so hot."[6]

"In one respect, we take into consideration how the artist reacted to the changes and can accept the changes to a certain point, as he did," Foulke reflected. Instead of speculating about the artist's

The image above shows the effect that a supersaturated salt solution had on a mock-up canvas, created by The Andy Warhol Museum staff, over the course of three days. It is a good predictor of what could happen to the original *Oxidation* painting if left untouched and exposed to climate fluctuations within the gallery. (Photo: Bryan Conley)

original intentions, Foulke turned to some concerning results of a time-lapse study performed on mock-up canvases exposed to salt solutions. "Our colleagues at the RJ Lee Group . . . found that the corrosion pattern eventually disappeared completely and even resulted in holes in the canvas. We have a responsibility to preserve the integrity of the collection," she asserted. "We could not risk letting these paintings continue to change at the rate they did in one week or the narrative we would be telling would be different than the story Warhol was trying to tell."

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Kaitlin Calva is an independent contributor and a former Editor of *JOM: The Magazine*.

For a closer look at the chemical reactions that changed the surface of the *Oxidation* painting, view the time-lapse video on The Andy Warhol Museum's website at **www.warhol.org/conservation/oxidation-paintings/.**

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From Discussions to Decisions: An Overview of TMS Events at MS&T24

Megan Enright and Kelly Zappas

Technical Meeting and Exhibition
MS&T24
MATERIALS SCIENCE & TECHNOLOGY

The TMS Fall Meeting held at the Materials Science & Technology 2024 (MS&T24) Technical Meeting and Exhibition took place from October 6–9, 2024, in Pittsburgh, Pennsylvania. More than 2,900 scientists, engineers, and students met to explore and present robust programming, connect at networking and social events, and take part in professional development events.

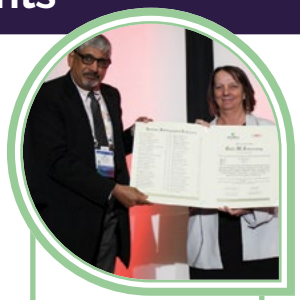
Join us as we dive into standout moments from MS&T24 in this article.

Technical Program Highlights

MS&T24 featured technical programming by TMS, the American Ceramic Society (ACerS), and the Association for Iron & Steel Technology (AIST). The Society for Biomaterials returned to MS&T24 as a co-sponsor and presented several symposia as part of the meeting's technical program.

Over four days, technical presentations were given in 91 symposia divided into 14 technical tracks. TMS technical committees organized 38 of those symposia in areas of interest to TMS members.

John Carpenter, Los Alamos National Laboratory, and **Eric Lass,** University of Tennessee, Knoxville, served as the chairs and the TMS representatives on the MS&T24 Program Coordinating Committee.



Julie Schoenung (right) accepts the TMS/ASM Distinguished Lectureship in Materials and Society award from 2024 TMS President Srini Chada (left) at the TMS plenary session at MS&T24.

Plenary Session

As the recipient of the TMS/ASM Distinguished Lectureship in Materials and Society award, **Julie M. Schoenung** delivered the TMS plenary talk at MS&T, "Saving the Planet through Sustainability-Informed Selection, Design and Discovery of Materials." Schoenung is professor and holder of the Wofford Cain Chair III, Department of Materials Science & Engineering and J. Mike Walker '66 Department of Mechanical Engineering at Texas A&M University. In her talk, she challenged audience members to engage in the conversation of how we advance materials selection, design, discovery, and development from a sustainability perspective.

"What we do as materials scientists is essential and critical to society and advancement of technology," Schoenung said. She described materials selection and discovery as a multi-attribute decision process, often driven by both performance goals and economics.

So, how do we bring sustainability into this process? Schoenung suggested reimagining the materials tetrahedron (processing/structure/properties/performance), to add sustainability as a fifth dimension, making it a pyramid where sustainability reaches all of the other points of the pyramid.

We need to focus on sustainability, she said, because sometimes our materials selections lead to unintended consequences. She pointed to lithium batteries (which are hazardous and flammable), lead-acid batteries (which have high recycling rates but contain toxic lead), and wind turbines (which provide clean energy but are hard to dispose of at end-of-life) as examples. Her talk looked at attributes of interest (energy, circularity, and toxicity), data sources to help quantify those attributes, and methods that can be used to assess tradeoffs.

The goal, she said, is not to stop doing what we do as materials scientists, but to do it in a way that's informed about some of the unintended consequences of the decisions we make.

Honoring Brian Gleeson

The TMS Corrosion and Environmental Effects Committee, the TMS High Temperature Alloys Committee, and the TMS Alloy Phases Committee sponsored **Advances in High-Temperature Oxidation and Degradation of Materials for Harsh Environments: A SMD and FMD Symposium Honoring Brian Gleeson**. This symposium recognized the exceptional quality of research and mentorship Brian Gleeson has demonstrated throughout his career while covering all aspects of the high-temperature corrosion process in which Gleeson has been a leader.

A variety of keynote, invited, and contributed talks were presented on the fundamentals of oxidation and materials degradation; alloy development and high-temperature oxidation; materials design and deposition-induced degradation and complex environment; and interface, coating, and properties for high-temperature performance during this symposium.

Gerald Meier, University of Pittsburgh, delivers his talk, "50+ Years of High-Temperature Corrosion at Pitt-MEMS," to open this symposium.

Grace de Leon, GE Vernova- Advanced Research Center, presents her talk, "High-Temperature Oxidation Behavior of Dissimilar Metal Weld Joins for Steam Power Applications."

Organizers and speakers pose with Brian Gleeson. From left to right: **Bruce Pint**, Oak Ridge National Laboratory; **Kinga Unocic**, North Carolina State University; **Elizabeth Opila**, University of Virginia, **Brian Gleeson**, University of Pittsburgh; **Wei Xiong**, University of Pittsburgh; **Richard Oleksak**, National Energy Technology Laboratory; **David Young**, University of New South Wales; **Rishi Pillai**, Oak Ridge National Laboratory; and **Borys Sereda**, DSTU.

View Photos from MS&T24

See photos from these events and more at **www.flicker.com/photos/tmsevents**.

A Sampling of TMS Programming at MS&T24

The sessions at MS&T24 covered a broad range of topics, from additive manufacturing and artificial intelligence to fundamentals and characterization. TMS collaborated with AIST in presenting iron and steel-related programming and with ACerS on a variety of topics including materials in extreme environments, biomaterials, and materials and systems for a hydrogen economy. TMS also sponsored many wholly-owned symposia, including nine on additive manufacturing topics, four on lightweight alloys, and a session on manufacturing challenges in electric vehicles. Below is a sampling of the conversations that took place in the TMS Fall Meeting session rooms at MS&T24.

Symposium: *High Entropy Materials: Concentrated Solid Solutions, Intermetallics, Ceramics, Functional Materials, and Beyond V*: **Dan Miracle,** Air Force Research Laboratory opened this symposium by discussing the urgency of moving the field of high-entropy alloys (HEA) forward. "A technology does not live forever," he cautioned. "If it doesn't move forward, the community moves on." He urged listeners to find a compelling application for HEAs and suggested that autonomous R&D and high-entropy alloys could be brought together to be "the next big thing."

Symposium: *Computational Materials for Qualification and Certification*: This session opened with an introduction by **Edward Glaessgen,** NASA Langley Research Center, to the Computational Materials for Qualification and Certification (CM4QC) steering group and its community vision roadmap. It was followed by a talk from **Derrick Lamm,** Lockheed Martin Corporate, on industry's vision for using CM4QC tools. "The vision for the future is one of testing analysis at every stage of the design process," said Lamm. **Lyle Levine**, National Institute of Standards and Technology, then talked about transitioning from basic research to industrial applications for metal additive manufacturing components, focusing on the importance of verification, validation, and uncertainty quantification.

Symposium: *Application of ICME Methods to Advance Sustainable Metallurgy and Metals Processing*: This symposium featured a joint session on Steels for Sustainable Development & Application of ICME Methods to Advance Sustainable Metallurgy and Metals Processing. In the talk "Pathways for Decarbonizing Steel," **Sridhar Seetharaman** of Arizona State University looked at the question of how iron and steel can decarbonize its production process while still remaining competitive with materials like aluminum. This joint session also looked at green ironmaking techniques, innovative processing methods for primary and secondary raw materials, and related topics.

In Memory of Mats Hillert

"We've lost a giant in this field," said John Agren, Royal Institute of Technology, during his keynote presentation for Austenite Formation and Decomposition V: A Symposium in Memory of Prof. Mats Hillert. His talk, "Mats Hillert's View on the State of Migrating Phase Interfaces," provided an overview of Hillert's accomplishments and his major contributions to phase transformations and the thermodynamics of materials and processing. In addition to his extensive research record, Agren also offered stories of his experience working with Hillert, including late-night phone calls discussing research topics.

This symposium took place over the course of three days and was sponsored by the AIST Metallurgy—Processing, Products and Applications Technology Committee; the TMS Steels Committee; and the TMS Phase Transformations Committee.

John Agren, Royal Institute of Technology, gives the keynote talk, "Mats Hillert's View on the State of Migrating Phase Interfaces."

Attendees gather for Austenite Formation and Decomposition V: A Symposium in Memory of Prof. Mats Hillert.

Professional Development Events

Sunday Workshops

On Sunday morning, attendees gathered for the Metal Additive Manufacturing Processes Workshop. Taught by **Joy Gockel**, Colorado School of Mines; **Sneha P. Narra**, Carnegie Mellon University; and **Kirk Rogers**, The Barnes Global Advisors, this course covered key metal additive manufacturing (AM) processes and their industrial applications. Attendees also discussed the AM technology landscape, fusion-based AM processes, emerging solid-state processes, and more.

Joy Gockel, Colorado School of Mines, instructs attendees at the Metal Additive Manufacturing Processes Workshop.

Emma White, DECHEMA Forschungsinstitut, leads discussions during the Powder Materials for Additive Manufacturing and Beyond course.

Sunday afternoon featured the Powder Materials for Additive Manufacturing and Beyond: Powder Properties and Handling to Improve Part Quality and Overall Safety course. Led by **Iver Anderson,** Ames National Laboratory; **Jordan Tiarks,** Ames National Laboratory; **Kyle Tsaknopoulos,** Worcester Polytechnic Institute; and **Emma White,** DECHEMA Forschungsinstitut, this course provided information about powder characteristics and properties. Additionally, attendees discussed safety measures; metal, ceramic, and polymer powders; and various powder characterization methods.

Navigating U.S. Immigration: Overcoming a Barrier for Materials Professionals Workshop

"The most important thing I can tell you is to have a roadmap . . . you should be prepared well in advance and always have a Plan B," said **Marco Pignone III, Esq.**, Getson & Schatz Law Firm, on Monday, October 7, at the Navigating U.S. Immigration: Overcoming a Barrier for Materials Professionals Workshop presented by the TMS Professional Development Committee. Pignone began this workshop with a presentation based on his expertise in immigration law, providing an overview of immigration status options in the U.S. and an explanation of the types of visas and the specifics of each.

Following Pignone, panelists **Matheus Balen,** SMS Group; **Linu Malakkal,** DOE Idaho National Laboratory; and **Zilong Hua,** DOE Idaho National Laboratory, provided firsthand stories as immigrant materials engineers. "Ask for help," Malakkal encouraged attendees, "and start early . . . it's all about the planning and starting as early as possible."

Following the anecdotes and advice from the speakers, attendees engaged in an interactive question-and-answer discussion with the panelists.

Panelists of the Navigating U.S. Immigration Workshop are introduced by Emily Kinser, TMS Professional Development Committee Chair. From left to right: **Linu Malakkal**, DOE Idaho National Laboratory; **Matheus Balen**, SMS Group; **Zilong Hua**, DOE Idaho National Laboratory; **Marco Pignone III, Esq.**, Getson & Schatz Law Firm; **Emily Kinser**, Advanced Research Projects Agency-Energy; and panel moderator, **Surojit Gupta**, University of North Dakota.

Student Activities

Material Advantage students had many opportunities to come together, network, and showcase their research at MS&T24. Some of these events included the Undergraduate Student Speaking Contest, the Student Networking Reception, the Ceramic Mug Drop Contest, the Ceramic Disc Golf Contest, and the Student Awards Ceremony.

Additionally, students were encouraged to attend the AIST Student Resume Coaching Workshop (pictured) led by **Shannon Clark**, ArcelorMittal Dofasco, the AIST Resume Coach. Clark provided advice on how to expand your network, shared best practices, and helped attendees develop an action plan for their resumes and CVs. "Resumes are not the key to getting the job, they are the key to getting an interview," Clark stated. She encouraged attendees to highlight what makes them unique in their resumes: "Your resume is a very personal thing, it's yours." Clark concluded the workshop by reviewing sample resumes with attendees, and the group utilized what they had learned to make corrections to the sections.

Don't miss your chance to attend Material Advantage events like these at MS&T25 in Columbus, Ohio. TMS offers Travel Grants to Material Advantage or TMS Graduate Student Program members. Applications for MS&T25 are due **June 15, 2025**. Learn more and apply today at **www.tms.org/Awards**.

BE PART OF TMS FALL 2025 AT MS&T25

Materials Science & Technology 2025 (MS&T25) will be held in Columbus, Ohio, from September 28–October 1, 2025.

The TMS Fall Meeting 2025 will feature a collection of symposia in the following subject areas:

- Additive Manufacturing
- Artificial Intelligence
- Biomaterials
- Ceramics and Glass Materials
- Fundamentals and Characterization
- Iron and Steel (Ferrous Alloys)
- Lightweight Alloys
- Materials-Environment Interactions
- Nuclear Energy
- Processing and Modeling
- Sustainability, Energy, and the Environment
- Special Topics

TMS FALL 2025 @ MS&T
MATERIALS SCIENCE & TECHNOLOGY

Visit **www.tms.org/TMSFall2025** to view a complete listing of TMS-sponsored symposia. You can also view the complete MS&T25 technical program—which includes symposia organized by TMS, ACerS, and AIST—at **www.matscitech.org/MST25**. Abstracts for all TMS Fall Meeting symposia and all other MS&T25 symposia are due May 1, 2025.

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NEW EDITORS ANNOUNCED FOR *METALLURGICAL AND MATERIALS TRANSACTIONS* JOURNALS

Kelly Zappas

Jonathan Cormier

Il Sohn

In December, **Tresa M. Pollock,** University of California, Santa Barbara, stepped down after eight years as principal editor of the *Metallurgical and Materials Transactions* (*MMT*) journals.

TMS is pleased to announce two new editors who will take over the role in January: **Jonathan Cormier** of ISAE-ENSMA and Institut Pprime in France as editor-in-chief for *Metallurgical and Materials Transactions A* (*MMTA*) and **Il Sohn** of Yonsei University in South Korea as editor-in-chief for *Metallurgical and Materials Transactions B* (*MMTB*).

Jonathan Cormier first became involved with *MMTA* in 2014 as a key reader for the journal. In this capacity, he handled articles related to high temperature materials, mostly superalloys. He served as an associate editor beginning in 2016. "*Met Trans A* is one of my favorite journals, as it is one of the unique journals focusing on physical metallurgy, and I have always received very detailed reviews for nearly all my submissions as an author," said Cormier. "Moreover, I have always felt that this journal has the tradition of providing comprehensive reviews to authors, as well as a fair and ethical reviewing process."

In addition to its value for focusing on physical metallurgy, Cormier notes, "this journal is a forum for the dissemination of knowledge in materials science, not only on 'fashionable topics,' but also on more traditional ones, such as welding, solidification, forging . . ."

Under his leadership, Cormier says that the journal will stay focused on its traditional coverage areas, but editors will also encourage submissions related to advanced manufacturing processes (such as additive manufacturing, sintering, etc.), medium- and high-entropy alloys, and future technologies for power generation. "My hopes for the journal are to keep a fair and ethical review process, to maintain diversity, to decrease the time to first decision, and to increase the impact factor," said Cormier.

Il Sohn was first introduced to *MMTB* during his graduate studies at Yonsei University in 1998, when he read an academic paper on the chemical metallurgy of slags, the field of research he would later study for some 25 years. "Over the years, *MMTB* has continued to not only publish outstanding works on the fundamentals of chemical metallurgy, solidification, process metallurgy, pyrometallurgy, and many other metals and materials processing, maintaining its rich tradition and history, but has also evolved to include and expand on modeling and simulations as research tools become more advanced, adopting numerical simulations and computational fluid dynamics, and accepting research areas in artificial intelligence in process metallurgy in the age of digital transformation," Sohn said.

Sohn served as a key reader for *MMTB* beginning in 2012 and as an associate editor beginning in 2018. The journal is unique, he said, in that it serves both the ferrous and non-ferrous research areas including minerals and composites. "Its broad topic in the processing and engineering of metals and materials allows a wide range of authors to take interest in the journal and submit their work. Our editorial team will continue to work with our authors and readers to maintain *MMTB*'s core functions and expand on new fields and tools of interest pertaining to metallurgical and materials processing and engineering."

Artificial intelligence applications to processing is one area where Sohn expects the journal to see increased interest. "Although this field is comparatively new, there have been several papers submitted and published in the journal, which will likely increase within the next few years." He also points to carbon-free electrolytic process innovations as a trending topic. "Although the fundamentals of electrolysis have been studied in past issues, works regarding electrolytic reduction in molten salts and oxides and its application to industry will garner renewed interest as anthropogenic carbon emissions in metals and materials processing become a critical factor in economics and environment. Hydrogen applied processing methods and supplementing research, which substitute existing carbon-based processes, will also be of significant interest to our readers."

Visit www.tms.org/Journals to read past and current issues of both *MMT* journals and to learn how to submit your work for a future issue.

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TMS MEETING HEADLINES

JOM THE MAGAZINE

Meeting information is current as of October 24, 2024. For the most recent updates on TMS-sponsored events, visit **www.tms.org/Meetings**.

TMS 2025 Annual Meeting & Exhibition (TMS2025)

March 23–27, 2025
Las Vegas, Nevada, USA

Discount Registration Deadline: January 31, 2025

Make plans to attend the co-located symposia at TMS2025: the Fifth Summit on Diversity in the Minerals, Metals, and Materials Professions (DMMM5); REWAS 2025, focusing on the Circular Economy for the Energy Transition; and the 5th Bauxite Residue Valorization and Best Practices Conference.

www.tms.org/TMS2025

TMS Specialty Congress 2025

June 15–19, 2025
Anaheim, California, USA

Discount Registration Deadline: April 30, 2025

The 3rd World Congress on Artificial Intelligence in Materials and Manufacturing (AIM 2025), co-located at TMS Specialty Congress 2025, marks a significant milestone in advancing the role of artificial intelligence (AI) within materials science, engineering, and manufacturing.

www.tms.org/SpecialtyCongress2025

TMS Fall Meeting 2025 at Materials Science & Technology (MS&T25)

September 28–October 1, 2025
Columbus, Ohio, USA

Abstract Submission Deadline: May 1, 2025

A complement to the TMS Annual Meeting held each spring, the TMS Fall Meeting at MS&T offers TMS members a chance to connect each year at a second large-scale, multidisciplinary meeting to explore the intersections of development, synthesis, and application.

www.tms.org/TMSFall2025

OTHER MEETINGS OF NOTE

Extraction 2025 Meeting & Exhibition (Extraction 2025)

November 16–22, 2025
Phoenix, Arizona, USA

www.extractionmeeting.org/Extraction2025

Materials in Nuclear Energy Systems 2025 (MiNES 2025)

December 7–11, 2025
Cleveland, Ohio, USA

www.tms.org/MiNES2025

TMS 2026 Annual Meeting & Exhibition (TMS2026)

March 15–19, 2026
San Diego, California, USA

www.tms.org/TMS2026

CO-SPONSORED MEETINGS

Offshore Technology Conference (OTC) 2025
May 5–8, 2025
Houston, Texas, USA
Co-sponsored by TMS

OTC Brasil 2025
October 28–30, 2025
Rio de Janeiro, Brazil
Co-sponsored by TMS

PRICM 12
August 9–13, 2026
Gold Coast, Australia
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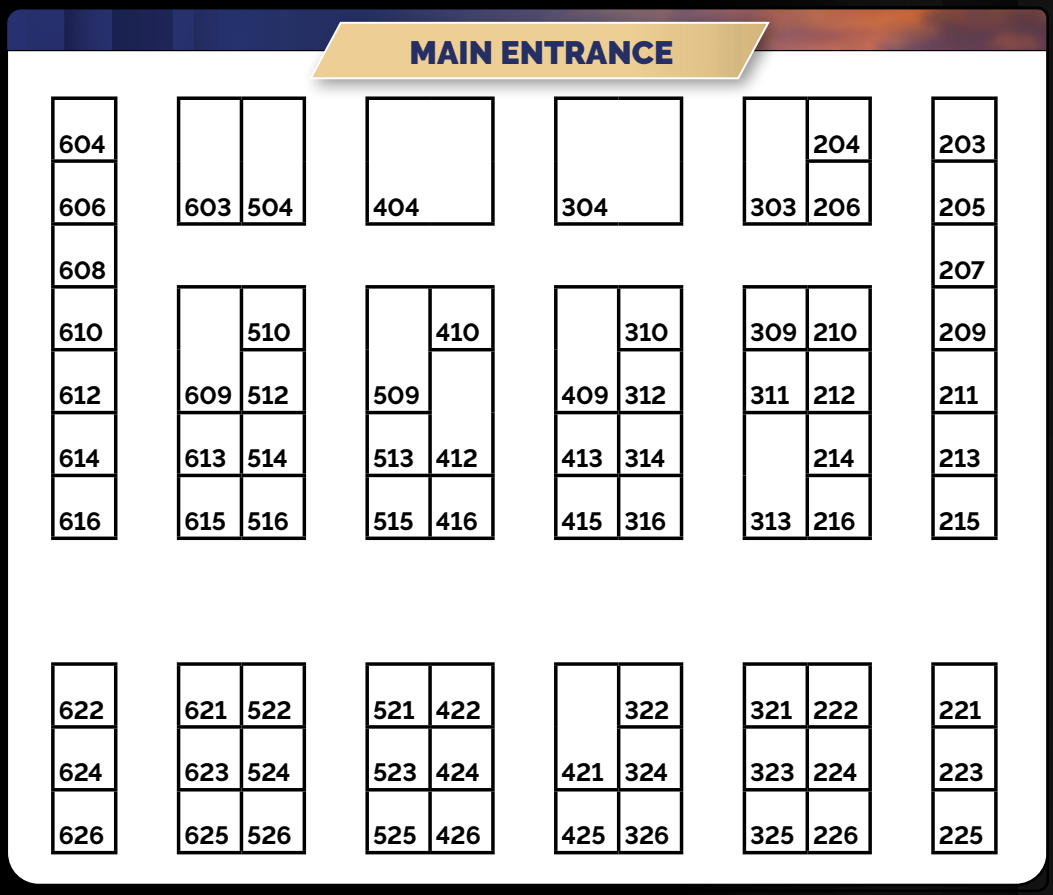

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Abstracts Due May 1, 2025

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