JOM

DECEMBER 2020

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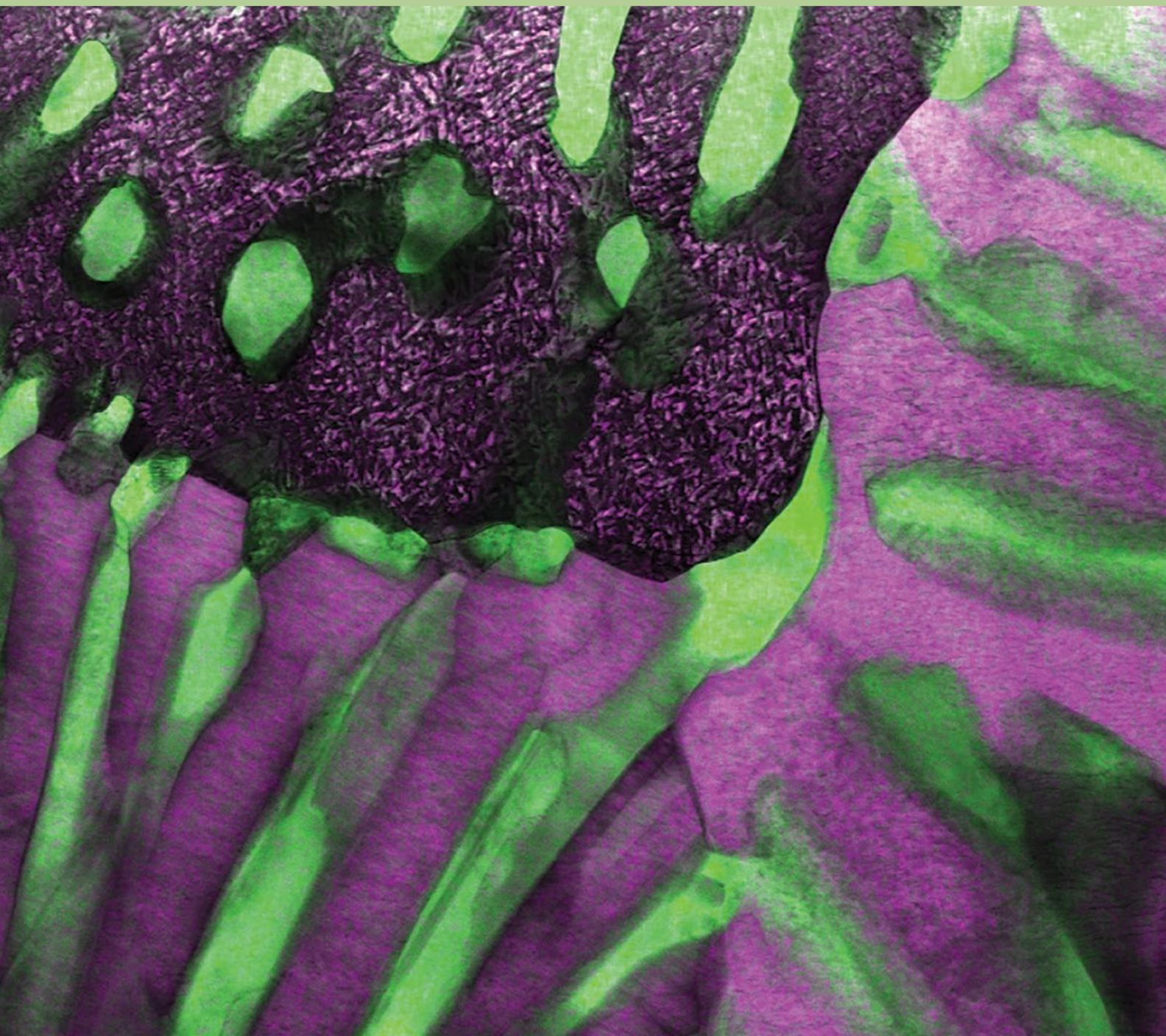

RECOMMENDED VIEWING: Great Materials Moments in the Movies

TMS Springer

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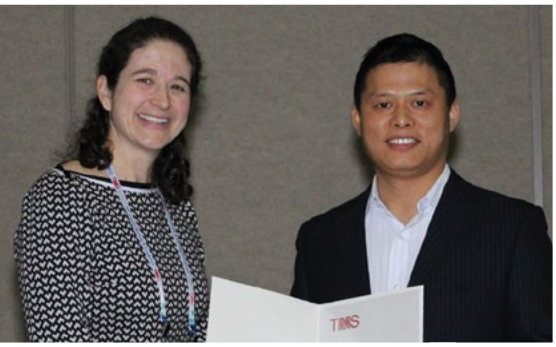




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4. **TMSFoundation@tms.org**

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Mesoscale Materials Science

Surface Engineering: Applications for Advanced Manufacturing

Technical Articles

Discussion

Correction

JOM

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About the Cover

From the article "Additive Manufacturing of Pure Mo and Mo+TiC MMC Alloy by Electron Beam Powder Bed Fusion" by Christopher Rock et al., shown is dendritic Mo with interdendritic Ti &C plus a fine lamellar TiC region with small discrete TiC particle precipitates. The lamellar structure represented shows the matrix to be Mo, and the dark lamellae consists of Ti and carbon. Composite image courtesy of Donovan N. Leonard of the Manufacturing Science Division, Oak Ridge National Laboratory.

December 2020 Guest Editors

Additive Manufacturing for Energy Applications
Additive Manufacturing Committee; Nuclear Materials Committee
Isabella van Rooyen, Idaho National Laboratory
Indrajit Charit, University of Idaho
Subhashish Meher, Idaho National Laboratory

Advances in Surface Engineering
Surface Engineering Committee
Tushar Borkar, Cleveland State University
Rajeev Kumar Gupta, North Carolina State University
Sandip Harimkar, Oklahoma State University
Arif Mubarok, PPG

Augmenting Physics-based Models in ICME with Machine Learning and Uncertainty Quantification
Invited
Somnath Ghosh, Johns Hopkins University
David McDowell, Georgia Tech
James Saal, Citrine Informatics

Graphene-based Composite Materials and Applications
Composite Materials Committee
Simona Hunyadi Murph, Savannah River National Laboratory

Mesoscale Materials Science
Invited
Saurabh Puri, Microstructure Engineering
Amit Pandey, Lockheed Martin Space

Surface Engineering: Applications for Advanced Manufacturing
Invited
Christopher Berndt, Swineburne University of Technology
Ma Qian, RMIT University

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 12
December 2020

"There is no getting 'back to normal,' experts say. The sooner we accept that, the better."
—CNN headline, Nick Paton Walsh

It is no secret that we live in a world of constant change. Sometimes the changes are dramatic but momentary, like tossing a large rock into a still pond. There is a great ga-loosh, a startling shockwave for the fish, extreme and then diminishing ripples, and an eventual return to quietude. Then, there are the tsunamis that rewrite the shoreline and all that is on it. Metaphorically, think not of a tossed rock but of an Apple, specifically one branded "iPhone." In a decade, smartphones brought about a sea of change as our ubiquitous connectivity tool. A different kind of world-changer is now working with much greater speed: COVID-19. In less than a year, it has made deep impacts to our mental, physical, emotional, and economic health. Books upon books will be written on the topic. The book of TMS will likely focus on how we convene our community.

It is surely no surprise to read that TMS events have suffered mightily under the pandemic. During 2020, everything since TMS2020 has been either postponed, cancelled, or virtualized. Will that carry into 2021 and beyond? That's a great question. The answer is evolving daily as circumstances are impossible to predict.

TMS has events planned for years to come. Indeed, the TMS Annual Meeting & Exhibition is booked through 2026. Every conference plan is predicated on holding an event of a particular size during a particular time at a particular place. Volunteers have promised to organize, staff has been allocated to provide the necessary operational support, and contracts have been signed with venues and third parties to provide hosting and support services. There's a lot of financial risk if the event fails to materialize as planned. This risk can run into multiple millions of dollars under a "worst case." A single impact of that size would greatly diminish the Society's reserves and challenge our sustainability. Pre-pandemic, such an outcome was an esoteric thought exercise. Today, not so much. And no, insurance is not coming to the rescue under the vast majority of these circumstances.

Each event is its own story. During 2020, we have staved off disaster by renegotiating with contract holders, working with our volunteer organizers and participants, pivoting endlessly, and exploring alternatives like postponements and virtualization. Ahhhh, there it is again. The word of 2020: "Virtualization." Virtualization is a tool that has been long available to event organizers, but it was infrequently used under the old normal as the experience is not the same as meeting in person, the logistics are complicated, the quality of connectivity is variable and unreliable, copyright management becomes more challenging, virtual presentations don't help satisfy contractual guarantees with host facilities, networking is dissatisfactory in the extreme, business models are not settled, and virtualization tools are an added expense. In the old normal, we lacked the incentives to confront and potentially conquer these obstacles. At this moment, we embrace virtualization as infinitely preferable to not meeting at all. And, there are some unique advantages, such as having presentations be available for a couple of months after the meeting (now, an attendee can literally see everything). Also, quality control requires that presentations be uploaded in advance, which eliminates the possibility of no-show speakers.

After we have a widespread vaccine and the end of travel restrictions, I anticipate that our new normal event options will comprise a mix of virtual-only, exclusively in-person, and hybrid blends. That is a sea of change to which I eagerly look forward (because the pandemic will be over!).

James J. Robinson
Executive Director
@JJRofTMS

"During 2020, everything since TMS2020 has been either postponed, cancelled, or virtualized. Will that carry into 2021 and beyond?"

If you like this monthly column in JOM, turn a few pages in this issue for the sequel to my 2004 materials in the movies article: "Return to 'Great Materials in the Movies': Part II: Beyond Transparent Aluminum."

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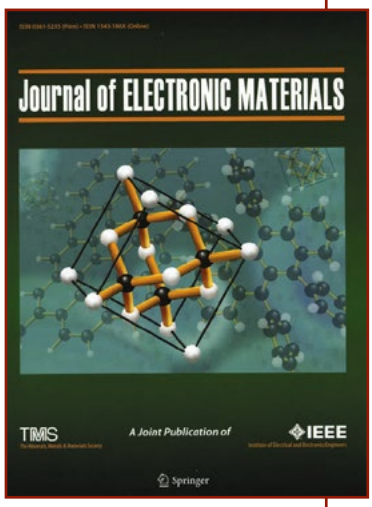
JOM themagazine

Review Article Proposals Solicited for the *Journal of Electronic Materials*; Submit Nominations for New TMS Award

Journal of Electronic Materials Seeks Proposals for Invited Review Articles



The *Journal of Electronic Materials* (*JEM*) is soliciting proposals for invited review articles on emerging applications of electronic materials. *JEM* reports on the science and technology of electronic materials, publishing articles of interest on semiconductors, magnetic alloys, dielectrics, ferroelectrics, photonic materials, and nanoscale materials.

For this call, review articles of particular interest will provide a new perspective and in-depth review to both non-specialists and specialists, with emphasis on emerging applications of electronic materials.

Topics of interest include recent experimental and theoretical research including, but not limited to:

- Electronic materials for energy conversion and storage
- Electronic materials for novel memory, logic, and interconnect applications
- Graphene and other 2D electronic materials
- Electronic materials for photonic interconnects and novel wavelength tunable light emission applications
- Electronic materials for power electronics and smart grid applications
- Bioelectronics materials, including applications to COVID-19 challenges

For the journal to invite a review article, the lead author should submit a proposal containing the information listed below (within a two-page limit):

- Topic or a tentative title for the review article
- Author names and affiliations, including contact information for the lead author
- Five selected relevant publications per author in the topical area of the proposal
- An abstract (less than 250 words) summarizing the background and motivation for the review article
- A comprehensive list of previously published articles (approximately 25 or more) to be discussed in the review. Ideally, the majority of these articles are by authors others than the proposing authors

If invited, a review article should be submitted within three months of the invitation date. Review articles will be peer reviewed in accordance with the high standards of *JEM*.

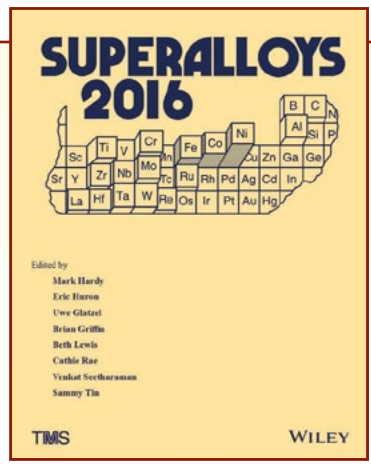
Review article proposals should be e-mailed directly to the Senior Editor, John Baniecki, at jbanieck@slac.stanford.edu. Additional journal details are available at www.springer.com/11664.

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.

Superalloys Archive Expands

The Superalloys Proceedings Archive has added *Superalloys 2016* to its online collection. The archive is free to all users through the support of the International Symposium on Superalloys Committee. To date, it houses more than 1,000 technical articles encompassing the history of these important materials. Visit www.tms.org/SuperalloysArchive to access the newly added papers and all other publications in the archive.



Newly Funded Award Honors Donald Sadoway

TMS members can now submit nominations for the new **Sadoway Materials Innovation and Advocacy Award** for mid-career professionals. Named for Donald Sadoway, John F. Elliot Professor of Materials Chemistry at the Massachusetts Institute of Technology (MIT), the award will recognize individuals who have made impactful and broad materials science and engineering achievements and possess a unique ability to champion their work and the field as a whole through education, public advocacy, or entrepreneurship.

To nominate a colleague for the inaugural award in 2022, **applications must be submitted to TMS staff at awards@tms.org by April 1, 2021**. The award recipient will be recognized at the TMS Annual Meeting & Exhibition and will receive a $3,500 prize.

Sadoway's former students, colleagues, and associates raised the award funds to honor Sadoway's influence on them, the MIT Department of Materials Science and Engineering, and the global materials science community. Additional details are available at www.tms.org/SadowayAward.

This award joins more than 15 other Society-level TMS awards, including several that are administered by TMS on behalf of American Institute for Mining, Metallurgical, and Petroleum Engineers (AIME), TMS's antecedent organization. These honors recognize the outstanding achievements of some of the most accomplished and promising materials scientists and engineers in the world. For more information on all awards, as well as histories on select named awards, visit www.tms.org/Awards.

Donald Sadoway thanks his past students, colleagues, and supporters for starting a new award in his honor at the TMS Foundation Donor Dinner in February 2020.

New Reserach Collaboration Features TMS Member

TMS member Nikhil Gupta, a professor in the Tandon School of Engineering at New York University (NYU), was awarded a multi-year collaboration with Anton Paar USA. Gupta's team at NYU will conduct its research using a high-end dynamic mechanical analysis (DMA) device from Anton Paar. Their research focus will build on a recently awarded patent for fundamental advancements in the method of processing data gathered by the DMA device, which allows the conversion of viscoelastic properties to elastic properties. These new research goals join the team's current focus on new security methods of 3D printing, developing filaments of advanced composites, and using machine learning methods for materials characterization.

Gupta has been an active member of TMS for more than 20 years, serving as a *JOM* advisor and on several technical committees, as well as on the Structural Materials Division (SMD) Council. In 2013, he received a TMS SMD Young Leaders Professional Development Award. Earlier this year, he was named a TMS Brimacombe Medalist, "for innovations in the development of lightweight porous materials and for commitment to educating the public about the impact of materials research on society."

Nikhil Gupta

In Memoriam: Lewis R. Aronin

TMS extends condolences to the family, friends, and colleagues of Lewis R. Aronin, who passed away at the age of 100 on May 21, 2020. Upon earning his B.S. in applied physics from Massachusetts Institute of Technology (MIT), Aronin spent several years in industry working for Waltham Watch Company before retuning to MIT as research staff on the MIT Metallurgical Project. When Nuclear Metals assumed the project in 1958, Aronin returned to industry, becoming the leader of physical metallurgy and manager of metallurgical research until 1966. He later joined Kennicott Copper Corporation Ledgmont Laboratory as a consultant before moving to the Army Materials Technology Laboratory, where he worked until 1990. During his retirement, Aronin volunteered for MIT's Age Lab, in the 85+ Lifestyle Leaders community panel.

A longtime member of TMS, Aronin was originally a member of TMS's antecedent organization, the American Institute of Mining, Metallurgical, and Petroleum Engineers.

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JOM themagazine

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

Cleveland-Cliffs Acquired ArcelorMittal

Cleveland, Ohio, USA: Cleveland-Cliffs Inc. purchased the U.S. operations of ArcelorMittal SA in October 2020 for $1.4 billion in cash and shares, becoming the biggest flat-rolled steel producer in North America. ArcelorMittal's U.S. business has more than 18,000 employees and 25 facilities, including mines, steel-making facilities, and finishing operations. They produced 12.9 million tonnes of steel in 2019. In March 2020, Cleveland-Cliffs bought steel producer AK Steel for $3 billion and expects its second major deal in less than a year to boost sales to the automotive market and help reduce costs.

Toyota and Panasonic Partner to Power Hybrids

Tokyo, Japan: Toyota Motor Corporation and Panasonic Corporation formed a joint venture, Prime Planet Energy & Solutions, to produce lithium-ion batteries for hybrid cars at a plant in western Japan through 2022. To meet growing demand for electric vehicles (EVs), a Panasonic factory in Tokushima Prefecture will have an estimated capacity for producing enough batteries for around 500,000 vehicles a year. As one of the world's biggest electric-vehicle battery makers, Panasonic currently faces increasing competition in the auto industry. Toyota, Japan's biggest carmaker, expects annual EV sales to reach 5.5 million in 2025, five years earlier than initially planned.

Jervois Buys Brazilian Nickel-Cobalt Refinery

Hawthorn, Australia: Jervois Mining Limited acquired the São Miguel Paulista nickel and cobalt refinery (SMP) from Companhia Brasileira de Alumínio, with the transaction set to be completed by the end of December 2020. Jervois, which holds mining assets in the United States, Uganda, and Australia, intends to become a vertically integrated producer through the acquisition, once its Idaho Cobalt Operations (ICO) begins commercial production. With an annual refined production capacity of 25,000 metric tonnes of nickel and 2,000 metric tonnes of cobalt, SMP will refine concentrate from ICO and return cobalt metal to the U.S. Jervois plans to supply refined nickel and cobalt products to industries such as specialty stainless steels, nickel and cobalt superalloys, cathode precursors, lithium-ion batteries, and electric vehicle manufacturers.

Scotland Opens First Commercial Gold Mine

Nedlands, Australia: Scotgold Resources Ltd. detected signs of more precious metals at its Cononish gold and silver project located in the Scottish Highlands north of Glasgow, U.K. Soil samples northeast of the project suggested the gold and silver structures may extend further than initially expected. The project has faced several delays, first to make site modifications and later due to interruptions caused by the coronavirus pandemic. The Cononish project is expected to pour first gold by the end of 2020 and is slated to become Scotland's first commercial gold mine. Scotgold envisions an underground mine with an initial production capacity of 23,370 ounces of gold annually, for up to nine years.

Beersheba, Israel: Archaelologists from Tel Aviv University, the Israel Antiquities Authority, and the Geological Survey of Israel excavated one of the oldest known copper-smelting workshops in Beersheba, Israel. The 6,500-year-old site may be the world's first use of a furnace. Dating to the fifth millennium BCE, the site provided artifacts that revealed a two-stage technology, furnace-based primary smelting followed by melting and refining in crucibles, through typological and chemical analyses. "It raises the possibility that the furnace was invented in this region," said Erez Ben-Yosef, Tel Aviv University. (Photo courtesy of Talia Abulafia/Israel Antiquities Authority.)

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Getting to Know the Incoming TMS Board of Directors

Kelly Zappas

In 2021, TMS will welcome two new members to its Board of Directors. **Jud Ready** of the Georgia Institute of Technology (Georgia Tech) and **Tim Rupert** of the University of California, Irvine (UCI) will begin their three-year terms on the TMS Board of Directors at the end of the TMS 2021 Annual Meeting & Exhibition, March 14–18, 2021. Take a few moments today to get to know these active TMS volunteers, to learn how TMS has influenced their careers, and to gain insight into what they hope to accomplish during their time in office.

Jud Ready
Vice President

Jud Ready first became involved with TMS in 1992 as a member of the Georgia Tech student chapter and later took on his first major leadership role as chapter president. He presented his work at his first TMS annual meeting in 1994, and he has attended the meeting every year since, missing the conference only when his children were born.

"Even then, my students went," he pointed out. "So, my research has been presented at every TMS Annual Meeting for more than a quarter century."

Ready, who is now deputy director, Innovation Initiatives, at Georgia Tech, says there are two things that keep him coming back to TMS meetings year after year. "It's the people and the science," he said. "TMS is so broad. The ability to keep learning new things keeps me coming back."

The network he's built at TMS—including collaborators, program managers, and friends—has also had a dramatic impact on his career.

"I would be nowhere close to where I am now, professionally, without the connection, the content resources, the professional relationships, and also the true friendships I've developed through my involvement with TMS," he said. "There's a great camaraderie compared to other societies. It's a much more friendly atmosphere."

It's no surprise, then, that one of the things Ready is most looking forward to during his term as president in 2022 is a return to normalcy with face-to-face meetings and live events. Still, he notes the benefits of the virtual events that have been held in the past year.

"Practicing doing conferences virtually has opened a lot of new opportunities for content delivery," he said. "It will be interesting to see how this adds to TMS's wealth of knowledge and to see how we fold these new capabilities into future events."

Overall, Ready hopes to contribute enthusiasm, amicability, and friendliness during his term on the TMS Board of Directors. "That's what sets TMS apart from other Societies. The social interactions that can feel forced or awkward at other conferences come naturally at TMS."

"I would be nowhere close to where I am now, professionally, without the connection, the content resources, the professional relationships, and also the true friendships I've developed through my involvement with TMS."
—Jud Ready

Tim Rupert
Programming Director

Tim Rupert's involvement with the Society began at the TMS 2008 Annual Meeting & Exhibition, when he was a first-year graduate student giving his first conference talk.

"I found a community that valued my work and provided an amazing forum for scientific discussion," he said. "Attending TMS meetings has let me share scientific ideas with colleagues and build new collaborations. Major TMS meetings like the Annual Meeting and the MS&T meeting are still 'must attends' for me today."

Rupert, who is now associate professor of materials science and engineering at UCI, found that involvement in the Society also offered a number of less obvious professional benefits.

"I found many career growth opportunities associated with the bottom-up organization structure of TMS, with the chance to organize symposia and become involved in committee leadership being specific examples," he said.

As the incoming Programming Director, Rupert recognizes the importance of the Society's programming decisions during this unusual time.

"Programming is always an area that is dynamic and high-impact, as the hot areas of materials science evolve quickly," he said. "But this space is especially important now as we all deal with COVID and its impact on our way of interacting with our peers."

"I am excited to dive into this position at a time when we truly need innovation in how we operate," he continued. "There will certainly be challenges and perhaps even occasional missteps, but it will also be exciting to have a chance to revamp certain aspects of our Society. I truly believe that challenges are opportunities, so I will bring that perspective into this position and work hard to lead us down a positive pathway."

"I found a community that valued my work and provided an amazing forum for scientific discussion."
—Tim Rupert

Who Will the TMS Board Welcome Next Year? You Tell Us!

TMS is now accepting nominations for two positions on the 2022–2025 TMS Board of Directors. The open positions are the Presidential Rotation and the Membership & Student Development Director. **Nominations will be accepted until January 15, 2021.** Additionally, positions for Light Metals Division Chair, Materials Processing & Manufacturing Division Chair, and Structural Materials Division Chair are also open on the 2022–2025 Board of Directors, but nominations are being developed directly through the technical divisions.

The Presidential Rotation encompasses three successive one-year positions: Vice President, President, and Past President. All three roles are officer positions within the Society and carry unique responsibilities. The role of President includes serving as chair of the Board of Directors.

The Membership & Student Development Director represents the entire membership in carrying out the professional activities of the Society concerned with professional and student membership and related activities, including diversity and inclusion initiatives.

Applicants' packages for these positions will be considered by the Society's Nominating Committee, which will then recommend a candidate for each position to the Board of Directors.

If approved by the Board of Directors, these endorsed candidates will be presented to the general membership for approval by July 2021.

To access complete job descriptions and qualifications for each office, as well as the Nominee Statement Form and nomination instructions, visit www.tms.org/BoardNominations. For additional information, contact Deborah Hixon, TMS Awards Program Administrator, at hixon@tms.org.

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Return to "Great Materials in the Movies": Part II: Beyond Transparent Aluminum

James J. Robinson

WHY A SEQUEL?

A long time ago, in a reality far, far away, I wrote the article, "The Reel Thing: One Editor's List of Great Material Moments in Movies," for the March 2004 *JOM*. It was enjoyable to contemplate and write, and it generated more feedback than anything that I've ever written for *JOM*. I even get the occasional request to pen a sequel—what might I do differently? What did I miss the first time? What would I include since the original premiered in 2004?

Yes, I could write something that would answer those questions but is 16 years too long a time to wait for a sequel? Probably not. We waited 35 years for a sequel to *Blade Runner* to arrive in the form of *Blade Runner 2049*. That turned out pretty well according to fans and critics alike.

So, let's give a sequel to "The Reel Thing" a go, especially as I suspect that we could all use something pleasantly distracting right about now. During the pandemic, I anticipate that many of you have been scrolling through a lot of streaming service menus. I know that I have. Rather than scrolling, try using the "search" function to find some of the

Thanks for Nominating!

Nominations for the "greatest materials moments in movies" were solicited on the official TMS social media accounts from May through July 2020. Thank you to all the members who took the time to nominate their favorite films and champion those nominations with insightful explanations.

Missed an opportunity to nominate? Don't forget to connect with TMS online so you never miss out on Society news.

@TMSSociety

@MineralsMetalsMaterialsSociety

www.linkedin.com/in/TMSSociety

movies recommended here. In seconds, we can pretty much access everything that has ever been made.

The TMS membership renewal campaign has the slogan of "Standing Together While We Stay Apart." So, for your viewing enjoyment, let's put a bit of a twist on that with "Viewing Together While We View Apart." Why not try a YouTube Watch Party with a few colleagues or some impressionable young folks ready to be enchanted with the possibilities of materials technology? Give yourself a break, TMS members, and follow me. . . . I'm gonna make you an offer that you can't refuse.

Reminder: The Original List From March 2004

The original article is simply a countdown of movies that I thought had a unique materials element or that was generally enabled by materials technology. The countdown leans in on science fiction as I often marvel at how much science fiction relies on just-on-the-other-side-of-tomorrow materials technology. In general, the success or failure of the article relied exclusively on the, ahem, charming non-rigor of my effort. Here's a refresher on that countdown (TMS members can easily access it on SpringerLink by logging in at www.tms.org and navigating to the *JOM* home page.):

10. *The Graduate* (1967)
9. *The Treasure of the Sierra Madre* (1948)
8. *Superman* (1978) *and X-Men* (2000)
7. *Goldfinger* (1964)
6. *Star Trek IV: The Voyage Home* (1986) and *Forbidden Planet* (1956)
5. *Blade Runner* (1982) and *Minority Report* (2002)
4. *The Lord of the Rings: The Fellowship of the Ring* (2001)
3. *Terminator 2: Judgment Day* (1991)
2. *The Absent-Minded Professor* (1961)
1. *Theremin: An Electronic Odyssey* (1993)

"The scene where Scotty derived the structure of transparent aluminum on a Macintosh computer foreshadowed the advent of computer-aided materials design, a reality we are now only beginning to realize."

—*Charles Ward on* Star Trek IV: The Voyage Home

THE TRANSPARENT ELEPHANT IN THE ROOM

In my experience, science fiction has inspired and engaged many TMS members who might one day bring a fantastical material to everyday reality. How many technologies have we seen on *Star Trek* in the 1960s that have become commonplace reality today? Tricorders and communicators? Got them in the form of smart phones. Replicators? Check out additive manufacturing. Infinitely knowledgeable computers that can control all of the systems of a starship? Ask Alexa.

While generations of scientists and engineers have realized these wonders, there is one eagerly anticipated material that we are still awaiting as utilized in *Star Trek IV: The Voyage Home* (1986). You know what I'm talking about, but let's hear it from TMS member Charles Ward, who wrote on TMS social media: "The scene where Scotty derived the structure of transparent aluminum on a Macintosh computer foreshadowed the advent of computer-aided materials design, a reality we are now only beginning to realize." Yes, we want that, and I anticipate seeing a presentation about transparent aluminum—the most evocative movie material of all—at a future TMS meeting.

HOW DOES THE SEQUEL DIFFER?

Clearly, I am again bringing more non-rigor to the article. It's what I do. But a new egalitarian component is added as the TMS editorial team conducted a social media campaign over the summer of 2020. (See sidebar, "Thanks for Nominating!") They asked our members and social media users to nominate the films that they thought should be added to the original list. This was unscientific, but many of the responses helped inform this article. We added some

suggestions from the editorial staff, who apparently, watch a lot of movies (but not on work time!). We also did a call back to letters that I received after publication of the original article. (See the November 2004, "Letters to the Editor," at SpringerLink.)

I took many of the inputs, ignored some others, and what you are reading now is what remains. Unlike the original, there is no ranking order, so that's new.

IS THE SEQUEL BETTER THAN THE ORIGINAL?

If not better, I'll be happy with "not that bad" or "about the same." And, if I've distracted you from the pandemic for 15 minutes or so and got you to discover a movie that you like, I've done my job.

Here goes . . .

NEW RELEASES SINCE THE ORIGINAL LIST

The "Marvel Cinematic Universe" in General, and *Iron Man* (2008) and *Black Panther* (2018) in Particular

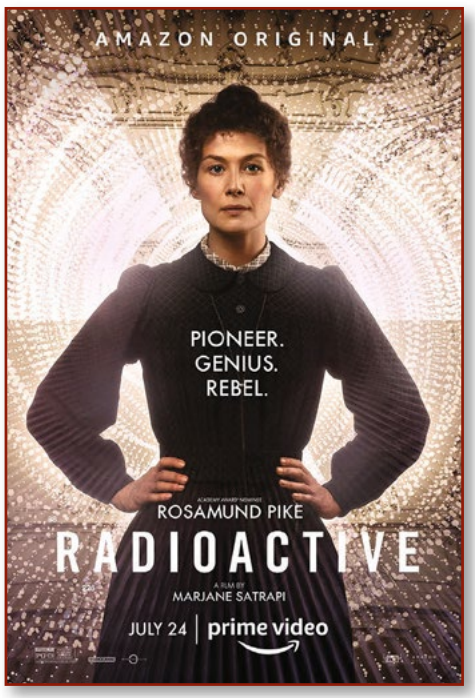
In little more than a decade and with no sign of waning, the 23 interconnected movies of the Marvel Cinematic Universe (MCU) thus far released have gained praise from critics, adoration by audiences, and billions of dollars from box offices. There is no analog, not even the *James Bond* and the *Star Wars* franchises. For the initiated—and based on my conversations over the years, a lot of TMS members are initiated—these "comic book movies" are infinitely more than "comic book movies."

The first in the series is Jon Favreau's *Iron Man,* starring Robert Downey Jr. as the misbehaving, brilliant, charismatic, and fabulously rich weapons manufacturer Tony Stark. Using his money, his ingenuity, the artificial intelligence he invents, a change of heart on armaments, and an array of cutting-edge materials technologies (from forging and lightweighting to additive manufacturing and nanotechnology), Stark invents the Iron Man armor. The remarkable suit enables an average man to become a superhero—no magic, no chemistry mishaps, no gamma radiation, no alien DNA; just invention and technology. The armor is continuously modernized throughout the film series and becomes more advanced, capable, and invincible with each installment.

I have little doubt that we are but days away from a fully functioning Iron Man suit to be used by the military to defend us or by Amazon to deliver packages.

If the Iron Man character personifies an unspoken thesis that materials science and engineering can be used to defeat virtually any problem (or mad titan), then Ryan Coogler's ***Black Panther*** demonstrated that mastery of materials manufacturing is central to the economic, cultural, and technological magnificence of great nations. In this case, Earth's greatest country may be the fictional African nation Wakanda, where a meteor embedded a deposit of the metal vibranium. While not on the Periodic Table, this element is lighter than steel while being more malleable and stronger. The Wakandians developed the technology to apply vibranium in countless marvelous ways to empower and defend their enlightened, Camelot-like nation.

TMS member Lauren Garrison noted via TMS social media that, "Black Panther's suit is a marvel of materials science. It has the ability to absorb energy from the blows received in combat, store that energy, and release it later. This is based on the real effect of piezoelectric materials." Adding to the film's appeal is the charisma of the late Chadwick Boseman as T'Challa, the Black Panther. He is inspirational, but so, too, is T'Challa's sister, Shuri. T'Challa may be the protector and political leader of Wakanda, but Shuri is every bit his equal, or better, as Wakanda's lead scientist and engineer. As we see the growth of diversity, equity, and inclusion in the materials community, there have been few better launching points for awakening young people as to the possibilities of materials science and engineering as a career than *Black Panther.* For more young people performing extraordinary feats with chemistry and materials, see the MCU's ***Spider-man: Homecoming*** (2017).



underlying materials technologies that enable not only the avatars but the environmental power suits that allow humans without an avatar to move about the moon. You don't have to leave Planet Earth or travel too far on it to find researchers hard at work on motor neuroprosthetics, exoskeletons, and robotics. For more extraordinary biomaterials in compellingly told science fiction, see the brilliant television series of artificial life and intelligence ***Westworld*** (2016-), the this-is-surely-happening-somewhere-right-now ***Ex-Machina*** (2014), and the anime classic ***Ghost in the Shell*** (1995).

Avatar (2009)

James Cameron's *Avatar*, like the transparent aluminum in *Star Trek IV,* is engrained on us with its magically propertied mineral unobtanium—the levitating "conflict" material of the lush and biologically diverse moon Pandora. The real materials magic comes in the form of the biomaterials and bioengineering that create living drones, or avatars, of indigenous creatures that allow a man or woman's consciousness to be temporarily transferred from a human brain to the avatar's artificial one. There's not a lot of explicit materials-talk in the movie, but you can easily imagine the complexities of the

Radioactive (2019)

Marjane Satrapi's recent Marie Curie film shines a light on the life of one of the world's most recognizable and influential scientists. In covering Marie and Pierre Curie's discoveries of radium and polonium, the film showcases both the intellectual and physical labor involved in their experiments, and paints Marie as a determined and ambitious researcher without shying away from the challenges she faced as an unconventional woman in a conservative society. In addressing how the Curies' discovery upended the scientific community and ultimately transformed the world, the film also reminds us that scientific discoveries oftentimes give us new and difficult questions in ethics and our understanding of right and wrong.

ADDITIONAL CANDIDATES FOR THE ORIGINAL LIST

The Thin Man (1934)

A personal choice: W.S. Van Dyke's *The Thin Man* introduced moviegoers to wealthy and heavy-drinking crime-solvers Nick and Nora Charles. The banter is quick and witty and a six-installment film-series was born. There's not much in the way of materials technology, candidly, but the opening film's murder victim was an inventor who is credited with creating a new smelting process for producing gold, silver, and copper. Reference to the process always reminds me of the late 1969 TMS President Paul E. Queneau, a developer of the Queneau-Schuhmann-Lurgi reactor for primary metals production and the subject of several articles in the 1970s, 80s, and 90s *JOM* by Paul and others.

The Fuller Brush Man (1948)

S. Sylvan Simon's comedy vehicle for Red Skelton was brought to my attention after publication of the original article by frequent *JOM* contributor Dennis Hasson, who wrote the monthly column "Retrospect" during the 1980s and 90s. Dennis described it as follows: "The movie's materials aspect was the shape memory behavior of one of Red's plastic brushes. Only recently, shape memory

> "Briefly, the plot revolves around catastrophic failures of airplanes due to metal fatigue; [Jimmy] Stewart's character has a theory to explain it, but no one listens to him until it is (almost) too late."
>
> —*Todd C. Hufnagel on* No Highway in the Sky

polymers, especially in medical applications (e.g., biodegradable sutures) were reported in the literature. The movie writer was definitely ahead of materials science research."

No Highway in the Sky (1951)

In response to the original article, no film was referenced more frequently by readers than Henry Koster's cinematic adaptation of Nevil Shute's novel *No Highway,* with its metallurgist hero. Nevil Shute is perhaps best remembered as the author of the end-of-days nuclear war novel, *On the Beach,* which was also adapted into a pretty good movie. *No Highway* predated *On the Beach* by nine years and was adapted as *No Highway in the Sky.* As TMS member Todd C. Hufnagel wrote to me 16 years ago, "Briefly, the plot revolves around catastrophic failures of airplanes due to metal fatigue; [Jimmy] Stewart's character has a theory to explain it, but no one listens to him until it is (almost) too late. It also provides an odd example of life imitating art. Just a few years after *No Highway in the Sky* came out, the De Havilland Comet (the first commercial jet airliner) experienced a series of tragic crashes that were ultimately attributed to fatigue failures." For so many obvious reasons, this film is the biggest omission on the original list.

The Man in the White Suit (1951)

Alexander Mackendrick's film concerns a Cambridge graduate working to develop an exceptionally durable fabric. As John Gerlach wrote to me back in 2004: "This movie has as its focus the invention and development of new materials. The action takes place in an English mill town. This movie concerns the efforts to make a miracle fiber that repels dirt. Cloth made from it never needs to be washed and it wears forever. Forget about those movies where materials are secondary. In this movie, materials science is front and foremost. It contains some of the best (realistic) scenes of a mid-century industrial chemistry laboratory that have ever appeared in film. The humor is first rate."

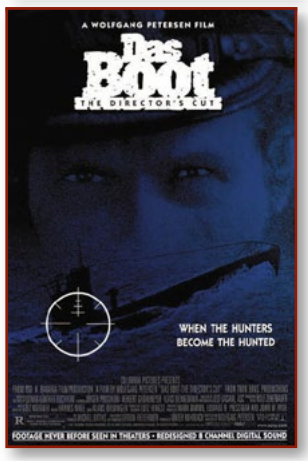
Das Boot (1981) and *Titanic* (1997)

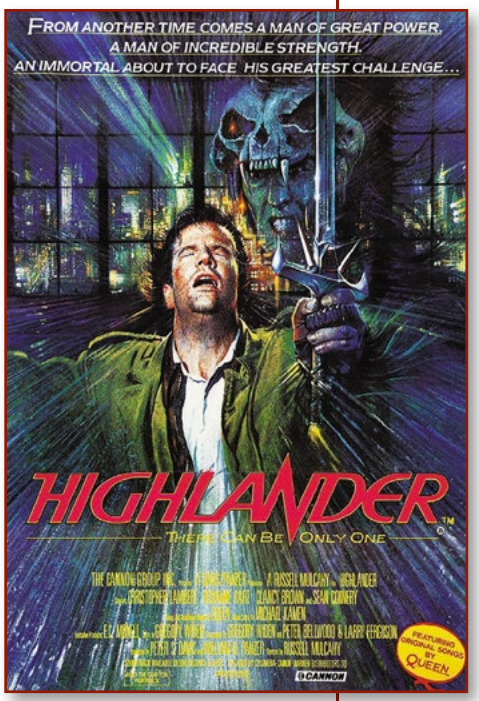
Seafaring is an exceptionally difficult materials service environment, even under the most benign of circumstances. Add the stresses of grazing a passenger liner against an iceberg or diving a U-boat below its operating limits and you are asking too much of even the most skilled steelmakers and shipbuilders.

Wolfgang Petersen's celebrated World War II classic *Das Boot* follows the crew of a German U-boat during the Battle of the Atlantic and gives a stark, yet realistic representation of very human sailors, war where you cannot see your enemies, and unforgiving machinery. I think that the word "claustrophobic" was invented by movie critics struggling to best describe the experience of both the characters and the viewers. As for materials, whenever the boat dives below its rated depth, the audience joins the crew in their suspense as the metal hull groans and rivets fly loose.

Metal and rivets are also the reason behind the night to remember as depicted most famously in James Cameron's *Titanic.* Consider the comments by TMS member Lauren Garrison as posted to TMS social media, "This amazing and tragic love story was made possible by the brittle failure of the steel hull of the *Titanic* ship. That ductile-to-brittle transition is one of the most famous in history and [is] taught to hordes of new materials science students each year to serve as a memorable warning of why material properties matter in design."

> "This amazing and tragic love story was made possibly by the brittle failure of the Titanic ship. That ductile-to-brittle transition is one of the most famous in history and [is] taught to hordes of new materials science students each year to serve as a memorable warning of why material properties matter in design."
>
> —*Lauren Garrison on* Titanic





WORST MOVIE MATERIALS MOMENT

Indiana Jones and the Kingdom of the Crystal Skull (2008)

I love the *Indiana Jones* films and am willing to forgive them a lot, but the weakest moments by far are in this disappointing fourth installment of the film series. If you've seen the movie, I don't even have to tell you the worst part. For the uninitiated, Indy is near a nuclear test site right before the blast. He climbs into a lead-lined refrigerator before the explosion. The appliance is tossed half a mile and Indy emerges none the worse for the experience. I read that some in the science community said that this sequence was not as implausible as it seemed. Nope, no way, not buying that hypothesis or that King Cool refrigerator.

GREATEST MATERIALS FILMMAKER

James Cameron

Notoriously demanding, endlessly innovative, and passionate about pushing the technical boundaries of filmmaking, James Cameron has given us three of the movies that appear in this article and the previous one: *Terminator 2: Judgment Day, Titanic,* and *Avatar.* Behind the camera, he pushes, breaks, and reinvents the envelope of what is possible as a filmmaker. You can see this clearly in how *The Abyss* and *Terminator 2* effectively introduced computer-generated imagery as a filmmaking revolution in special effects, how he punctuated *Titanic* with exquisite underwater photography of the actual shipwreck, and how *Avatar* reinvented three-dimensional photography and expanded computer-generated imagery to the level of photorealism. Cameron commenting on his influences: "I was always fascinated by engineering. Maybe it was an attempt maybe to get my father's respect or interest, or maybe it was just a genetic love of technology, but I was always trying to build things." In addition to working on four *Avatar* sequels, he is currently backing a business venture focused on asteroid mining. He represents all aspects of STEAM—science, technology, engineering, arts, and mathematics.

> "Sean Connery introduces himself thus: 'I am Juan Sánchez Villalobos Ramírez, Chief Metallurgist to King Charles V of Spain. And I am at your service.' Come on, what metallurgist wouldn't want to be as cool as Sean Connery?"
>
> —*Richard Bliss on* Highlander

THE MOVIE MATERIALS MOMENT OF THE AGES

Highlander (1986)

This ridiculous but fun Russell Mulcahy film does not feature much in the way of evocative technology and what-if science. Instead, it focuses on a race of sword-wielding immortals who seek their own kind to fight and ultimately decapitate to the music of Queen. The last immortal standing will be a really special guy. ("There can be only one!") True fact: *Highlander* spawned five sequels, two television series, and an animated series. Anyway, it does contain one cinematic materials moment for the ages. As Richard Bliss recently commented via TMS social media: "Sean Connery introduces himself thus: 'I am Juan Sánchez Villalobos Ramírez, Chief Metallurgist to King Charles V of Spain. And I am at your service.' Come on, what metallurgist wouldn't want to be as cool as Sean Connery?"

And that, dear reader, is the last word on this topic until the next sequel.

James J. Robinson is the Executive Director of TMS and a former Editor of *JOM*. His Twitter handle is @JJRofTMS. Ashley-Anne Bohnert, TMS Outreach and External Communications Lead, also contributed to this article and managed the "Greatest Materials Moments in Movies" social media campaign that generated much of this article's content.

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TMS meeting headlines

Meeting dates and locations are current as of October 1.
For the most up-to-date list of TMS-sponsored events, visit www.tms.org/Meetings.

Other Meetings of Note

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
Cranberry Township, Pennsylvania, USA

13th International Conference on the Technology of Plasticity (ICTP 2020)
July 25–30, 2021
Columbus, Ohio, USA

The 14th International Symposium on Superalloys (Superalloys 2021)
September 12–16, 2021
Seven Springs, Pennsylvania, USA

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

Materials in Nuclear Energy Systems (MiNES 2021)
September 19–23, 2021
Pittsburgh, Pennsylvania, USA

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

TMS2021
150th Annual Meeting & Exhibition

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

- TMS kicks off its 150th anniversary celebration year at the TMS 2021 Annual Meeting & Exhibition (TMS2021). Plans for this year's meeting include:
  - More than 85 symposia planned in 13 topic areas.
  - An All-Conference Plenary session featuring Anne Lauvergeon, founder/CEO of ALP, chair of École des Mines de Nancy, and former CEO of Areva SA.
  - Two co-located events: The Fourth Summit on Diversity in the Minerals, Metals, and Materials Profession (DMMM4) and the Fifth International Symposium on Nickel and Cobalt (Ni-Co 2021).

TMS ICME
MANUFACTURING · DESIGN · MATERIALS

April 18–22, 2021
Hyatt Regency Lake Tahoe
Lake Tahoe, Nevada, USA
Register by March 5, 2021
www.tms.org/ICME2021

- Confirmed plenary speakers at press time will include Bita Ghaffari, Ford Motor Company; Andrea Rovinelli, Argonne National Laboratory; Peter Voorhees, Northwestern University; and Charles H. Ward, Air Force Research Laboratory, among others.
- Book by March 26 to receive the group rate at Hyatt Regency Lake Tahoe. This waterfront resort in the Sierra Nevada mountains serves as both the congress location and hotel.

Mg 2021
12th International Conference on Magnesium Alloys and their Applications

June 15–18, 2021
Hotel Omni Mont-Royal
Montreal, Canada
Discount Registration Deadline: April 30, 2021
www.tms.org/Mg2021

- The 12th International Conference on Magnesium Alloys and their Applications (Mg 2021) aims to cover the breadth of magnesium research and development, from primary production to applications to end-of-life management. Sign up to receive updates on registration and more on the conference website.
- The plenary speakers confirmed at press time will include John Allison, University of Michigan, and Johnathan Weiler, Meridian Lightweight, among others. Visit the Technical Program page of the Mg 2021 website for details about the technical topics and speakers.

3DMS

June 29–July 2, 2021
Hyatt Regency Washington on Capitol Hill
Washington, D.C., USA
Register by May 18, 2021
www.tms.org/3DMS2021

- Register now for the 5th International Congress on 3D Materials Science (3DMS 2021) to discuss topics such as three-dimensional characterization, visualization, quantitative analysis, modeling, and development of structure–property relationships of materials, as well as big data and machine learning issues associated with 3D materials science.

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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.**

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

July 2021
Manuscript Deadline: February 1, 2021

Topic: Machine Learning in Design, Synthesis, and Characterization of Composite Materials

Scope: Machine learning methods are enabling unprecedented advances in the area of composite materials. These methods are versatile in handling a large number of parameters and are helping in developing novel materials structures and compositions for the given application requirements. This topic is intended to cover all aspects of application of machine learning methods to the field of composite materials, including design of microstructure, synthesis condition optimization, and evaluation of properties.
Editors: Nikhil Gupta, Simona Hunyadi Murph, and Ramasis Goswami
Sponsor: Composite Materials Committee

Topic: Nanomaterials and Composites for Energy Conversion and Storage

Scope: The emergence of nanostructured and composite materials has resulted in significant advancements in energy conversion and storage, such as fuel cells, photovoltaic cells, batteries, and supercapacitors. The topic scope includes the design and development of

low-dimensional nanomaterials; photocatalysts and photoelectrochemical devices for solar fuel production; semiconductors nanomaterials for new-generation solar cells; computational nanomaterial science; and electrode nanomaterials for efficient energy storage systems including batteries and supercapacitors, etc.
Editors: Yu Lin Zhong, Soumendra Basu, and Ziqi Sun
Sponsor: Energy Committee and Energy Conversion and Storage Committee

Topic: Phase Transformations during Solid-phase Welding and Processing

Scope: Papers are invited covering phase transformations and interfacial phenomena during solid-phase welding and processing.
Editors: Piyush Upadhyay and Arun Devaraj
Sponsor: Shaping and Forming Committee

August 2021
Manuscript Deadline: March 1, 2021

Topic: Additive Manufacturing: Functionally Graded Alloys

Scope: Functionally graded metals or "gradient alloys" have the potential to add a completely new dimension to metal additive manufacturing by allowing the composition of near-net-shaped parts to be strategically controlled. Successful demonstrations of applications, challenges, and paths forward for the research area are reflected. Emerging metal additive manufacturing technologies that are more conducive to functionally grading metals can be discussed, along with comments about the intersection between metal printing and metal coating.
Editors: Somayeh Pasebani and Tom Stockman
Sponsor: Additive Manufacturing Committee

Topic: Defect and Phase Transformation Pathway Engineering for Desired Microstructures

Scope: Extended defects such as dislocations and internal interfaces have been frequently utilized to tune desired phases and optimize mechanical properties. This special topic aims to publish research that brings together state-of-the-art characterization tools and computational tools for fundamental understanding of defect-microstructure interactions and the corresponding defect engineering strategies to design new microstructures, both homogeneous and heterogeneous / hierarchical for unprecedented properties.
Editors: Yufeng Zheng, Rongpei Shi, and Rajarshi Banerjee
Sponsor: Phase Transformations Committee

Topic: Multiscale Methods for Design of High Performance Coatings

Scope: This topic emphasizes new results in the development and application of multiscale techniques (both experimental and computational) toward the design of high-performance coatings. Particular applications of interest include thermal barrier coatings, wear coatings, and coatings for extreme environments.
Editors: William J. Joost, R. Wesley Jackson, Mark Carroll, and Pantcho Stoyanov
Sponsor: ICME Committee

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Total No. of Copies (Net Press Run)	2,438	1,734
Paid and/or Requested Circulation		
Paid/Requested Outside-County Mail Subscriptions Stated on Form 3541 (*Include advertiser's proof and exchange copies*)	7	6
Paid In-County Subscriptions (*Include advertiser's proof and exchange copies*)	0	0
Sales Through Dealers and Carriers, Street Vendors, Counter Sales and Other Non-USPS Paid Distribution	811	589
Other Classes Mailed Through the USPS	0	0
Total Paid and/or Requested Distribution	818	595
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Free Distribution Outside the Mail (Carrier or Other Means)	1	1
Total Free Distribution	1,620	1,139
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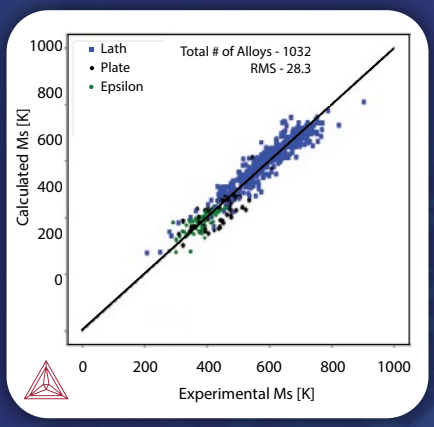
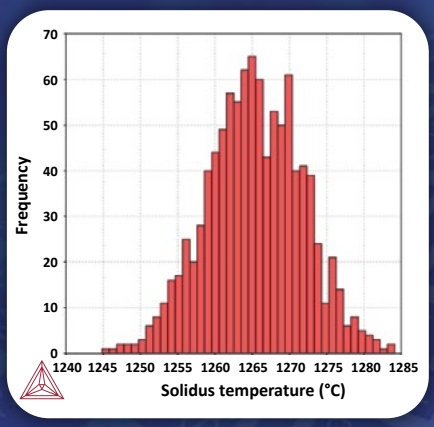


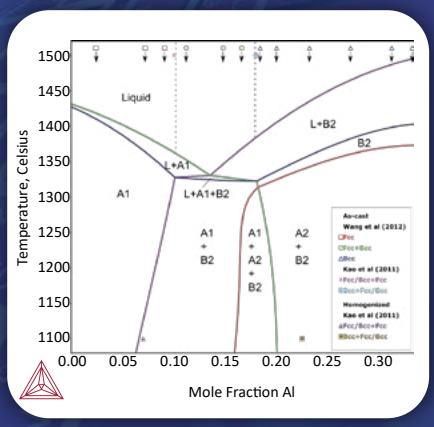
Comparison of calculated and experimental Ms temperatures for a wide range of steels

Nickel



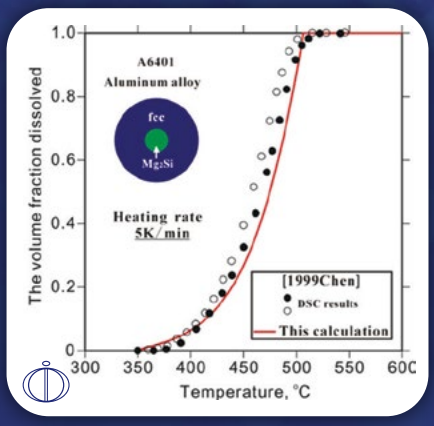
Variation in solidus temperature over 1000 compositions within alloy 718 specification

High Entropy Alloys



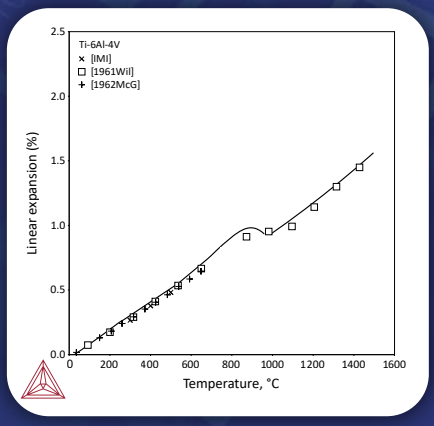
Calculated phase diagram along the composition line of CoCrFeNi-Al

Al Alloys



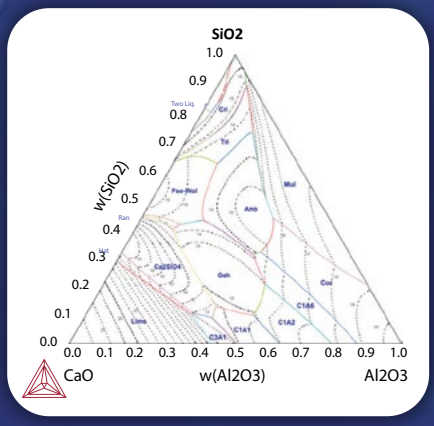
Dissolution of Mg2Si precipitate in Alloy A6401

Ti and TiAl Alloys



Linear expansion vs Temperature for Ti-6Al-4V

Oxides



Ternary liquidus projection in oxide systems

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