DECEMBER 2022
www.tms.org/JOM

JOM THE MAGAZINE

News and insights about TMS, its members, and the p[illegible]t serves

CONNECTING OFF-WORLD METALLURGY TO THE REAL WORLD

Emily Swallow is The Armorer in THE MANDALORIAN, exclusively on Disney+. © 2019 Lucasfilm Ltd. & ™. All Rights Reserved. Artist: François Duhamel (Used with Permission)

TMS2023: A Preview by the Numbers

TMS Springer

THE WORLD COMES HERE.

TMS 2023

152nd Annual Meeting & Exhibition

MARCH 19–23, 2023 | SAN DIEGO, CALIFORNIA, USA
#TMSANNUALMEETING | www.tms.org/TMS2023

REGISTER AND BOOK HOUSING TODAY: JOIN US FOR THE FULLY IN-PERSON TMS2023

Join us at one of our most popular destinations for the TMS Annual Meeting & Exhibition: San Diego, California! Historically, San Diego has hosted the Society's best-attended meetings, and—with more than 4,500 abstracts submitted—we expect strong attendance once again for TMS2023.

WHY TMS2023

"I really enjoy meeting new collaborators, catching up with friends and colleagues, attending excellent programs and symposia, having wonderful hallway conversations, and exchanging crazy ideas scribbled on restaurant napkins."

—**Fadi Abdeljawad,**
Assistant Professor, Department of Mechanical Engineering and Department of Materials Science & Engineering, Clemson University

KEY DEADLINES

January 31, 2023: Discount Registration Deadline
February 23, 2023: Housing Deadline

SCAN ME

REGISTER AND BOOK HOUSING AT: www.tms.org/TMS2023

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

Volume 74
Number 12
December 2022

5700 Corporate Drive
Suite 750
Pittsburgh, PA 15237
USA
Phone: 1-724-776-9000
Web: www.tms.org/JOM
E-mail: membership@tms.org

TMS
Springer

ABOUT THE COVER

The cover image features The Armorer from the Disney+ series, *The Mandalorian*. As the guardian of the secrets for crafting the show's mystical "beskar steel," The Armorer holds a position of power and spiritual leadership among her people. TMS members Suveen N. Mathaudhu, Eric M. Taleff, and Jeffrey Wadsworth explore the similarities between the metallurgical mythology of the *Star Wars* universe in which *The Mandalorian* is set and the traditions of ancient steelmaking in this month's cover article, "This is the Way: Tracing the Path between Damascus Steel and Beskar."

Cover Image Credit: Emily Swallow is The Armorer in THE MANDALORIAN, exclusively on Disney+. © 2019 Lucasfilm Ltd. & ™. All Rights Reserved. Artist: François Duhamel (Used with Permission)

Access Technical Journal Articles

TMS members receive free electronic access to the full library of TMS journals, including *JOM*. Technical articles published in *JOM*: The Journal are available on the Springer website. TMS members should log in at www.tms.org/Journals to ensure free access.

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 and engineering, from minerals processing and primary metals production to basic research and the advanced applications of materials. Learn more at www.tms.org.

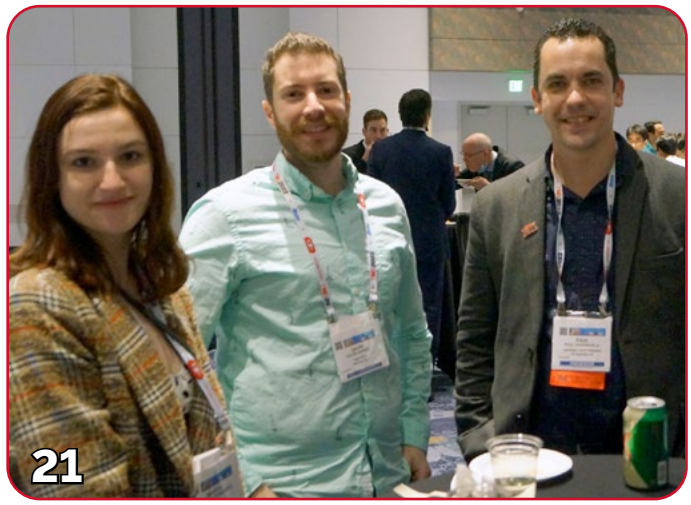
Postmaster:

Send address changes to: *JOM: The Magazine*, 5700 Corporate Drive Suite 750, Pittsburgh PA, 15237 USA. Periodicals postage paid at Pittsburgh, PA and additional mailing offices.

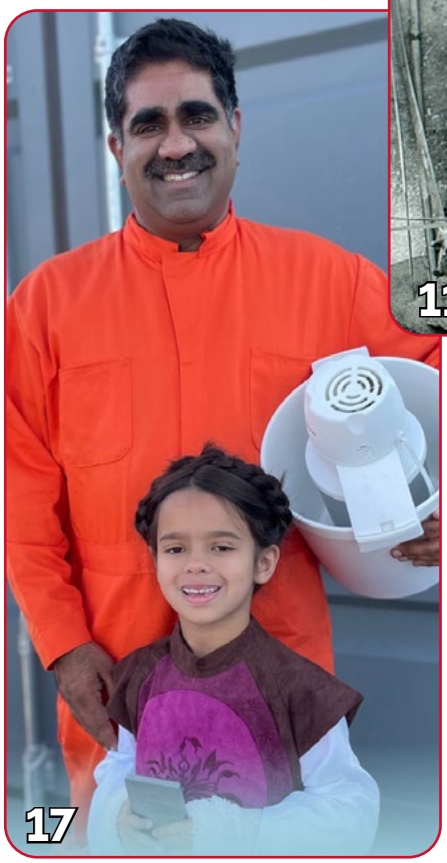
TABLE OF CONTENTS

JOM Volume 74 Number 12 December 2022

FEATURES



DEPARTMENTS



JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05586-5

IN THE FINAL ANALYSIS

JOM THE MAGAZINE

"I love San Diego as [the] location. Have attended now 15 times and still this is my favourite"
—Comment from TMS2020 Attendee Survey

Volume 74
Number 12
December 2022

James J. Robinson
Executive Director
@JJRofTMS

In a few months, TMS will return to San Diego, California, as the venue for our next annual meeting and exhibition: TMS2023. The last time that TMS convened in San Diego was three years prior in 2020. TMS2020 was the event at which the Society broke its attendance record. TMS2020 also proved to be one of the last major in-person conferences held in the United States before the country shifted into shutdown mode because of the spread of COVID-19. The following year's annual meeting could only be held as a virtual event; no one liked that. Next, TMS2022 was held in person but with a virtual option and to significantly reduced attendance.

We are now three years later, and TMS2023 will be all in-person and will not offer virtual or hybrid options. Critically, the threat of COVID-19 has diminished significantly. (Please remain true after this writing!) Still, our collective anxiety index has not ticked down completely—We have concerns over inflation, recessionary forecasts, lingering supply chain issues, and understaffing in all businesses. The world doesn't want us to have a good night's sleep just yet! Offsetting those concerns are an excellent technical program, a membership community eager to reconvene and network, and international travel that continues to unlock.

Also working in our favor: The lure of our host city, San Diego. As an association, TMS loves San Diego, and we have visited it frequently through the 2000s. Our venue space this coming year is familiar but with a twist. We have moved the conference to the south end of the convention center and have contracted the Hilton Bayfront at the south entrance to be our headquarters hotel—not the Marriott Marquis on the north side as has been our past practice. The spaces that we are using are newer, and we believe that you will find it all to be an enhanced experience as the center and hotel combine to present the event as an integrated whole.

Without sounding too much like an advertisement, TMS leadership very much encourages you to book your housing at the Hilton Bayfront. Attendees staying there will experience the most convenient location to benefit from all aspects of the meeting, including technical programming, committee meetings, exhibition, and social functions. It will surely be the hub of networking and camaraderie-building activities. Registrants staying at the headquarters hotel will also benefit from the exclusivity of an in-hotel conference registration desk for TMS2023, which will make unnecessary standing in long registration lines on Monday morning in the convention center.

There is one additional consideration to staying at the Hilton Bayfront. It is this: TMS has to promise the headquarters hotel that a certain number of sleeping rooms will be used by conference attendees. This gives guests preferential hotel benefits and gives the Society access to the hotel event rooms that it must employ to hold sessions, committee meetings, receptions, etc. It also enables the Society to precisely construct the desired event experience for attendees. Simple enough, but there is significant financial risk in this business model—If the Society fails to meet the sleeping room commitments, TMS must pay the difference or more. That blows up a budget quite quickly!

Regardless of where you book your room (did I mention that I endorse the Hilton Bayfront?), the TMS community is gathering steam to convene in San Diego because it wants—no, *needs*—to meet, talk, share ideas, mentor, be mentored, recruit, be recruited, present, see presentations, seek opinions, give opinions, and meet suppliers. Every bit of anecdotal data tells me that the TMS community is eager to put COVID behind it and reengage at conferences.

The TMS Annual Meeting and Exhibition feels like "home," and during March 19-23, 2023, TMS will celebrate homecoming with you.

"We are now three years later, and TMS2023 will be all in-person and will not offer virtual or hybrid options."

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05584-7

JOM TECHNICAL TOPICS

JOM THE MAGAZINE

JOM: The Journal includes peer-reviewed technical articles covering the full range of minerals, metals, and materials. TMS members receive free electronic access to the full library of TMS journals, including *JOM*. For the full Editorial Calendar, visit **www.tms.org/EditorialCalendar.**

Review the technical topics included in the current issue of *JOM*: The Journal here, and then go to **www.tms.org/JOM** to log in access technical journal articles on the Springer website.

// DECEMBER 2022

Advances in Reversible Solid Oxide Electrochemical Cells for Energy Conversion

Scope: Reversible solid oxide electrochemical cells (RSOECs) can play a key role in clean energy storage and conversion by utilizing the time varying difference in supply and demand of clean (solar and wind) energy. When supply exceeds demand, the RSOECs can be run in an electrolyzer mode using the excess energy to split steam and generate hydrogen. When demand exceeds supply, the hydrogen can be used to generate electricity by running the RSOECs in a fuel cell mode. The scope of this special topic includes electrochemical performance, microstructural and mechanical stability, new materials and modification techniques that reduce polarization in the electrodes and electrolyte, poisoning effects and mitigation, among others, when the RSOECs are run in the electrolyzer mode, fuel cell mode, as well as cycling between the two modes.
Editors: **Soumendra Basu**, Boston University, and **Yu Zhong**, Worcester Polytechnic Institute
Sponsors: Energy Conversion and Storage Committee and Energy Committee

Advances in Surface Engineering

Scope: This special topic captures recent advances in processing, characterization, simulation/modeling, and applications related to surface engineering of materials. Areas of interest include surface protection from wear and corrosion, surface characterization techniques, surface alloying, and nano-structured surfaces.
Editors: **Tushar Borkar**, Cleveland State University, **Arif Mubarok**, PPG, and **Jasthi Bharat**, South Dakota School of Mines & Technology
Sponsor: Surface Engineering Committee

Interactions Between Biomaterials and Biological Tissues and Cells

Scope: This topic investigates the physical, mechanical, biological, and biochemical interactions between engineered biomaterials and biological tissues and cells. Topics of interest include biointerfaces, mechanobiology, biocompatibility, tissue compatibility, inflammatory responses, biodegradation, toxicity, tissue regeneration, protein-materials interactions, cell-material interactions, and biomimetic and bioinspired surfaces.
Editors: **Jing Du**, Pennsylvania State University; **Dinesh Katti**, North Dakota State University; and **Vinoy Thomas**, University of Alabama at Birmingham
Sponsor: Biomaterials Committee

Phase Stability and Transformation of Energy Storage Materials

Scope: This special topic covers: (1) structure, chemistry, and processing of energy storage materials; (2) phase transformation, phase stability, and compositional short-range ordering in energy storage materials; (3) recycling of energy storage materials; (4) advanced characterization including neutron scattering, 3-dimension scanning electron microscopy, scanning transmission electron microscopy, in-situ x-ray diffraction, etc.; (5) chemo-mechanical processing of energy storage materials; (6) computational modeling: first-principles density functional theory, molecular dynamics, Monte Carlo simulations, phase field, CALPHAD, etc.
Editors: **Songmao Liang**, CompuTherm; **Bin Ouyang**, Florida State University; **Shih-Kang Lin**, National Cheng Kung University; and **Hans Jürgen Seifert**, Karlsruhe Institute of Technology
Sponsor: Alloy Phases Committee

Contribute to *JOM*: The Journal

Visit **www.tms.org/JOM** to access author tools that will answer your questions during every step of the manuscript preparation process, from determining the appropriate technical topic for your paper to reading the final product on Springer.
For further information on contributing to *JOM*, contact *JOM* Editor Maureen Byko at mbyko@tms.org.

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05587-4

TMS MEMBER NEWS

JOM THE MAGAZINE

Share the Good News!

Contact Lynne Robinson, Department Head, Marketing and Communications, at lrobinson@tms.org. to share your professional accomplishments. Please note that only news submitted by current TMS members will be considered.

Joy Gockel Named America Makes Ambassador

Joy Gockel was named to the 2022 class of America Makes Ambassadors. America Makes launched the Ambassador Program in 2017 to honor and recognize those who champion and demonstrate outstanding dedication to America Makes and its mission.

A TMS member since 2016, Gockel has served on a variety of TMS committees including the Additive Manufacturing Bridge Committee, the Education Committee, the Mechanical Behavior of Materials Committee, the Emerging Professionals Committee, and was a member of the Structural Materials Division (SMD) Council. Gockel is a recipient of the 2021 SMD Young Leaders Professional Development Award and was selected to participate in the 2021 Emerging Leaders Alliance Program. She also served as an organizer for the Processing-Structure-Properties Foundations in Additive Manufacturing online TMS course held in January 2022.

Paul Ohodnicki Featured by *Pittsburgh Business Times*

In August 2022, **Paul Ohodnicki**, CorePower Magnetics and University of Pittsburgh, was featured in the "20 People to Know in Energy" series by the *Pittsburgh Business Times*. In a question-and-answer style article, Ohodnicki discussed energy, electrification, and the related workforce challenges.

A TMS member since 2009, Ohodnicki is a recipient of the 2010 Functional Materials Division (FMD) Young Leaders Professional Development Award. Currently, Ohodnicki is serving as the chair of the study team for the TMS accelerator study, *Accelerating Research and Technological Development in the Additive Manufacturing of Energy-Related Functional Materials*, and as the TMS FMD Director/Chair on the TMS Board of Directors.

Correction

JOM: The Magazine staff apologizes for the misspelling of **Savannah River National Laboratory** in the September 2022 article, "TMS Member News."

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION

Publication Title: *JOM*; Publication No.: *281-200*; Filing Date: *October 1, 2022*; Issue Frequency: *Monthly*; No. of Issues Published Annually: *12*; Annual Subscription Price: *$995*; Complete Mailing Address of Known Office of Publication: *One New York Plaza, Suite 4600, NY, NY 10004-1562*; Contact Person: *William Coatsworth; Telephone: (212) 815-0245*; Complete Mailing Address of the Headquarters or General Business Office of Publisher: *One New York Plaza, Suite 4600, NY, NY 10004-1562*; Publisher: *Springer Science & Business Media, One New York Plaza, Suite 4600, NY, NY 10004-1562*; Editor: *Maureen Byko, TMS, 5700 Corporate Drive Suite 750, Pittsburgh PA, 15237*; Owner: *The Minerals, Metals & Materials Society, 5700 Corporate Drive Suite 750, Pittsburgh PA, 15237*; Known Bondholders, Mortgagees and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages or Other Securities: *None*; The purpose, function and nonprofit status of this organization and the exempt status for federal income tax purposes has not changed during the preceding 12 months; Publication Name: *JOM*; Issue Date for Circulation Data Below: *August 2022*.

Extent and Nature of Circulation	Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
Total No. of Copies (Net Press Run)	63	63
Paid and/or Requested Circulation		
Paid/Requested Outside-County Mail Subscriptions Stated on Form 3541 (*Include advertiser's proof and exchange copies*)	1	1
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	47	43
Other Classes Mailed Through the USPS	0	0
Total Paid and/or Requested Distribution	48	44
Free Distribution by Mail (Samples, Complimentary and Other Free)	15	19
Free Distribution Outside the Mail (Carrier or Other Means)	0	0
Total Free Distribution	15	19
Total Distribution	63	63
Copies Not Distributed	0	0
Total	63	63
Percent Paid and/or Requested Circulation	76.03%	69.84%

The Statement of Ownership will be printed in the December 2022 issue of this publication.

I certify that all information furnished on ths form is true and complete. _____
Signature of Publisher

I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions *(including fines and imprisonment)* and/or civil sanctions *(including multiple damages and civil penalties)*.

This statement presents information filed on U.S. Postal Service's Statement of Ownership, Management, and Circulation Form (PS Form 3526, July 2014) as required by 39 U.S.C. 3685.

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05585-6

THIS IS THE WAY: TRACING THE PATH BETWEEN DAMASCUS STEEL AND BESKAR

Suveen N. Mathaudhu, Eric M. Taleff, and Jeffrey Wadsworth

(L-R): The Mandalorian (Pedro Pascal) and the Armorer (Emily Swallow) in Lucasfilm's THE BOOK OF BOBA FETT, exclusively on Disney+. © 2022 Lucasfilm Ltd. & ™. All Rights Reserved. Artist: Francois Duhamel. (Used with permission)

Ba'jur bal beskar'gam.	*Education and armor;*
Ara'nov, alit,	*Self-defense, our tribe,*
Mando'a bal Mand'alor –	*Our language and our leader –*
An vencuyan mhi.	*All help us survive.*

Rhyme taught to Mandalorian children to help them learn the Resol'nare – the six tenets of Mando'ade culture[1]

Since the very first scene in the first episode of the Disney *Star Wars* space-western series, *The Mandalorian*, the rarity and importance of the metal armor cladding our protagonist, Din Djarin (aka "Mando") is apparent. In this scene, a trawler asks Mando, "Is that real beskar steel?" The dual cultural and utilitarian nature of beskar provide a consistent thread as the stories around Mando progress, with the material serving many purposes during key plot points. From securing the sacred valuable ingots pillaged by the Empire, to being crafted into blaster- and lightsaber-resistant pure armor by skilled artisans, to a spherical shifter knob fidget toy, the value and implementation of beskar are at the forefront of *The Mandalorian*'s story.

HISTORY OF BESKAR

"Mandalorian iron" was first introduced into the *Star Wars* universe in 1994 in the now non-canonical *Tales of the Jedi* comic series. The first mention of Mandalorian iron as beskar appears in a 2006 issue of *Star Wars Insider* in a story titled: "The Mandalorians: People and Culture."[2] This article provides a basis for the depiction of beskar in the *Star Wars: Clone Wars* and *Star Wars: Rebels* animated series, and *The Mandalorian* and *The Book of Boba Fett* live-action Disney series. It specifically describes the unique properties and metallurgical heritage of beskar as follows:

"Armor, especially the distinctive full-face helmet with T-shaped visor, is the enduring image the galaxy has of Mando'ade. Armor is prized, especially if it is made from near-impervious beskar (Mandalorian iron), a metal that gets its remarkable strength not only from its natural properties but also from Mandalorian metalworking techniques. The addition of carbons in the foundry creates a molecular cage structure—lighter than normal metals and yet still remarkably strong. Repeated folding of the metal during forging further enhances beskar's strength. It's still regarded as more desirable than durasteel and even cortosis."[2]

This depiction of beskar is clearly inspired by ancient tales of steel-making that pulled humanity out of the Bronze Age and into the Iron Age. The mixing of iron and carbon to make steel provided the underpinning technologies that advanced the world in countless ways. Further, the allusion to a combination of properties in the material, along with acknowledgement of the skill of Mandalorian metalwork, lend an air of mystery to the fabrication techniques. Fast-forwarding to *The Mandalorian* series, we learn and see clues as to how the beskar can be manipulated, with the biggest clue to the real-world inspiration (ignoring that the story occurs "A long time ago in a galaxy far away…") presented in the pattern seen on the Imperial cast ingot bounty paid to Mando to secure The Child.

ABOUT THE AUTHORS

Suveen Mathaudhu (he/him/his) is a professor in the Metallurgical and Materials Engineering Department at Colorado School of Mines. He greatly enjoys connecting and communicating materials science to broad, diverse communities through associations with pop culture. He has been a TMS member since 1999, and currently serves as on the TMS Board of Directors as the chair of the Structural Materials Division.

Eric Taleff is a professor of Mechanical Engineering and a member of the Materials Science and Engineering Graduate Program at The University of Texas at Austin. Since 1995, he has been a member of TMS, where he has volunteered and generally bounced around amicably, primarily in the Structural Materials Division. His interests include all aspects of mechanical metallurgy.

Now retired, **Jeff Wadsworth** is the former president and chief executive officer of Battelle, following careers at Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, Lockheed, and Stanford. He joined TMS in 1976. His avid interest in Damascus steels, welded Damascus steels, and carbon dating of ancient steel objects led to many talks on these topics, the most unusual location being San Quentin State Prison (as an invited guest…)

INTRODUCING A NEW GENERATION TO AN ANCIENT ART

Established in 2015, the TMS Bladesmithing program has brought metallurgical concepts and mythology to life by challenging student teams to produce a blade by hand hammering or trip hammer forging in a fiery competition held every other year. In the alternate years, students have the opportunity to present work on bladesmithing topics at the TMS Bladesmithing Symposium. For more information on TMS Bladesmithing, visit www.tms.org/bladesmithing. And, plan to attend the next Bladesmithing Symposium slated for the TMS 2023 Annual Meeting Exhibition, March 19-23, San Diego, California.

INSPIRATION OF DAMASCUS STEEL

> **"It is amazing how beautiful beskar can be when forged by its ancestral artisans."**
>
> —The Client, admiring Mando's armor, S1, Ep7 of *The Mandalorian*

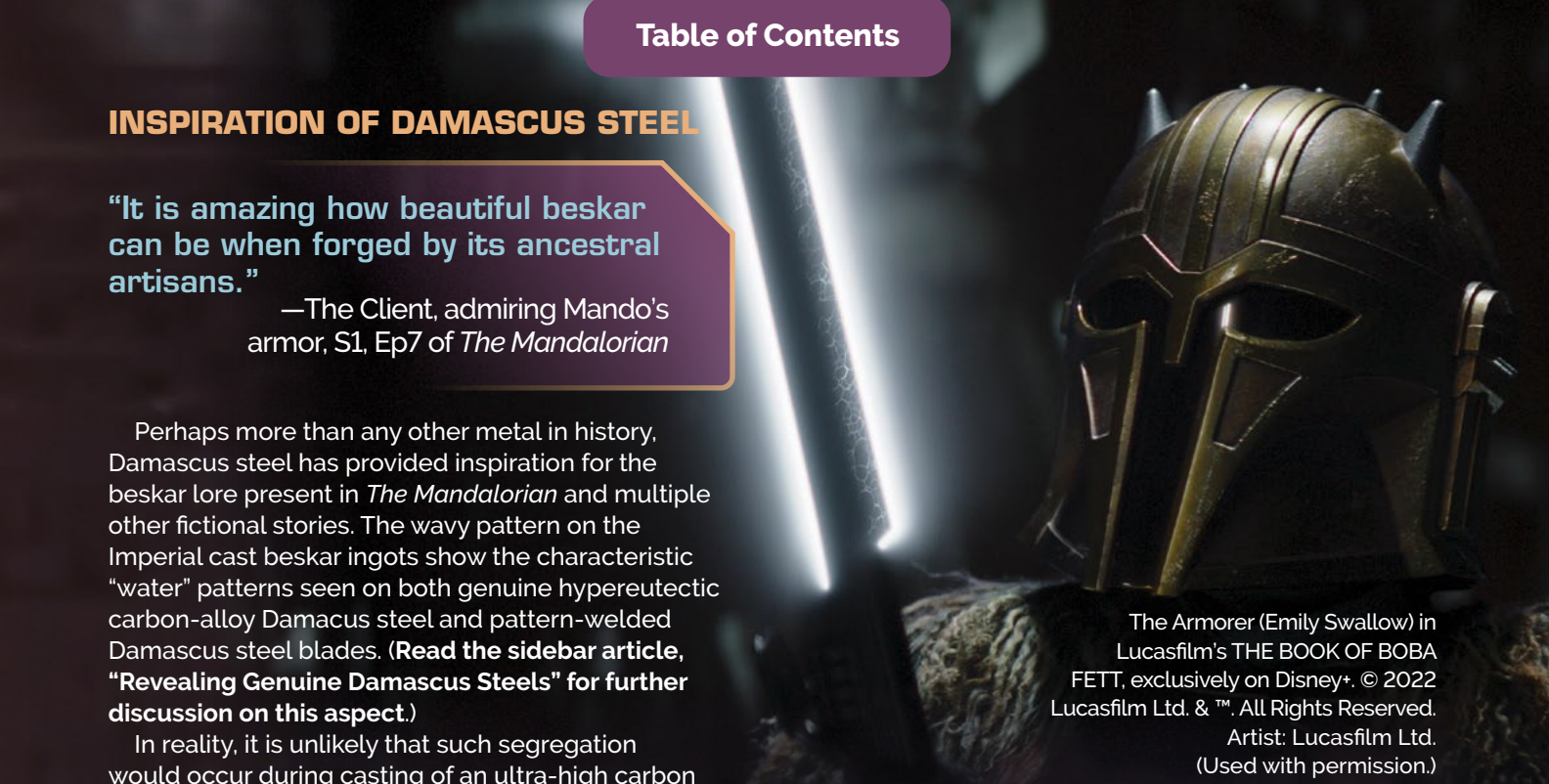
Perhaps more than any other metal in history, Damascus steel has provided inspiration for the beskar lore present in *The Mandalorian* and multiple other fictional stories. The wavy pattern on the Imperial cast beskar ingots show the characteristic "water" patterns seen on both genuine hypereutectic carbon-alloy Damacus steel and pattern-welded Damascus steel blades. (**Read the sidebar article, "Revealing Genuine Damascus Steels" for further discussion on this aspect**.)

In reality, it is unlikely that such segregation would occur during casting of an ultra-high carbon steel alloy. These patterns are developed through combinations of thermally driven phase segregation during cooling, multiple forgings/foldings/rollings, and chemical etching of the metal surface. But given the ubiquity of welded Damascus steels, it is obvious why the show creators would choose to use this pattern to convey rarity, extreme performance, and legendary craftsmanship.

THE PROCESSING AND PROPERTIES OF BESKAR AND DAMASCUS STEELS

The depictions of beskar in *Star Wars* media portray it as a material with physical and mechanical properties far beyond conventional materials, and only achievable through the knowledge of its fabrication. In *The Book of Boba Fett,* the Armorer converts a dangerous beskar spear into a chainmail vest. As part of this process, the Armorer repetitively heats, forges and finally quenches the beskar. This is very similar to the techniques used by smiths to repeatedly heat and hammer "bloom" iron to remove impurities. If pure beskar is deemed most desirable, then this purification step would be critical. At the same time, beskar is shown to be crush-resistant, acid- resistant, blaster-resistant, and lightsaber-resistant as well.

In their time, Damascus steels likely had a similar mythos, particularly as it relates to the secrecy around their fabrication **(Read the sidebar article, "Can Sword Making Technologies be "Lost"? for further exploration of this topic.)** Would Damascus steel be able to deflect a blaster bolt or lightsaber? Likely not, but for the people of the time, an ancient Damascus sword likely carried an aura of "magic" and extreme value, like that of beskar.



The Armorer (Emily Swallow) in Lucasfilm's THE BOOK OF BOBA FETT, exclusively on Disney+. © 2022 Lucasfilm Ltd. & ™. All Rights Reserved. Artist: Lucasfilm Ltd. (Used with permission.)

THE ARMORER: AN ICON OF REPRESENTATION

> **"Armor is often handed down between generations, especially the beskar type. It's intricately customized to suit the wearer's need and tastes and is worn by both genders."[2]**
>
> —"The Mandalorians – People and Culture"[2]

The wearing of Mandalorian beskar armor has never been restricted to men in the *Star Wars* universe, and neither has the role of the artisans that craft beskar, guard the secrets of its manipulation, and provide political and spiritual leadership. In *The Mandalorian* series, the character of The Armorer is a female master craftsperson of beskar, using the imaginary tools of a "cryo-forge," beskar "gravity hammer," and "magnetic tongs", with the latter two also serving as tools for personal defense. This depiction is a welcome transformation from the traditional portrayals of blacksmiths as always male. In an interview with starwars.com, Emily Swallow, the actress who plays The Armorer states "It's a huge honor to get to represent this character and a huge joy. . .the thing that just fills me up more than anything else is the way that she gives women and girls strength."[3] The Armorer is an amazing example of representation that can provide the diversity of the next generation with characters that they can see themselves in.

REVEALING GENUINE DAMASCUS STEELS

In *The Mandalorian*, *The Book of Boba Fett* and other canon *Star Wars* elements, there is an understanding that there are "grades" of beskar, with pure beskar being put forward as the most desirable variety. As with beskar Imperial ingots, historical Damascus steel was characterized by wavy, water-like patterns created by carbide particles in *genuine* Damascus steels or by layers of a second steel composition in *welded* Damascus steels (Figure 1).

It is the earliest encounters of Europeans with genuine Damascus steels, presumably near Damascus, Syria, from which the name originated for this group of steels with their now famous damascene patterns. The genuine Damascus steels of the ancient world exhibit a visible pattern described by carbide particles whose origins are still the subject of controversy. It is now generally accepted that both local composition variations and movement of material during forging play important roles.

The inability of early Europeans to reproduce steels with the enviable properties and beautiful surface patterns of genuine Damascus steels led many artisans to apply the pattern welding technique to produce materials with damascene surface patterns but generally poorer mechanical properties than genuine Damascus steels, at least by anecdotal accounts. The pattern welding technique forges together two or more steels of different composition into patterns determined by the forging schedule, giving extreme control of the patterns created. Patterns are revealed through the different responses of these steels to a surface treatment, usually chemical etching. When pattern welding—a technology common to many historical societies throughout the world—is applied to simulate the patterns of genuine Damascus steels, the resulting material is termed a welded Damascus steel. Pattern welded Damascus steels are available today from artisans across the globe in spectacularly beautiful forms. But the fundamental metallurgy of these is quite different from that of the genuine Damascus steels of history.

In *The Mandalorian,* unlike the Imperial ingot, Din Djarin's armor appears to have a mirror finish, with no evidence of waviness or segregation, providing evidence of solute impurities in the starting materials and in other sub-standard or impure beskar alloys that only a skilled Armorer can refine to high purity. Din Djarin also observes of the Darksaber, made and employed by Tarre Vizla, an ancient Mandalorian Jedi, that "the hilt is of a quality of beskar that I have never seen before."

So, while surface patterns were historically noted as the mark of good properties in historical genuine Damascus steels, it appears that the absence of such patterns denotes the best quality of the fictional beskar.

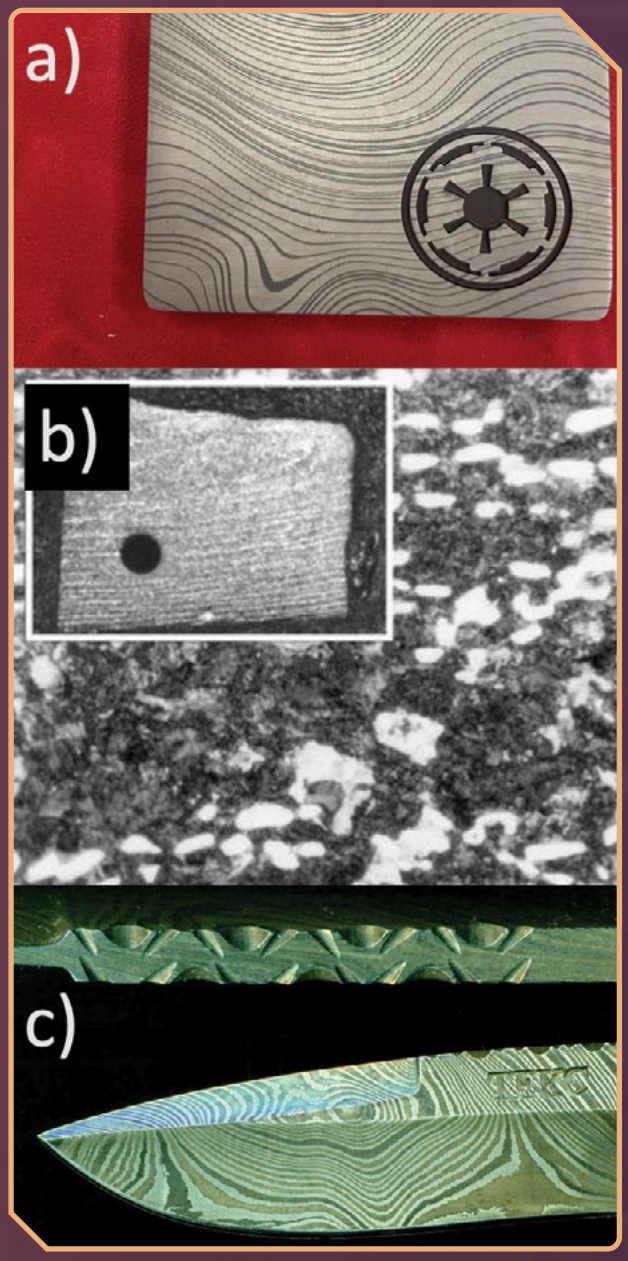


Figure 1: Three wavy materials a) Prop beskar Imperial ingot showing sinuous patterns reminiscent of Damascus steels. The sample is nominally 70mm wide. (Photo credit: S. Mathaudhu), b) A macrograph of a fragment from a Damascus blade (about 10 mm a side) showing the characteristic pattern. The microstructure reveals the mix of fine and coarse carbides; the latter carbides are aggregated and make the visible light-colored part of the macroscopic pattern.[4] (Used with Permission), c) pattern welded "Damascus" steel blade (nominally 20 mm wide)[5]

CAN SWORD MAKING TECHNOLOGIES BE "LOST"?

In *Star Wars* canon and *The Mandalorian*, beskar is only available on Mandalore and its moons. The art and tools for the forging of beskar armor are closely guarded secrets only in the possession of Armorers, who would die rather than reveal this knowledge. In our universe, it is commonly believed that the art and science of making Damascus steel were only in the possession of select artisans and has been lost to the ages (Figure. 2). Methods to produce the hypereutectoid (high-carbon) steel ingots, called wootz, from which Damascus steels were forged and the forging processes used to create Damascus steels are still being researched, and hopefully rediscovered.

Many modern hypereutectoid steel blades have been made that bear striking similarities to the Damascus steels of ancient times. Figure 3 displays micrographs of ultra-high carbon steels (UHCS) produced in the laboratory of the late Professor Oleg Sherby at Stanford University in the modern era (1980s).[4] In parallel, our understanding of the unique microstructures in Damascus steels has recently deepened through the use of unique electron microscopy and other modern characterization techniques. Unraveling the mysteries of Damascus steels may satisfy our anthropological curiosity, but the reality is that modern steel alloys have desirable properties that far surpass those achieved by historical Damascus steels. Modern metallurgical theory indicates that uniformly distributed fine carbides, as opposed to carbides coarse enough to be visible in a damask pattern, provide the best microstructures for achieving strength, ductility, and toughness.

That being said, it is clear that the Damascus steel blades made with wootz were far superior in strength, toughness, and edge retention to other steels of the same time period, at least throughout Europe and the Near East. The secrets to making stronger metals have been a driving force for sword performance improvements. Early copper and bronze alloys are relatively weak, with Diamond Pyramid Hardness (DPH) values of 50-70. Wrought iron has a similar hardness (DPH = 100), but cold working doubles this value (DPH ~200), which matches some complex bronze alloys. The addition of a high amount of carbon (>1.5%) is what truly contributed to a disruptive change. A Damascus sword, even in the annealed condition, demonstrated DPH values of 320-370—and after heat treatment could reach hardnesses as high as (DPH ~1000).[6]

Historically, there was great secrecy surrounding the metallurgy of sword production. For example, the master Japanese sword-maker, Akihira Miyairi (1927-1977), named a Living Treasure of Japan, knew where to go for iron-rich river sand but did not keep records of the location, nor did he write anything down. Therefore, the only way to mimic his prowess is to continue to try different methods.

Rest assured that while the specific details of Damascus steel (and beskar) production are not exactly known, we have, as a society, discovered numerous ways of producing better materials and continue to do so with the efforts of many dedicated TMS members.

Figure 2: A sword maker of Damascus, whose swords were once considered the finest in the world.[7]

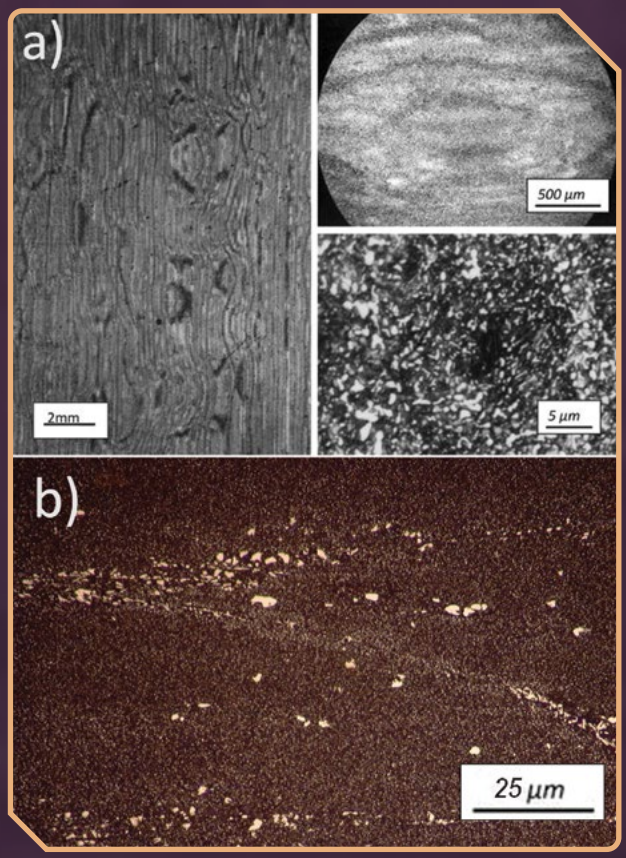


Figure 3: a) Macrographs and micrographs of a UHCS processed to produce a visible pattern. The microstructure reveals coarse carbides in bands that lead to the visible structure.[4] (Used with Permission), b) Microstructures of UHCS damask material where the coarse carbides contribute the macroscopically visible surface patterns upon etching (Photo credit: E. Taleff.)

THE TMS CONNECTION

The legends of beskar and Damascus steels are just the surface of the connectedness between the materials we study and pop-culture representations. But for beskar and the Mando'ade, we'd like to think that the connection runs deeper. The poem at the beginning of this feature, taught to Mandalorian foundlings, is quite applicable to one's experience as a member of TMS. Education is clearly a primary mission of our society, as is the "protection" and advancement of knowledge. We recognize our unique role in the advancement of humanity through improving materials, and we've heard it said that "TMS is my tribe." Walk into any TMS technical talk or discussion, and it's clear that we have our own language. And, every year we elect leadership to provide vision and guidance for the direction of our TMS tribe. Combined, "All help us survive," and in the words of Mando, "Loyalty and solidarity are the way."

REFERENCES

1. *Star Wars: The Bounty Hunter Code, from the files of Boba Fett*. Daniel Wallace, Ryder Windham, and Jason Fry pg. 139, Chronicle Books, 2021
2. *Star Wars Insider*, "The Mandalorians – People and Culture," #86, March/April 2006, IDG Entertainment
3. https://www.starwars.com/news/emily-swallow-interview-the-book-of-boba-fett, March 8, 2022
4. Wadsworth, J. Connections: Superplasticity, Damascus Steels, Laminated Steels, and Carbon Dating. *JOM* **68**, 3150–3160 (2016). https://doi.org/10.1007/s11837-016-2122-8
5. Knife made by Trail's End Knife Company,Collinsville,OK.2011. https://commons.wikimedia.org/wiki/File:Knife_blade_600dpi_spine_1200dpi.jpg
6. Wadsworth, Jeffrey. "Archaeometallurgy Related to Swords." *Materials Characterization* 99 (2015): 1-7.
7. A bladesmith from Damascus, Syria, Copyright 1900 by Underwood and Underwood. Public access information: https://en.wikipedia.org/wiki/Damascus_steel#/media/File:Damascus_bladesmith.jpg

A FICTIONAL EXPLORATION OF THE "SCIENCE" OF BESKAR

The next section, "Processing--Structure-Property Relationships in Pure Beskar and Beskar Alloy", is an attempt to extract canonical knowledge from the *Star Wars* universe to generate an (obviously) "make-believe" scientific manuscript. In other words, we have endeavored to use the physics and knowledge of the "real" world to explain the behaviors of fictional beskar materials. Some of the assertions were challenging and present interesting questions.

Journal of Outer-Rim Metallurgy and Materials, A., Vol. 1138, No. 5, 11 ABY

PROCESSING-STRUCTURE-PROPERTY RELATIONSHIPS IN PURE BESKAR AND BESKAR ALLOY

Willrow Hood, Ph.D.[1]
[1]Shadow University - Cloud City Campus, Bespin, Anoat Sector, Outer Rim Territories

ABSTRACT

Mandalorian iron, also known as beskar, has long been recognized for its incredible strength and resistance to corrosion, blaster fire and lightsaber attacks, making it ultimately suitable for armor (*beskar'gam)*. The study of beskar alloys to elucidate the underlying mechanisms for these remarkable behaviors has been limited by the lack of access to high-quality samples and the usage of closely guarded, specialized synthesis and processing techniques. In this report, historic literature is probed, and an Empire foundry-produced cast Imperial ingot is studied to determine microstructure, corrosion, hardness and blaster resistance. The findings are compared with what is known of Mandalorian-produced pure (unalloyed) beskar to extrapolate the unique processing benefits known only to Mandalorian metalsmiths (*naur'alor)*. It is hypothesized that the unique tools of the *naur'alor*, namely, full-power Arc Pulse Generator induction melting and refining, cryo-forging, and gravity hammering with magnetic tongs, result in pure beskar, with nano-twinned microstructure with high Phrik hardness values (>900 Ph), and a permanent magnetic field (>20T) that effectively blocks most blaster and lightsaber attacks. These findings provide background knowledge for the future technological implementation of beskar and its alloys.

EDITOR'S NOTE: This is a work of fiction and is not to be cited as a scientific publication.

INTRODUCTION

The ore from which Mandalorian iron (also known as Mandalorian steel, beskar steel or colloquially by its *Mando'a* name, *beskar*) has only been discovered in the Outer Rim Mandalorian system on the planet Mandalore and its moon, Concordia. The rare mineral is thought to have formed eons ago, with its first metallurgical refinement and usage being documented in the Great Jedi Library on Ossus circa 5000 BBY (Before the Battle of Yavin). However, the knowledge was lost with the destruction of the library in 4000 BBY. The *Dha Werda Verda* epic and surviving Taung texts write of the Taung species (also known as the Shadow Warriors or Progenitors) arriving from Coruscant (then known as Notron) in ~100,000 BBY, largely due to the presence of the beskar ore, and then harnessing the rare material. The Taung Progenitors also modeled and formed the cultural basis of Mandalorian society, including the reverence for beskar metallurgy.

The first documented implementation to create armor (*Beskar'gam,* translated from *Mando'a* as "iron skin") was believed to have occurred in ~501 BBY with swords (*beskade*), manacles, crush gauntlets, tombs and starships following soon after. The most recent, yet sparse knowledge on beskar metallurgy was documented by Pilas Manaitis in the *Strategic Resources of the Galaxy (*19 BBY):

"Beskar is a uniquely resistant iron that develops a wide range of properties – and colors – in the hands of skilled metalsmiths. Depending on the alloy, it can take any form from plate, laminate, and wire to foam, mesh, micronized particles, and even a transparent film. Mandalorians jealously guard their beskar-working skills and refuse to sell the formulas at any price; attempts to reproduce finished beskar elsewhere have been disappointing. The ore is found solely on Mandalore, and only Mandalorians know how to work it to maximize its extraordinary properties. Therefore, if you want beskar, you must take Mandalore. But that inevitably proves easier to say than to do."[1]

Beskar (Bs) is known to exist in various alloys and forms, including pure (elemental/unalloyed) beskar or alloyed beskar (with various concentrations of carbon (C), ciridium (Ci) or other microconstituent elements such as zersium (Ze), tydirium (Ty) and Phrikite (Ph) added. The added usage of "iron" and "steel" likely stems from two factors: 1) the suspected similarity in metal-working methods to iron (Fe) and steel (Fe-C) materials, such as those used to fabricate durasteel, thus leading non-Mandalorian people and cultures to use more generalized non-*Mando'a* terms, and 2) the lack of desire by Mandalorians to sully the name *beskar* with a translation. For the purpose of this study, "pure beskar" will refer to pure, elemental materials, and "beskar alloy" will refer to beskar with other desired or undesired elemental additions.

Following the Great Purge of Mandalore circa 2 ABY (After the Battle of Yavin), the Empire collected the vast majority of beskar ore for smelting, closed the Mines of Mandalore, and cast the seized beskar and beskar alloy into Imperial ingots (Figure 1). While rare, the open market presence of beskar alloy has created renewed interest in scientifically exploring the fundamental processing-microstructure-property-performance relationships that give beskar alloy its unprecedented functionality, utility and value, namely high-strength and blaster resistance. In this paper, we have studied the microstructure of beskar alloy fabricated by processing methods created in the scientific laboratories of the Empire, we have measured the resulting resistance to mechanical and blaster (plasma) damage, and then we hypothesize the observed behaviors in context of reported traditional, semi-secret Mandalorian processing of pure beskar, and the properties resulting from such methods.

Figure 1: Imperial ingot of beskar alloy obtained from the Cloud City Empire Foundry. (EDITOR'S NOTE: Photo of prop ingot. Photo credit: S. Mathaudhu)

MATERIALS AND METHODS

The beskar alloy used for this study is nominally 0.968 wide x 2.262 tall x 0.322 thick (all measurements in atto-parsecs) (Figure 1) and was acquired from the Cloud City Empire Foundry in 5 ABY. The materials were melted, refined and re-cast into Imperial ingots using a technology derivative of an Arc Pulse Generator (APG) that inductively superheats and melts or vaporizes beskar. The foundry induction melters are designed based on an Empire salvaged and rebuilt APG that is not as powerful as the original and unable to remove minute amounts of trace elements from the beskar alloy. The Imperial ingots were carried in a first-generation protective camotono (Figure 2) (Famillton-Leach, Hoth Ice Planet, Anoat Sector, Outer Rim Territories), to shield them from potential external detection and demagnetization.

Sectioning of the sample proved difficult based on the high resistance to conventional durasteel or cortosis cutting tools, so a modified continuous blaster (MK Industries, Bestine, Tatooine, Outer Rim Territories) was used to section off small pieces for investigation. The chemical composition of the ingots, as determined by glow-discharge mass spectroscopy (Palpatine Corp., Coruscant, Core Worlds), is shown in Table 1.

EDITOR'S NOTE: This is a work of fiction and is not to be cited as a scientific publication.

Table 1: Composition (in wt%) of a beskar alloy Imperial Ingot			
Material	Beskar (Bs)	Carbon (C)	Ciridium (Ci)
Imperial Ingot	98.142	1.831	0.027

Figure 2: Camtono (Famillton-Leach) used for the safe and concealed transport of Imperial beskar alloy ingots. A standard imperial ingot is shown for scale. (EDITOR'S NOTE: Photo of prop camtono. Photo Credit: S. Mathaudhu)

Samples were mechanically polished using tydirium paper (Gromas Mining Cooperative, Gromas 16, Perkell Sector, Mid-Rim Territories), and final polished using a colloidal phrikite suspension (Blood Moon Industries, Gromas 16, Perkell Sector, Mid-Rim Territories). The extreme hardness of the beskar alloy prevented standard mechanical tension testing. Therefore, indentation hardness testing using a Phrik diamond-shaped tip indentor (Gromas Mining Cooperative, Gromas 16, Perkell Sector, Mid-Rim Territories) was used to measure the hardness. A modified Pistoeka sabotage droid (buzz droid) (Colicoid Creation Nest, Colla IV, Inner Rim Territories) was fitted with an x-ray diffractometer in one sensor eye, an ultrasensitive magnetometer in the second sensor eye, and a combination scanning/transmission electron microscope in the third sensor eye. The sensor eyes were used to study lattice/phase structures, magnetic fields and microstructural investigations, respectively. Blaster resistance testing was done on standard plate geometries with a IB-94 model blaster pistol and a DL-44 model heavy blaster pistol (BlasTech Industries, Capital City, Lothal, Outer Rim Territories).

Due to the rarity and the decimation of Mandalore, no pure beskar has been found for research investigations, and correspondingly, the tools used by the *naur'alor* to process high-purity beskar, including a cryo-forge, beskar gravity hammers, and beskar magnetic tongs are unavailable for this study. Thus, hypotheses on the differences between the Empire-produced beskar alloy and the *naur'alor*-produced pure beskar are solely based on anecdotal reports and speculation.

RESULTS AND DISCUSSION

Inspection of Figure 1 clearly shows indications of water-like wavy flow and contrast patterns indicative of alloy phase separation. These findings point away from the Imperial ingot being composed of pure beskar, and instead being an alloy containing a high-volume fraction of carbon (hypereutectoid) such that beskar carbide phase segregation occurs. Closer inspection with the buzz droid electron microscope sensor eye reveals contrast differences owing to carbide forming elements (CFEs) and the presence of spheroids nucleated with the addition of the trace heavy element, ciridium (Ci) (Fig. 3).

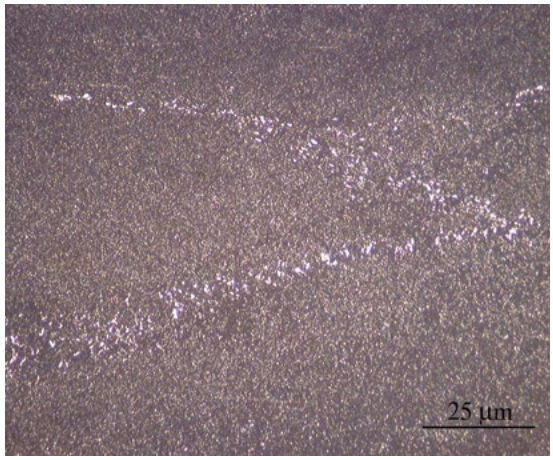


Figure 3: An electron micrograph of the Imperial ingot made of a carbon- and ciridium– containing beskar alloy. Banding is macroscopically observed in the beskar alloy due to carbide forming elements (CFEs) which manifest as clustered spheroid beskar carbides, and more divorced beskar carbide spheroids that have formed with the aid of the ciridium. (EDITOR'S NOTE: Photo Credit: Eric Taleff)

The addition of carbon and ciridium is likely intentional on the part of the Empire metalsmith to provide strengthening via the presence of spherical hard carbides and carbide rafts in lieu of the secret and specific knowledge and tools needed to fabricate the stronger pure beskar. Further, the repeated folding of the metal allows the distribution of the carbon, ciridium and perhaps other trace impurities to prevent weak spots and defects in the beskar alloy. There have been historical reports of Jedis Force-sensing that exploits critical microscopic flaws in *beskar'gam*. Metallographic comparison with the archival armor of Mandalorian Kal Skirata show some key difference in armor alloy design. The Skirata *beskar'gam* was found to have no carbon, and ~2 wt% ciridium, with no evidence of armor lamination via folding. This heavier beskar alloy was found to provide extreme strengthening through dispersed beskar-ciridium nanoprecipitates in the beskar matrix, preventing the motion of dislocations in the beskar lattice.

EDITOR'S NOTE: This is a work of fiction and is not to be cited as a scientific publication.

Surface buzz-droid x-ray characterization of the Imperial beskar alloy ingot reveals the presence of semi-stable beskar oxide and ciridium oxide layers, whose thickness allows for optical color control of the beskar alloy, and some measure of corrosion and acid resistance. Indeed, the sheen of *beskar'gam* has been observed to be sustained over centuries of usage.

The measured Phrik hardness of the Imperial ingot is shown in comparison to other structural armor materials including steel, durasteel, titanium and cortosis (Table 2). The hardness values are consistent with the underlying microstructural mechanisms that control strength in each material, including the properties, volume fractions and dispersion of the secondary phases. The large standard deviation observed in the cortosis sample stems from the anisotropy resulting from the fibrous nature of the underlying microstructural domains. The hardness of the beskar alloy, in part, explains it's high resistance to physical damage and attacks.

Buzz droid investigations of the magnetic field in the Imperial ingot reveal the presence of a moderately high permanent magnetic field (11 T), which likely necessitates the transportation in a camtono with magnetic shielding. The magnetic field intensity is high, but significantly less than ancient *naur'alor* forged beskar armor, such as the Skirata armor. Different Mandalorian beskar alloys have shown variable resistance to blaster penetration in historical use, based on the energy of the blaster and quality of the beskar alloy. The Imperial ingot was resistant to penetration from the BlasTech IB-94 blaster pistol, but did not survive even one test shot from the older, but more powerful DL-44 heavy blaster, which completely penetrated and oxidized the ingot (Figure 4). Hardness can be, to the first order, correlated with ballistic resistance, but given the energetic nature of the plasma bolt fired by blasters, did not play a role in the observed differences in protection capabilities.

We have come to a point where speculation on the processing and properties of pure beskar is appropriate. Rumors have pointed to a *naur'alor* Armorer on the planet of Nevarro, who has fabricated pure *beskar'gam* for a Mandalorian who was observed on Tatooine to be amply defended against strong blaster attacks.. The assumption of the *beskar'gam* being pure beskar is defended by reports of the *beskar'gam* having a mirror-like finish, which is not consistent with the wavy phase separation patterns of beskar alloy Imperial ingots. There is a consensus that pure beskar is more valuable than beskar alloy due to the former's significantly higher protection against physical attacks (e.g. a Rancor bite), acidic corrosion (e.g. Krayt Dragon acid), blaster bolts and lightsabers attacks.

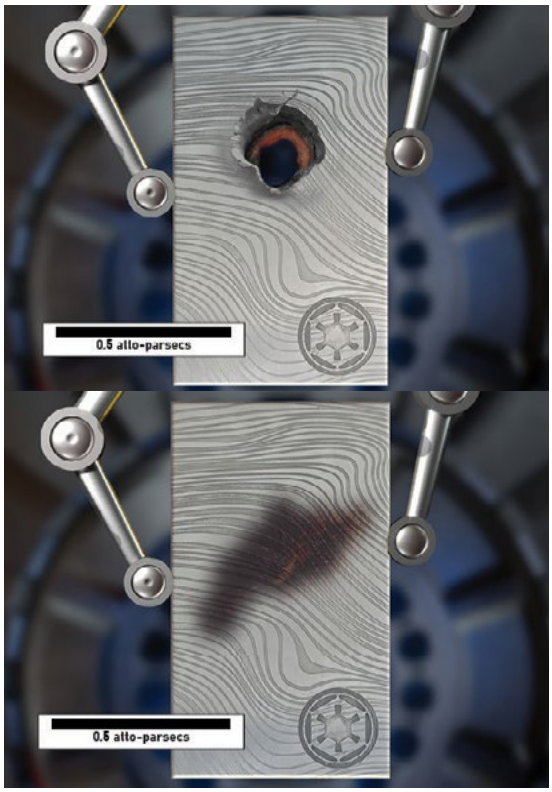


Figure 4: (Top): Full penetration and oxidation of the 0.322 atto-parsec thick Imperial ingot by a single shot from BlasTech DL-44 blaster pistol. (Bottom): Minor damage to the same ingot by a single shot from a BlasTech IB-94 blaster pistol. (EDITOR'S NOTE: These figures, depicting a prop Imperial ingot, are original illustrations created by David Rasel)

It is hypothesized that the unique processing tool suite used by a *naur'alor* (APG induction melter, cryo-forge, beskar gravity hammer and beskar magnetic tongs), while simple in appearance, are critical to the production of high-quality pure beskar, and its resulting properties. The cleanliness and purity of the beskar is likely maintained through the use of a more powerful induction melting capability than the Empire's reverse-engineered, underpowered APG foundry devices, and skilled gravity hammering to remove trace impurities. The *naur'alor*-designed APG's induction levitation provides for separation from impurities contained in physical crucibles, and the high temperatures provide for vaporization of embedded carbons and other interstitials. The induction levitation also would provide for density-driven separation and removal of heavy carbide forming elements such as ciridium.

Table 2: Phrik hardness of beskar alloy Imperial ingot compared to other armor metals (Ph units)

Steel	Durasteel	Titanium Alloy	Cortosis	Beskar alloy (this study)	Pure Beskar (speculated)
165±21	305±18	350±27	500±113	600±7	>900

EDITOR'S NOTE: This is a work of fiction and is not to be cited as a scientific publication.

After induction melting and gravity hammering, the remaining metal would all be high-purity beskar. It is speculated that the pure beskar obtains its extreme hardness and strength due to the cryo-forging, which in other pure metals, has resulted in the formation of nanometer-scale twin lathes, whose many boundaries block the movement of dislocations, and tremendously strengthen the pure material above conventional methods (see estimated Phrik hardness of >900 Ph in Table 2). Perhaps the formation of a protective and stable, transparent beskar-oxide layer on the surface of the pure *beskar'gam* is the source of its reported excellent acid resistance, similar to the layered beskar-oxide/ciridium oxide on beskar alloy that is known to be resistant to acids, such as Sarlacc pit digestive fluids.

The gravity hammer and magnetic tongs used by the *naur'alor*, may appear to be archaic in nature. However, it is strongly speculated that they provide the key to pure beskar's blaster and lightsaber resistance. It is often assumed that blasters and lightsabers utilize coherent laser light, with extremely high energy, but this is incorrect. The assumption that beskar is also resistant to the high temperatures of the blaster bolt and lightsaber (~8,000°C – 25,000°C) are also incorrect. To unravel this mystery, one must realize that the particle beam produced by a blaster stems from the excitement of gaseous ammunition into high-energy ionic particles (a plasma) that are compacted into the form of a fired "bolt". Similarly, lightsabers are weapons designed to harness the energy of kyber crystals to generate a plasma contained by a stabilizing magnetic field generator. The magnetic field works both ways—containing the plasma but also allowing the deflection of plasma bolts from blasters. With this knowledge, the utility of the gravity hammer and tongs becomes more clear—They are used to supercede the lower magnetic field of alloyed beskar (~5-11T) towards a strong, permanent magnetic field (~20T) in pure beskar through a combination of deformation from the gravity hammer and an applied stabilizing magnetic field from the tongs. The temperature of a lightsaber or blaster bolt is irrelevant given the plasma blocking nature of the beskar. This does not mean that the kinetic energy carried by the attacking weapons does not interact somewhat with the beskar and beskar alloys. Rather, it is minimized through the presence of the strong magnetic field, which, in part rationalizes the blaster test findings. The high energy of an MK sniper blaster or a DL-44 heavy blaster pistol are certainly enough to damage the beskar alloy, but unlikely to affect pure beskar from long ranges. It would appear that both Imperial ingot beskar and pure beskar are both impervious to plasma bolts from a IB-94 blaster due to the lower energy of the plasma bolts, combined with the strong protective magnetic field of the beskar materials.

CONCLUSION

The processing-microstructure-property relationships of an imperial beskar alloy ingot were investigated to reveal the underlying physical mechanisms for the enhanced strength, corrosion resistance and blaster/lightsaber resistance. The alloy ingots, created with an underpowered arc pulse generation device, are revealed to contain carbon and trace heavy ciridium elemental additions that result in the formation of hard beskar carbide rafts and ciridium carbide spheroidal inclusions, both which lend the alloy enhanced strength. The corrosion resistance is owed to the presence of stable oxide surface layers, and the moderate lightsaber/blaster resistance is due to the magnetic plasma suppression field in the alloy. The mechanisms for the improved performance in pure beskar are hypothesized from anecdotal reports and second-hand observations. It is speculated that a fully powered arc pulse generator enables the induction refinement and purification of the beskar alloy, with further refinement coming from skilled heating and hammering. Then, the high pressure cryo-forge is used to introduce high-densities of nano-twinned domains, which offer significant strengthening over alloying and hard-phase mechanisms, while simultaneous fabricating components of the *beskar'gam*. The post-processing using a gravity hammer and magnetic tongs likely induces an extremely high magnetic field (>20T) that would be able to block the plasma energy from high-power blasters or kyber crystal-powered lightsabers. Disappointingly, the lack of knowledge of the whereabouts of any of the *naur'alor* tools and instruments will stifle the broader application of pure beskar, and therefore novel alloying and processing mechanisms to improve on the properties of alloyed beskar are suggested as a path forward.

ACKNOWLEDGEMENTS

The author would like to thank the Imperial Security Bureau (ISB) for the funding that supported this work. Special thanks is given to ISB Program Officer, M. Gideon. He would also like to thank the Galactic archeologist, Dr. C.L. Aphra for useful conversations concerning the historical usage of beksar and insights into the presence and detection of pure beskar across the galaxy.

REFERENCES

1. Pilas Manaitis, *Strategic Resources of the Galaxy (*19 BBY)
2. The Bounty Hunter Code, (recovered from the files of Boba Fettj, Cloud City, Bespin, ~2 ABY)

BIOGRAPHY

Willrow Hood, Ph.D. received his doctorate in Outer Rim Metallurgy from the University of Coruscant in 10 BBY, where he focused on extractive metallurgy, and physical metallurgy.

EDITOR'S NOTE

The following "real world" references were used in preparing this work:

1. *Legends, Star Wars, An Imperial Commando Novel*, 501st, Karen Traviss, pg 142, Del Ray, 2009 and 2)
2. *Star Wars: The Bounty Hunter Code, from the files of Boba Fett*. Daniel Wallace, Ryder Windham, and Jason Fry pg. 139, Chronicle Books, 2021

EDITOR'S NOTE: This is a work of fiction and is not to be cited as a scientific publication.

REAL-WORLD (AND OFF-WORLD) INSPIRATIONS

Part of the fun in thinking about fictional materials is to consider the "mapping" of the behaviors of real-world materials with those of the fictional analogues. For the exercise of developing "Processing-Structure-Property Relationships in Pure Beskar and Beskar Alloy," we allowed ourselves the luxury of pulling concepts from real-world scientific papers to retroactively explain the amazing, depicted properties of beskar:

Co-author Suveen Mathaudhu is pictured here as Willrow Hood, along with his daughter Leia (6-years old), cosplaying as young Leia Organa, princess of Alderaan.

How do you melt and process a near "indestructible" metal?

In *The Mandalorian*, beskar is observed in many forms, all implying the ability to melt, shape and form the "indestructible" material. In the *Star Wars Rebels* animated series, a superweapon called an "Arc Pulse Generator" is created for targeting and superheating beskar alloy armor from a distance, thus vaporizing the armor wearer. The closest thing we have in the real world is *induction melting*, where a coil carrying an alternating current surrounds a chamber of metal or a piece of metal. This induces an electromagnetic field and Eddy currents, which result in temperatures above the melting point for most metals without any physical contact between the induction coils and samples. This same process can be used for melt decontamination of steel and other materials.[1] Zhao et al. have used induction melting to remove difficult-to-separate radionuclides from stainless steel and carbon steel.

How can a "pure" material be stronger than an alloy?

The "purity" and "quality" of beskar seen in *The Mandalorian* are correlated with both value and performance, with pure beskar performing better than alloyed beskar, or perhaps beskar with impurities. Imagining it is an elemental material, we are forced to consider some circumstances where pure materials can be stronger than alloys. The "easy" solution would be to say that the beskar has no defects, and thus ideal strength ($\sim G/2\pi$). However, this would not be thermodynamically practical or realistic (sic.) Instead, we take inspiration on recent works that show that pure materials can be tremendously strengthened through introduction of nano-twin features. Zhang et al.[2] have shown that high-pressure processing of pure iron lead to nanotwinned martensite with a hardness of 830 HV, which compares favorably with the Vickers hardness of steels with carbon contents greater than 0.6 wt% (800 – 900 HV). Perhaps more closely connected to *The Mandalorian*, whose Armorer uses a cryo-forge, are results purporting ultrastrong nanotwinned pure titanium after cryoforging.[3] These and other reports point to emerging or future pathways for making ultrastrong metals using cryogenic processing and other novel methods.

How can a metal be resistant to lightsabers and blaster bolts?

Beskar armor is often depicted to be highly resistant to blaster bolts and lightsaber attacks, but perhaps not impervious. The conventional wisdom is that lightsabers are not lasers, per se, but instead plasma swords, and similarly, blasters shoot plasma bolts, and not lasers. Confined plasmas arcs can reach temperatures up to 25,000°C, perhaps leading one to believe that beskar is highly heat resistant. But this goes at odds with the ability to melt it (as the Armorer is shown to do) or heat up to an orange glow when in contact with a forge or a lightsaber. The melting point of a common steel is nominally 1500°C, and the highest melting point metal in our universe is tungsten (~3400 °C) so something else must be the operative mechanism of defense in beskar other than resistance to heat.

To answer this, we can extrapolate from the beskar tools used by the Armorer—a "gravity hammer' and "magnetic tongs." Magnetic fields have been used by laboratory researchers to confine high-temperature plasmas (150,000,000 °C) that occur during nuclear reactions, and that are 10 times hotter than the center of the sun. Further, plastic deformation has been shown to be able to magnetize ferromagnetic materials like iron, nickel and cobalt. On the scientific front, Edalati et al.[4] have used high-pressure torsion to improve the strength of pure cobalt via nanotwinning, while simultaneously increasing the magnetic coercivity and magnetic retentivity. These processing approaches point to the high force/pressure ("gravity") in the hammer and magnetism in the tongs playing a role wherein the beskar is strongly magnetized, thus repelling the plasma fields produced by either a lightsaber or a blaster bolt, but likely not for extended contact, nor for blaster bolts at close distances.

REFERENCES

Read These Papers for More Scientific Insights

1. Zhao, P.; Chung, W.; Lee, M.; Ahn, S. Experimental Study on Melt Decontamination of Stainless Steel and Carbon Steel Using Induction Melting. Metals 2021, 11, 1218. https://doi.org/10.3390/met11081218
2. Hongwang Zhang, Yuhui Wang, Yan Peng, Pinwen Zhu, Jianhua Liu, Zongqiang Feng, Guilin Wu & Xiaoxu Huang (2019) Unprecedented strength in pure iron via high-pressure induced nanotwinned martensite, Materials Research Letters, 7:9, 354-360, DOI: 10.1080/21663831.2019.1612792
3. Zhao, Shiteng, et al. "Cryoforged nanotwinned titanium with ultrahigh strength and ductility." Science 373.6561 (2021): 1363-1368. https://doi.org/10.1126/science.abe7252
4. Edalati, Kaveh, et al. "High-pressure torsion of pure cobalt: hcp-fcc phase transformations and twinning during severe plastic deformation." Applied Physics Letters 102.18 (2013): 181902. https://doi.org/10.1063/1.4804273

AND, A FEW NOTABLE *STAR WARS* REFERENCE POINTS

There are dozens of Star Wars allusions embedded in "Processing-Structure-Property Relationships in Pure Beskar and Beskar Alloy" for eagle-eyed fans to discover. We share a few to get you started:.

1138

The number 1138 (the fictional volume number of the fictional "Processing-Structure-Property Relationships in Pure Beskar and Beskar Alloy") plays an important role in many Lucasfilm productions and as tribute to George Lucas' first film, *THX 1138*.

Willrow Hood

Willrow Hood has developed a following since his three-second appearance in *Star Wars: The Empire Strikes Back* (1980). In the film, he was seen fleeing Cloud City with what very obviously was an un-modified home ice-cream maker. Audiences were re-introduced to this device in *The Mandalorian*, where a similar container, called a *camtono*, was shown to be a safe for transporting beskar, thus explaining why Willrow Hood would escape with only that in hand in ~3 ABY. For "Processing-Structure-Property Relationships in Pure Beskar and Beskar Alloy", we framed Willrow Hood as a materials scientist, whose purpose in carrying around the camtono was to transport beskar samples for research and study.

Elements and Materials of the Star Wars Universe

All of the unique materials (ciridium, zersium, tydirium, phrikite, durasteel, cortosis) and metals (steel, titanium) listed in "Processing-Structure-Property Relationships in Pure Beskar and Beskar Alloy" come from *Star Wars* stories. Specific attention is paid to carbon and ciridium, both of which are referenced as being components in beskar alloy

Institutions of Higher Education

Yes, the University of Coruscant and Shadow University are real research and higher degree granting institutions in the *Star Wars* universe. They probably are not accredited.

Acknowledgements

Imperial Security Bureau leader Moff Gideon was responsible for the destruction of Mandalore and ransacking of the beskar. It would make sense that he would fund research on beskar metallurgy. Another occasional Darth Vader ally referenced is archaeologist Dr. Chelli Lona Aphra, who provides an excellent close out quote from the *Doctor Aphra* audiobook (2021):

"Isn't that all the more reason to do it? Isn't that what being an archaeologist is about? Making new discoveries, finding treasures of the past, being able to see the…the fullness of the history of the entire galaxy? If we want to make real discoveries, it's always going to be a little dangerous—"

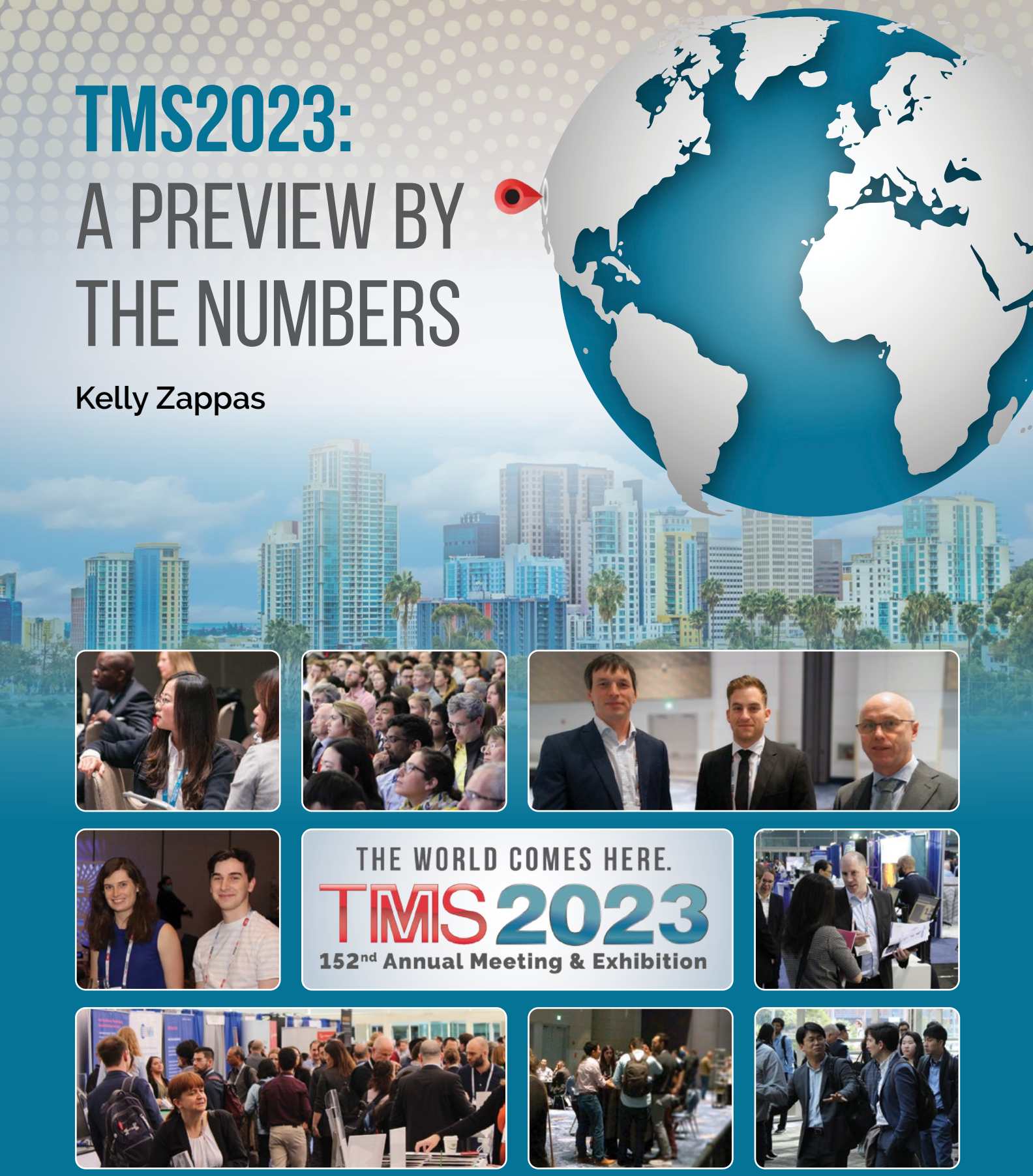
—Dr. Chelli Lona Aphra, arguing with Sava Toob-Nix in favor of unsanctioned expeditions

We dare say that an understanding of history, finding new discoveries, and understanding the materials of our universe may indeed come from the "unsanctioned expeditions" of the next generations.

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05588-3

TMS2023: A PREVIEW BY THE NUMBERS

Kelly Zappas



After two unconventional years of virtual and hybrid gatherings, the TMS 2023 Annual Meeting & Exhibition (TMS2023), to be held March 19–23, marks the return to a fully in-person event, with plenty of opportunities for face-to-face networking, informal discussions, and interesting technical exchanges. In 2023, the meeting returns to San Diego, California, for the first time since the record-breaking 2020 event, which gathered more than 4,600 minerals, metals, and materials scientists and engineers from around the world.

We have yet to see how many individuals will come together for TMS2023, but we can offer a few key numbers that will provide you with a sense of the size and scope of this year's meeting.

99 TECHNICAL SYMPOSIA

More than 4,700 abstracts were submitted for TMS2023. Accepted abstracts will be delivered as oral and poster presentations at 99 symposia throughout the week. Symposia have been planned by all five TMS technical divisions in the following topic areas:

- Additive Technologies
- Materials Processing
- Mechanics & Structural Reliability
- Nuclear Materials
- Physical Metallurgy
- Light Metals
- Characterization
- Nanostructured Materials
- Advanced Materials
- Electronic Materials
- Energy & Environment
- Biomaterials
- Materials Design
- Corrosion
- Special Topics

Visit the technical programming section of the TMS2023 website to view a complete listing of symposia plans.

5 HONORARY SYMPOSIA

Each of the five TMS technical divisions will honor the career of a distinguished leader in their field with a special symposium at TMS2023.

TMS Light Metals Division (LMD)
Honoree: Barry J. Welch
Symposium Title: 60 Years of Taking Aluminum Smelting Research and Development from New Zealand to the World

TMS Structural Materials Division (SMD)
Honoree: Easo George
Symposium Title: Alloy Behavior and Design Across Length-Scales

TMS Materials Processing & Manufacturing Division (MPMD)
Honoree: Jonathan A. Dantzig
Symposium Title: Frontiers in Solidification

TMS Functional Materials Division (FMD)/SMD
Honoree: Zi-Kui Liu
Symposium Title: Materials Genome, CALPHAD, and a Career over the Span of 20, 50, and 60 Years

TMS Extraction & Processing Division (EPD)
Honoree: Patrick R. Taylor
Symposium Title: New Directions in Mineral Processing, Extractive Metallurgy, Recycling, and Waste Minimization

3 DIVISION LUNCHEON LECTURES

The various TMS technical divisions come together throughout the week at TMS2023 to enjoy camaraderie, celebrate award recipients, and hear about important topics relevant to their work at the Technical Division Luncheons. The following invited speakers will deliver talks at the luncheons:

EPD/MPMD Luncheon
Paramita Das,
Global Head of Marketing, Development and ESG Metals and Minerals, Rio Tinto

SMD/FMD Luncheon
Roger Narayan,
Distinguished Professor in the Joint Department of Biomedical Engineering, University of North Carolina and North Carolina State University

LMD Luncheon
Slade Gardner,
President and Founder, Big Metal Additive

Visit the TMS2023 website for additional information on the speakers and their topics. You can purchase a ticket through the TMS2023 registration form to receive lunch and participate in the full event. The lecture is free for all attendees.

4 AWARD LECTURERS (AND COUNTING)

The following award recipients will deliver featured talks at TMS2023. Several emerging professional award speakers will also be announced in the coming months; visit the TMS2023 website for the most up-to-date information.

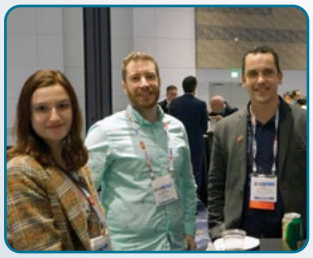
Extraction & Processing Division Distinguished Lecturer
Corale L. Brierley,
Brierley Consultancy LLC

William Hume-Rothery Award
Gerbrand Ceder,
Samsung Distinguished Professor of Engineering, University of California, Berkeley

Institute of Metals/Robert Franklin Mehl Award
Carl Koch,
Kobe Steel Distinguished Professor, North Carolina State University

William D. Nix Award Lecturer
Eduard Arzt,
INM–Leibniz Institute for New Materials and Saarland University

2 RETURNING EVENTS FROM 2022



At the TMS 2022 Annual Meeting & Exhibition in Anaheim, California, TMS introduced two new features that will return for 2023. The conference will open with a **Welcome Reception** on Sunday evening, inviting all attendees to come together to meet with old friends, make new connections, and socialize before starting the busy annual meeting week. Then, on Monday morning, attendees are invited to a **Welcome Breakfast** to start the day off right before proceeding to the day's technical sessions.

3 DAY EXHIBITION

A three-day pass to the TMS2023 Exhibit Hall lets attendees meet with exhibitors, discover new solutions and services, and socialize with fellow attendees at networking events. Plan to join your peers in the exhibit hall for networking and happy hour receptions on Monday and Tuesday during prime exhibit hours.

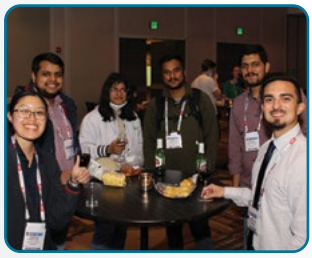
The TMS2023 Exhibition will run from Monday, March 20 through Wednesday, March 22.

11 PROCEEDINGS **PUBLICATIONS**

TMS2023 attendees in most registration classes receive free online access to the complete collection of proceedings publications. Before the meeting, preregistered attendees will receive information on how to download proceedings content. The following titles are planned:

- *Advances in Powder and Ceramic Materials Science 2023*
- *Advances in Pyrometallurgy: Developing Low Carbon Pathways*
- *Characterization of Minerals, Metals, and Materials 2023*
- *Energy Technology 2023: Carbon Dioxide Management and Other Technologies*
- *Friction Stir Welding and Processing XII*
- *Light Metals 2023*
- *Magnesium Technology 2023*
- *Materials Processing Fundamentals 2023*
- *New Directions in Mineral Processing, Extractive Metallurgy, Recycling and Waste Minimization: An EPD Symposium in Honor of Patrick R. Taylor*
- *Rare Metal Technology 2023*
- *TMS 2023 152nd Annual Meeting & Exhibition Supplemental Proceedings*

2 STUDENT **COMPETITIONS**



Undergraduate and graduate students always have a strong presence at TMS Annual Meetings, and TMS2023 will feature two competitions that help showcase student talent. On Sunday evening, students will take part in the **TMS Materials Bowl,** a fast-paced materials knowledge and trivia competition. Later in the week, students will have the chance to show off their work at the **Technical Division Student Poster Competition**.

Other student-specific events will include the **Student Mixer** networking event, a **Student Career Forum** panel discussion, the **TMS Bladesmithing Symposium**, and, new this year, an **Ace the Job Hunt Workshop**. Visit www.tms.org/TMS2023 for more information.

7 **BENEFITS** FOR HILTON SAN DIEGO BAYFRONT GUESTS

This year, the TMS headquarters hotel will be the Hilton San Diego Bayfront. Book your room at the Hilton through the TMS2023 website to take advantage of the following benefits:

- **Prime Location:** The Hilton will be the location for select programming and networking events throughout the week at TMS2023 and is the closest hotel to TMS programming and events at the convention center.
- **Convenient Registration:** A dedicated registration and hospitality desk at the Hilton lets you get your badge and other registration materials at the hotel, meaning you won't have to wait in registration lines at the convention center.
- **Expedited Service:** In addition to receiving your registration materials at the hotel, Hilton guests have access to a dedicated line at the TMS2023 registration desk in the convention center for expedited service.
- **Breakfast Discount:** Enjoy a 20% discount on the Hilton's daily breakfast buffet.
- **Amenities:** All TMS guests staying at the Hilton receive free WiFi in their guest rooms and free access to the Hilton fitness center.
- **Raffle for Those Who Book Early:** Reserve your room early and you'll be entered into a raffle to win free transportation from the airport to the hotel, a room with a scenic view of the bay, or an upgrade from a standard room to a suite.
- **Special Rates for TMS 2023 Attendees:** Book your room through TMS and our official housing provider, onPeak, at www.tms.org/TMS2023 to receive the special discounted rate for conference attendees.

1 **MONTH LEFT TO REGISTER** AT THE DISCOUNTED RATE

The deadline to register for TMS2023 at the discounted early registration rate is **January 31.** Be sure to make your meeting plans by this date to receive the best rate on conference attendance and to reserve your place at networking and social events.

KEY DEADLINES

Discount Registration Deadline: January 31, 2023
Housing Deadline: February 23, 2023
Meeting Dates: March 19-23, 2023
Exhibit Dates: March 20-22, 2023

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05589-2

Getting to Know the 2023 TMS Board of Directors

Kelly Zappas

In 2023, seven new members will join the TMS Board of Directors for three-year terms. This month, *JOM* talks with each of our new leaders about their past experiences as TMS members and active volunteers and their hopes for the Society's future. Each of these individuals will begin their term at the end of the TMS 2023 Annual Meeting & Exhibition (TMS2023) in San Diego, California, March 19-23, 2023.

Srinivas Chada
Vice President

In 2023, **Srinivas Chada**, a principal engineer at Amazon-Project Kuiper, will serve one year as TMS Vice President before moving into the role of 2024 TMS President. His involvement in TMS, however, stretches back to his days as an undergraduate student in India, when he read *JOM* every month. "I was always fascinated with the colorful metallographs and technical articles," said Chada.

Then he had the chance to attend a TMS-sponsored conference during his first year as a graduate student. "That was hook, line, and sinker as I had the opportunity to meet and listen to lectures by professors and scholars whose books and publications I had read as an undergraduate," he said. "I became active in TMS that day, and my continued activity with TMS is due to my advisor, Raymond Fournelle, who served as *JOM* advisor for several years, and other people who influenced me by volunteering their time with TMS. Several of these individuals freely helped and advised me during my Ph.D. studies. This, more than anything, has made me realize how important it is to give back to the Society—my second family—lest I fail to pay it forward. That is what makes TMS my home Society."

Looking back, Chada was able to name a long list of members who provided mentoring and friendship throughout his career. "As a grad student, I got technical and professional advice from them," he said. He shared one of these instances when a fellow TMS member, Iver Anderson, photocopied and mailed him an entire master's thesis to help him with his research. He also recalled a TMS annual meeting when another member, Prasad Godavarti, pointed out Chada to a colleague who was looking for an intern candidate. This led Chada to an internship at Motorola.

"There have been countless people—we don't have time and paper enough if I start listing names—that took time to listen to a grad student and help," said Chada. "As I entered the ranks of working in the industry, these contacts and friendships provided invaluable references and, in some cases, job opportunities. These scholars and giants in the field of materials science took (and continue to take) time and effort to help and foster."

As someone who has served on the TMS Board of Directors twice before—as Programming Director and Functional Materials Division Director—Chada has seen how the Board and presidents contribute to and influence the Society's future.

"As I still have a lot to pay forward and have ideas to make TMS the 'home' Society for existing as well as new members, I thought seeking a term in the presidential rotation would be the right platform," he said. "I want to continue the cadence from the past presidents on making TMS the primary choice for materials science engineers and scientists. I also would like to keep the technical programming strong and relevant for fast and ever-changing technologies without losing our fundamentals as a metallurgical society. Furthermore, I want all members to experience what I feel about TMS, that it is their home society and second family where they can make life-long friendships while learning, teaching, and sharing technical advances in minerals, metals, and materials science."

"I want all members to experience what I feel about TMS, that it is their home society and second family where they can make life-long friendships while learning, teaching, and sharing technical advances in minerals, metals, and materials science."
–Srinivas Chada

"I feel TMS and its membership have much to offer the world. I want to see to it that we also have the most effective means available for others to access it."
–Jonathan Madison

"I enjoy spreading the word of materials science and engineering to both public and government officials, and I love answering the question 'Materials engineering—what is that?' that we so often hear from people outside of our field."
–Michael Titus

"The beauty of TMS is its members. That's why I became involved, because it was a very welcoming Society. That grassroots structure and that welcoming feeling are what I'd like to help maintain and communicate to new members."
–Saryu Fensin

Alexis Lewis
Financial Planning Officer

Alexis Lewis is not new to TMS leadership, having served as the chair of Membership and Student Development on the TMS Board of Directors—as well as on numerous technical and administrative committees—before being selected to serve as Financial Planning Officer. Lewis, who is the deputy division director in the Division of Civil, Mechanical, and Manufacturing Innovation in the U.S. National Science Foundation's (NSF) Directorate for Engineering, began her TMS career as an undergraduate and attended her first TMS Fall Meeting in 2003.

"I had just joined the Naval Research Laboratory as a postdoc," she said. "It was great to be able to share my research and hear so many other ideas and perspectives. I became active as a volunteer a few years later, joining a few technical committees and eventually co-organizing sessions with the Advanced Characterization, Testing, and Simulation Committee. The collegiality and truly bottom-up structure of TMS keeps me involved. It's a society for, of, and by the membership."

Lewis said that the networking and community building at TMS events have had a huge positive impact on her career. "Many of my best collaborations started with a conversation at a coffee break or after a session at a TMS conference," she said. "Leading the organization of the first 3D Materials Science Congress is where I learned how much I enjoyed bringing groups of people together to discuss and ultimately advance a scientific idea. The part of TMS that's had the most impact on me has been working with the Diversity, Equity and Inclusion Committee, and at the Diversity in the Minerals, Metals, and Materials Professions Summits. The conversations I've had and activities I've participated in have opened my eyes in so many ways, and I continue to learn new things by working with an ever-growing, diverse group of colleagues."

As Financial Planning Officer, Lewis is excited about the many new offerings and formats that TMS has developed in the past few years and hopes to bring a perspective on how to navigate these financially. "These are certainly interesting times for an organization like TMS—we'll be constantly evaluating and re-evaluating the ways in which we bring the community together for the next several years as we continue to navigate through and beyond the pandemic," she said.

The main reason she applied for the open board position was because a current Board member encouraged her to do it. "I might not have thought of it otherwise, and I am so glad to have had that nudge," she said. "If you have a colleague who you think would make a great TMS volunteer leader, please encourage them early and often!"

Jonathan Madison
Content Director

"TMS has influenced my career in more ways than I can sufficiently describe in this forum," said **Jonathan Madison**, who begins his term as Content Director on the TMS Board of Directors in 2023. "From constructive critique of my technical work; to helping me become a better scientist and researcher; to opportunities to author, review and guest-edit in highly respected journals; to spirited debate on issues of major import to the materials field in particular, science in general, and even society at large; to priceless opportunities to help develop others. My technical career, personal outlook, and professional network have all benefited immeasurably."

Madison first became involved with TMS in graduate school as a Material Advantage member and then became more deeply involved in TMS technical and functional committees after completing his Ph.D. at the recommendation of his thesis advisor.

"I think the item that has kept me so active in the Society over the years has been the opportunity to work with friends, colleagues, and new acquaintances from all over the world to make a real difference in our field and our profession," Madison said. "It is an awesome opportunity that is rare to come by in any other way."

This personal connection to the Society is one reason Madison decided to join the Board. "I felt it was time for me to give back to the organization that has given me so much and I could think of no greater way to contribute to the Society, than to pursue service on its Board of Directors," said Madison.

In his new position as Content Director, Madison is looking forward to the opportunity to influence the future of TMS at its highest level of governance.

"I hope to help TMS realize, or perfect, at least one new mode of communication and/or content curation within the Society for all of the amazing technical, professional, and member content we have in our possession," he said. "I feel TMS and its membership have much to offer the world. I want to see to it that we also have the most effective means available for others to access it."

Michael Titus
Public & Governmental Affairs Director

Like many of his Board colleagues, **Michael Titus**, who is currently assistant professor of materials engineering at Purdue University, first became involved with TMS as a graduate student, giving his first presentation at Materials Science & Technology 2011 (MS&T11), then joining the High Temperature Alloys Committee in 2015.

"During those early years, I was always impressed by the strong support TMS provides for students and early career researchers via mentoring activities, professional workshops, and networking events," he said. "It is clear that TMS invests in future scientists and engineers, and that is what keeps me involved."

He recalls feeling very accepted and welcomed at those first few TMS-sponsored conferences. "These conferences opened up many networking opportunities to meet leaders in the field and share ideas early on in my career," he said. "Many of these interactions positively influenced my Ph.D. work and continue to shape my career trajectory and research interests today."

Titus noted that he is grateful to TMS and its members, who have provided many opportunities for professional advancement through student support, networking, and technical presentations, journals, and studies. "Now I wish to give back to TMS and its members by serving as Director of Public & Governmental Affairs. I enjoy spreading the word of materials science and engineering to both public and government officials, and I love answering the question 'Materials engineering—what is that?' that we so often hear from people outside of our field."

In his new role, one of Titus's major objectives is to significantly expand the public reach of materials science and engineering (MSE) and TMS through various social and traditional media platforms, outreach events, and other professional settings

"As a consumer of science and engineering content on social media platforms," he said. "I want to see MSE better represented in these spaces."

Kester Clarke
Professional Development Director

Kester Clarke describes TMS as the place that has been his home Society for most of his professional career, pointing to the personal relationships he has developed with fellow members as the most beneficial aspect of membership.

Clarke, an associate professor in the Metallurgical and Materials Engineering Department at Colorado School of Mines, first became involved with TMS through Material Advantage and attending an MS&T meeting to present his work as a graduate student.

"I continued to go to the Annual Meeting and MS&T regularly to see all the new and interesting work everyone was doing," he said. "I soon became involved in several technical committees to support and drive programming, joined functional committees to be involved in professional development activities, and then served in officer roles in several technical and functional committees, which helped me see the longer-term strategic initiatives TMS was pursuing. All these roles have been a bit of work, but have really benefitted my career and professional network, and it's been neat to meet so many devoted and inspirational colleagues along the way."

When he moved to academia after holding positions in industry and at a national laboratory, Clarke joined the TMS Education Committee and soon found that the education-focused activities in TMS were a perfect opportunity to learn best practices and novel approaches to teaching and graduate education.

"Many excellent education-focused articles in *JOM,* the annual Judson Symposium at MS&T, and the student-run symposium at the TMS Annual Meeting are all beneficial activities that I have learned a tremendous amount from," said Clarke. When the opportunity arose to apply for the Professional Development Director position, he jumped at the chance.

"I look forward to working with all of the other Directors to maintain a strong future for TMS that ensures future students and professionals in materials fields have the same great opportunities I have had," said Clarke. "There are always challenges as the world changes around us, but I think the people of TMS (all of us!) will continue to find ways to support and improve everyone's experience in the minerals, metals and materials professions–long may we run."

Elsa Olivetti
Extraction & Processing Division Chair

In her new role as chair of TMS's Extraction & Processing Division (EPD), **Elsa Olivetti** hopes to support further engagement across the membership around areas of sustainability and climate change, given the pivotal role that materials play in developing solutions to mitigate impact and adapt to a changing planet.

Olivetti is currently the Esther and Harold E. Edgerton Career Development Professor in the Department of Materials Science and Engineering and co-director of the Climate and Sustainability Consortium at the Massachusetts Institute of Technology (MIT). She first became involved with TMS as a presenter when she was a postdoctoral associate in 2008.

"TMS has provided an extraordinary community for me to learn from in all aspects of my work," she said, "from detailed technical conversations with individuals from industry, to opportunities to organize plenary sessions given by leaders in my field, to opportunities to link with academic colleagues. TMS has continued to be the most valuable place for me to connect with colleagues across academia and industry, learn about the cutting edge of our field, develop leadership and organizing skills, and contribute in some small way to shape the roadmap for our discipline."

Olivetti says she is grateful for each of these opportunities and looks forward to the next chapter of her TMS story as EPD chair. "It's a division I feel quite passionate about serving to help grow the expertise and impact of the domain."

Saryu Fensin
Functional Materials Division Chair

Saryu Fensin attended her first TMS Annual Meeting as a graduate student. "But that wasn't the meeting where I became involved with TMS," she said. In 2010, when she began her postdoc at Los Alamos National Laboratory, her coworkers Rusty Gray and Ellen Cerreta (both former TMS presidents) encouraged her to not just attend the conference, but to become involved with the Society. They brought her with them to committee meetings and showed her how TMS worked.

"That's how I started volunteering," she said. "I get much more out of volunteering than I do just attending a meeting. Once I got involved, the meeting became more interesting and more beneficial to my career."

Fensin said she's met a lot of different people through TMS that she wouldn't have met otherwise, and those connections have led to longer-term collaborations and friendships that have had a positive influence on her career. "Being active in TMS has expanded my horizons. I would not have met all these people had I not been involved."

Fensin's position on the Board will be representing the Functional Materials Division (FMD), but she has also served as chair of the Mechanical Behavior of Materials Committee within the Structural Materials Division (SMD), represented TMS on the Materials Science & Technology Program Coordinating Committee meeting, and been a member of the TMS Programming; Diversity, Equity, and Inclusion; and Public and Governmental Affairs committees. She believes this diverse background and broad experience with TMS will serve her well in her new position.

"I have a very diverse background within TMS, with a lot of cross collaborations, having worked with both FMD and SMD," she said. "I hope to bring that collaborative experience in being very active in different divisions to my role on the TMS Board of Directors."

"The reason that I've always liked TMS is that it's always been a ground-up organization," she said. "The beauty of TMS is its members. That's why I became involved, because it was a very welcoming Society. That grassroots structure and that welcoming feeling are what I'd like to help maintain and communicate to new members."

Nominations Open for 2024-2027 TMS Board of Directors

TMS is now accepting nominations for two positions on the 2024–2027 TMS Board of Directors. The open positions are the Presidential Rotation and Program Director/Chair. Nominations will be accepted until January 15, 2023.

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 2023.

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**.

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05590-9

Table of Contents

Investing in What Works

TMS FOUNDATION

Lynne Robinson

Paul Ohodnicki (left) spoke at the 2020 TMS Foundation Donor Appreciation Dinner on the impact that the support of the Foundation had on his career. He is pictured with Diamond Society members Robyn and Rob Wagoner.

Amy Clarke (right) is thanked by 2019 TMS President James Foley at the 2020 TMS-AIME Awards Ceremony for her service on the TMS Board of Directors. Clarke's career journey with TMS can be traced to her receiving the 2008 MPMD Young Leaders Professional Development Award. She was later named the 2010 TMS-JIM Young Leaders International Scholar and the 2013 TMS-FEMS Young Leaders International Scholar.

Paul Ohodnicki sees it as a game changer.

A current TMS Board member and associate professor, University of Pittsburgh, Ohodnicki received the 2010 Functional Materials Division Young Leaders Professional Development Award just as his career was taking off. "I have benefited tremendously from my involvement with TMS both professionally and personally over the course of my career and it would never have been possible without the original support from the TMS Foundation for that early career award," he said.

"There are only a handful of philanthropic causes which I have made a major commitment to as I look to give back at this stage in my career," Ohodnicki, a TMS Foundation Silver Society member continued. "The TMS Foundation is and will continue to be one of those core commitments that I will make for the remainder of my career because of the impact that it had on me."

For more than a quarter of a century, the TMS Foundation has provided student scholarships and early career support to now hundreds of established science and engineering professionals. The value of this investment in the up-and-coming generations of TMS members is clear. As one example, 8 out of the current 14 TMS Board members, including Ohodnicki, are past recipients of a Young Leader Award.

With the Foundation's impact able to be measured in the careers that it has helped support, Carl Cady, TMS Foundation Board of Trustees Chair and Gold Society member, maintains that donating to the Foundation provides a very direct way to make a difference in the profession. "I have been a proud supporter of the TMS Foundation for years because I believe that my donations are being used to help our field make advancements that benefit everyone," said Cady, technical staff, Los Alamos National Laboratory.

The TMS Foundation is building on that positive legacy with its 2022 year-end appeal focused on increasing access to support in the following ways:

- **Double the Number of TMS Family Care Grants**
- **Re-Establish the Presidential Scholarship**
- **Double the Number of Young Leaders Professional Development Awards**

Learn more about contributing to the TMS Foundation at **www.TMSFoundation.org**

Amy Clarke, TMS Foundation Board Trustee and Silver Society member, notes that she encourages all TMS members to make the TMS Foundation one of their charitable causes this year. "The TMS Foundation provided me with amazing early career opportunities," said Clarke, John Henry Moore Distinguished Professor of Metallurgical and Materials Engineering, Colorado School of Mines. "I support the TMS Foundation to enable similar opportunities for others and encourage my colleagues to do the same."

Give to the TMS Foundation 2022 Year-End Appeal

Deadline: December 31, 2022

Donate Online: Use our online contribution form at **www.TMSFoundation.org/Contribute**

Donate by Mail: You can mail your donation to the TMS Foundation at 5700 Corporate Drive, Suite 750, Pittsburgh, PA 15237.

Questions? E-mail TMS Foundation staff at **TMSFoundation@tms.org** or call us 1-724-776-9000

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05591-8

MEET THE 2023 CLASS OF TMS SCHOLARS

Megan Enright

The 2023 class of TMS Scholars reflect the bright future of the minerals, metals, and materials professions.

Through the TMS Foundation, the TMS community has provided these promising young individuals with much-appreciated financial assistance which has allowed them to continue their studies. In addition to helping with the cost of education, many of the scholarships awarded include travel grants to aid these students in attending highly regarded professional meetings, like the TMS annual meeting. This enables them to begin networking with professionals in their field, to expand their technical knowledge, and to build their professional profile.

Several of the following scholarships will be awarded during the TMS 2023 Annual Meeting & Exhibition (TMS2023) technical division functions, portions of which are open to all TMS2023 attendees. Various other awards and scholarships will be conferred at the TMS-AIME Awards Ceremony during TMS2023—All TMS2023 participants are invited to attend as part of their registration.

TMS2023 will be held from March 19-23, 2023, in San Diego, California, USA. Learn more and register today at **www.tms.org/TMS2023**. While you are there, be sure to reach out to this promising group of scholars and congratulate them on their achievements!

SUPPORT STUDENTS LIKE THESE

TMS FOUNDATION

The scholarships featured in this article not only remove boundaries to education, but also support students in pursuing a deeper involvement in the greater materials community that can help open doors and build careers. Students are facing unprecedented challenges to their career paths, making assistance and assurance provided by these scholarships more important than ever.

All the awards highlighted in this article are made possible by the TMS Foundation and its generous supporters. You can ensure that the good work of the Foundation continues by making a donation today at **www.TMSFoundation.org/Contribute**. For more information or to discuss donation options, contact TMS Foundation staff at TMSFoundation@tms.org.

TMS DIVISION AWARDS

TMS Division Scholarships Recipients will also receive a dollar-for-dollar scholarship match through the Battelle Matching Scholarship Program. This is made possible through the generous support of Battelle and its retired chief executive officer, Jeffrey Wadsworth.

Additionally, students who receive a Battelle Matching Scholarship will be eligible for a Battelle Materials Graduate Student Award when they matriculate to a graduate school to continue studies in a materials-related field.

Extraction & Processing Division (EPD) Scholarship

Awarded through the EPD and the TMS Foundation to sophomore or junior undergraduate students majoring in the extracting and processing of minerals, metals, and materials.

Madison Pixler
University of Notre Dame

"I would like to thank the EPD for selecting me as this year's scholarship recipient. I chose to attend Notre Dame because I knew the education that I would receive would be one that cultivates both my mind and my heart; I also knew a membership at TMS would help me to develop critical skills to apply in the materials industry. The funds of this scholarship provided generously by the TMS Foundation, Battelle, and its former Chief Executive Officer and President, Jeffrey Wadsworth will go directly to paying for my tuition and will allow me to relieve financial stress while focusing on my chemical engineering degree."

Functional Materials Division (FMD) Gilbert Chin Scholarship

Awarded through the FMD and the TMS Foundation to sophomore or junior undergraduate students studying subjects related to synthesis and procession, structure, properties, and performance of electronic, photonic, magnetic, and superconducting materials, as well as materials used in packaging and interconnecting such materials in device structures.

Griffin Tong
University of Wisconsin

"Two years ago, I chose to study materials science and engineering instead of medicine. Since then, the opportunities and experiences that I have gained through TMS and Material Advantage have been tremendously positive, and with the support of this award, I know that I'm on the right path. I feel like my hard work is finally paying off and is even helping me to fund my education and grow my network."

Light Metals Division (LMD) Scholarship

Awarded through the LMD and the TMS Foundation to outstanding sophomore or junior undergraduate students majoring in metallurgical and/or materials science and engineering with an emphasis on both traditional and emerging light metals.

Marley Downes
Drexel University

"I am extremely grateful to be receiving the 2023 LMD Scholarship. Being a part of TMS and Material Advantage has given me numerous opportunities to grow outside of my classroom education, and I am excited for everything I will get to see and learn at the TMS annual meeting in the spring. This scholarship will help me progress through my education without the heavy burden of debt, and I am very thankful to TMS for giving me this opportunity."

Materials Processing & Manufacturing Division (MPMD) Scholarship

Awarded through the MPMD and the TMS Foundation to sophomore or junior undergraduate students majoring in metallurgical and/or materials science and engineering, with an emphasis on manufacturing, integrating process control technology into manufacturing, and basic and applied research into key materials technologies that impact manufacturing processes.

Anush Singhal
Georgia Institute of Technology

"From connecting with professors who are a part of the TMS community in Canada and who recommended this field of study, to networking, social, and professional events hosted at Georgia Tech by our Material Advantage chapter; TMS has provided me with a community of members to connect with. I plan to attend graduate school and obtain a Ph.D. in materials science with a focus on sustainable materials research in electronics. I am honored to receive the MPMD Scholarship and would like to thank the

TMS Foundation, Battelle, and Jeffrey Wadsworth for supporting my education, providing me with new experiences, and investing in my future."

Structural Materials Division (SMD) Scholarship

Awarded through the SMD and the TMS Foundation to sophomore or junior undergraduate students majoring in metallurgical and/or materials science and engineering with an emphasis on the science and engineering of load-bearing materials, including studies into the nature of a material's physical properties based upon its microstructure and operating environment.

Sydney Fields
University of Nevada, Reno

"I am sincerely honored to be selected as the recipient of the SMD Scholarship. As a member of TMS and Material Advantage, I have connected with others with similar interests and taken advantage of additional research opportunities. This scholarship will help support my education, future research, and my TMS travel."

ACTA MATERIALIA AWARDS

Acta Materialia Undergraduate Scholarship

Supported by the generosity of Acta Materialia Inc. and issued under the TMS Foundation, this scholarship is available to undergraduate students majoring in metallurgical engineering, materials science and engineering, or to undergraduate students with a significant interest in the materials area.

Berk Soykan
Drexel University

"I am incredibly grateful to TMS, Acta Materialia Inc, and Material Advantage for this scholarship which will significantly support one year of my undergraduate studies at Drexel University and my attendance of the TMS Annual Meeting & Exhibition in 2023. I have been interacting with Drexel's Material Advantage chapter since the beginning of my college experience and it has been a continuous wealth of information on the many subfields within materials science and engineering, a reliable source of professional development opportunities, and a link to the materials community in industry and academia alike. With the support of this scholarship, I am looking forward to completing my undergraduate degree and applying to Ph.D. programs with a particular interest in physical metallurgy and material design."

Raymond Wysmierski
University of Tennessee

"I joined Material Advantage in the fall of 2021 and, since then, I have grown extensively because of this organization. The scholarships, industry nights, and leadership opportunities have greatly excelled my professional career, and I could not be more thankful. I have so many events to look forward to this upcoming academic year: trivia nights, conferences, materials bowls, and engineering competitions to name a few. Following graduation, I plan to earn a master's degree in materials science and engineering and seek out industry positions in automotive manufacturing and metallurgy."

AIME AWARDS

AIME Henry deWitt Smith Scholarships

This scholarship is awarded to graduate students majoring in mineral, metal, and/or materials engineering. The award aims to advance the mineral industries by assisting students in the pursuit of graduate education in mining, metallurgical, materials, or petroleum-related disciplines.

Jack Grimm
University of Washington

"I already owe much to TMS and Material Advantage for introducing me to not only the vast span of materials science research, but also the field-leading experts behind those projects. It was thanks to the first TMS meeting I attended in 2018 (through Material Advantage) that I was able to identify my interests, make impactful connections, and develop my early career trajectory. I am grateful to have been selected for the Henry deWitt Smith Scholarship, and I hope to pay this honor forward through the promotion of materials science through education, outreach, and research."

Haozheng Qu
Purdue University

"The Henry deWitt Smith Scholarship Award is a tremendously humbling honor for me to receive from TMS and AIME. I am so grateful for the decision to join TMS at the very beginning of graduate school, for I have gained valuable exposure to state-of-the-art research and opportunities to interface with world-class experts in materials science over the past four years. This prestigious award is an amazing recognition for my efforts in this exciting journey of my Ph.D. studies and a great encouragement for me to keep pressing on exploring and advancing our understanding of the materials universe."

TMS BEST PAPER CONTEST

This award recognizes student essays on global or national issues as well as technical research papers relating to any field of metallurgy or materials science.

Best Paper Award – First Place Graduate

Lin Gao
University of Virginia

Paper: "Exceptional Ductility Induced by Intrinsic Grain Boundary Engineering"

"It is my great honor to receive this award. TMS provides me with this new opportunity to be involved in this professional society. I am profoundly grateful for the help and support from the TMS Foundation, my supervisor Tao Sun, and all my co-authors. This award not only recognizes our current research but also encourages me to make more efforts to explore this field of material science."

Best Paper Award – Second Place Graduate

Benjamin Stegman
Purdue University

Paper: "Reactive Introduction of Oxide Nanoparticles in Additively Manufactured 718 Ni Alloys"

"TMS membership has significantly helped me further my career through access to technical programming and it has expanded my connections with its international presence. This award will also help increase my reputation within the additive community and hopefully help me progress professionally."

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05592-7

In Case You Missed It:

BUSINESS NEWS FROM THE FIELD

Do you have business or industry news of interest to the minerals, metals, and materials community?

JOM THE MAGAZINE

Submit your announcement or press release to Lynne Robinson, Department Head, Marketing and Communications, at lrobinson@tms.org.

Pittsburgh, Pennsylvania, USA: NASA and Astrobotic completed testing with prototypes of NASA's water-hunting Volatiles Investigating Polar Exploration Rover (VIPER) and Astrobotic's Griffin lunar lander. During testing at NASA's Glenn Research Center in Cleveland, VIPER was driven down Griffin's sizeable ramps in simulated lunar surface situations to prove safe egress after landing on the Moon. (Photo Credit: Astrobotic)

Nucor Modernizes Mill Projects

Charlotte, North Carolina, USA: Nucor Corporation plans to invest $200 million over a five-year period in mill modernization projects at its Nucor Steel Berkeley division located in Huger, South Carolina. Pending permit and regulatory approvals, a portion of the capital investment will include the construction of a new air separation unit (ASU) for the purpose of supplying industrial gases for the mill's steelmaking operations. When complete, the ASU will be operated by UIG LLC, a Nucor wholly owned subsidiary, that specializes in industrial gas supply. Nucor Steel Berkeley is currently supplied with industrial gases under a long-term supply agreement. This project will allow Nucor, through UIG, to produce and supply all the gases needed for the steel mill from the new Nucor owned facility, both now and into the future.

Steel Partners Plan New Demo Plant

Canonsburg, Pennsylvania, USA: Primetals Technologies and South Korean steel producer POSCO agreed to develop a demonstration plant for hydrogen-based hot metal production in South Korea. The plant will be built around HyREX technology developed by Primetals, which uses sinter fines that forego the need for agglomeration processes such as pelletizing and sintering. POSCO intends to continue evaluating the commercial feasibility of hydrogen-based hot metal with an eye to replacing its blast furnaces with HyREX plants. Start-up of the plant is scheduled for early 2027.

West Des Moines, Iowa, USA: Collins Aerospace broke ground in July 2022 on a $14 million expansion of its additive manufacturing center in West Des Moines, Iowa. The 9,000-square-foot expansion will allow Collins to make room for more 3D metal printers, in addition to the three it already has onsite. The first new printer will have eight times the build volume of the existing printers and Collins expects it to be fully operational in late 2023. The company will use the new machines to enhance current production capabilities and expand the portfolio of metals it can use to additively produce engine components at the site. (Photo Credit: Collins Aerospace)

RHI Magnesita Selects Tampa for Headquarters

Vienna, Austria: Refractories maker RHI Magnesita will open a North American headquarters in Tampa, Florida, in the spring of 2023. The company made the selection after seeing tremendous market development in the mid-Atlantic and southeastern area of the U.S. The Austrian company serves customers around the world, with around 13,000 employees in 28 main production sites and more than 70 sales offices.

Reep Develops a "Deprinter"

Tel Aviv, Israel: Reep Technologies, Ltd. developed a new device that can remove ink from a sheet of paper and plans to launch a circular printing services business in 2023. Its laser "deprinter" offers a new way to reuse and recycle paper, specifically office paper. Reep coats its paper before printing to prevent it from deeply absorbing the ink. The laser deprinter applies heat to evaporate the ink, and the sheet can be used again. Reep hopes to achieve as much as a 90% reduction in carbon dioxide and the consumption of resources through circular printing.

JOM: The Magazine, Vol. 74, No. 12, 2022
https://doi.org/10.1007/s11837-022-05593-6

TMS MEETING HEADLINES

JOM THE MAGAZINE

Meeting dates and locations are current as of October 17, 2022. For the most recent updates on TMS-sponsored events, visit **www.tms.org/Meetings**.

TMS 2023 Annual Meeting & Exhibition (TMS2023)

March 19–23, 2023

San Diego, California, USA

Discount Registration Deadline: January 31, 2023

TMS2023 will feature high-quality technical programming, but the real reason that attendees keep coming back year after year to the TMS annual meeting is the valuable interactions with their colleagues and mentors. Make your plans to join them and register today:

www.tms.org/TMS2023

Superalloy 718 & Derivatives 2023

May 14–17, 2023

Pittsburgh, Pennsylvania, USA

Discount Registration Deadline: April 3, 2023

Superalloy 718 & Derivatives 2023 will explore all aspects of metallurgical processing, materials behavior, and microstructural performance for a distinct class of 718-type superalloy and derivatives. Leading names in the field are involved as presenters or engaged in stringently curating presentations to ensure the highest quality programming.

www.tms.org/Superalloy718-2023

TMS Fall Meeting 2023 @ Materials Science & Technology (MS&T)

October 1-5, 2023

Columbus, Ohio, USA

Abstract Deadline: April 3, 2023

TMS Fall 2023 will present robust programming, networking and social activities, and professional development events tailored to TMS member interests within the broader structure of the MS&T conference series, giving attendees an opportunity to experience both their TMS community and the resources of all the MS&T partnering societies.

www.tms.org/FallMeeting/TMSFall2023

3rd World Congress on High Entropy Alloys (HEA 2023)

November 12–16, 2023

Pittsburgh, Pennsylvania, USA

Abstract Deadline: June 16, 2023

With its specific technical focus and ample networking opportunities, HEA 2023 has been developed to attract research leaders from industry, government, and academics from across the globe, as well as students and postdocs interested in the science and engineering of metallic materials and high-performance alloys.

www.tms.org/HEA2023

// Other Meetings of Note

7th World Congress on Integrated Computational Materials Engineering (ICME 2023)

May 21-25, 2023

Orlando, Florida, USA

www.tms.org/ICME2023

TMS 2024 Annual Meeting & Exhibition (TMS2024)

March 3–7, 2024

Orlando, Florida, USA

www.tms.org/TMS2024

15th International Symposium on Superalloys (Superalloys 2024)

September 8–12, 2024

Champion, Pennsylvania, USA

www.tms.org/Superalloys2024

Offshore Technology Conference (OTC) 2023
May 1-4, 2023
Houston, Texas, USA
Co-sponsored by TMS

European Metallurgical Conference (EMC 2023)
June 11–14, 2023
Düsseldorf, Germany
Co-sponsored by TMS

OTC Brasil 2023
October 24–26, 2023
Rio de Janeiro, Brazil
Co-sponsored by TMS

Materials in Nuclear Energy Systems (MiNES 2023)
December 10–14, 2023
New Orleans, Louisiana, USA
Co-sponsored by TMS

TMS FALL 2023

@ MATERIALS SCIENCE & TECHNOLOGY

October 1-5, 2023 | Columbus, Ohio | #TMSFallMeeting

CALL FOR ABSTRACTS

Abstracts Due April 3, 2023

Join your TMS colleagues for the TMS Fall Meeting 2023 at Materials Science & Technology (TMS Fall 2023) in October.

Submit your work to one of 24 TMS-sponsored symposia planned in the following subject areas:

- Additive Manufacturing
- Artificial Intelligence
- Ceramic and Glass Materials
- Education and Career Development
- Fundamentals and Characterization
- Iron and Steel (Ferrous Alloys)
- Lightweight Alloys
- Modeling
- Nuclear Energy
- Processing and Manufacturing
- Special Topics

SUBMIT YOUR WORK TODAY!

Scan the QR code or visit:

www.tms.org/TMSFall2023

WHERE MATERIALS PEOPLE

DEVELOP

As a TMS member, you can build your profile in the community, share information and career advice with others, and access leadership opportunities.

Apply for TMS Awards or Nominate a Colleague

Explore the TMS Career Center

Apply for Young Professional Programs

> "Our members care about each other at every level and having that support structure and the ability to give back has kept me engaged."
>
> — ***Suveen Mathaudhu***, *Chair of TMS Structural Materials Division, 2022-2025 TMS Board of Directors*

Renew Your TMS Membership for 2023!
members.tms.org

TMS MEMBERSHIP

Thermo-Calc Software

Empowering Metallurgists, Process Engineers and Researchers

Do you rely on handbook data?
What if the materials data you need doesn't exist?

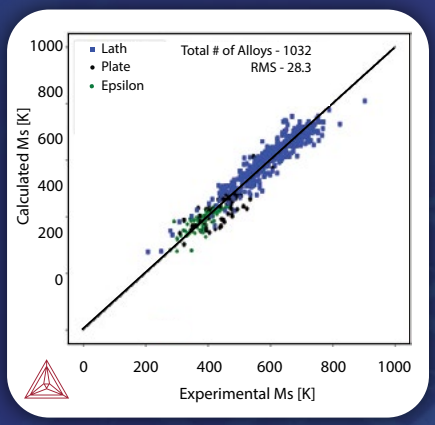
With Thermo-Calc you can:

- ✓ **Calculate** phase-based properties as a function of composition, temperature and time
- ✓ **Fill in** data gaps without resorting to costly, time-consuming experiments
- ✓ **Predict** how actual vs nominal chemistries will affect property data
- ✓ **Base Decisions** on scientifically supported models
- ✓ **Accelerate** materials development while reducing risk
- ✓ **Troubleshoot** issues during materials processing

Over 40 Thermodynamic and Kinetic Databases

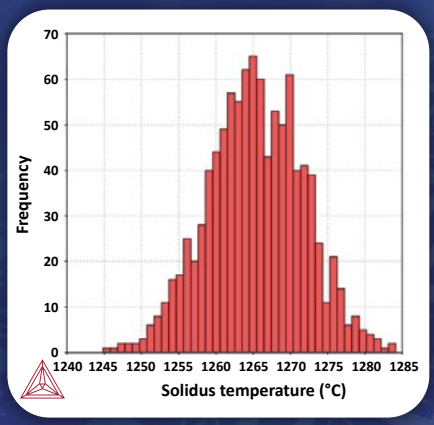
Choose from an extensive selection of thermodynamic and mobility databases in a range of materials, including:

Steel and Fe-Alloys



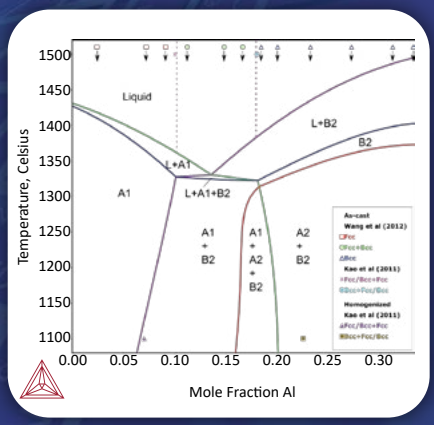
Comparison of calculated and experimental Ms temperatures for a wide range of steels

Nickel



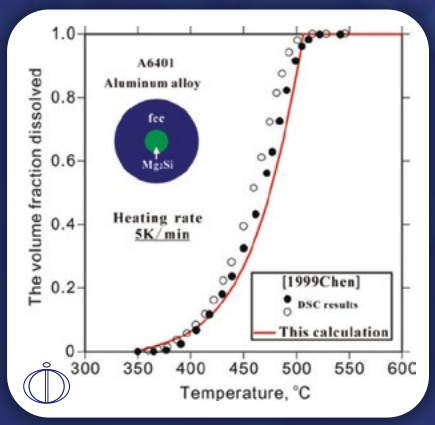
Variation in solidus temperature over 1000 compositions within alloy 718 specification

High Entropy Alloys



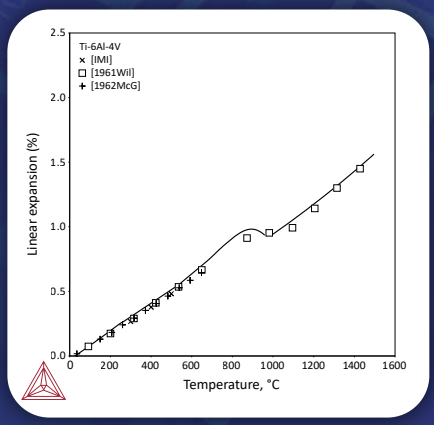
Calculated phase diagram along the composition line of CoCrFeNi-Al

Al Alloys



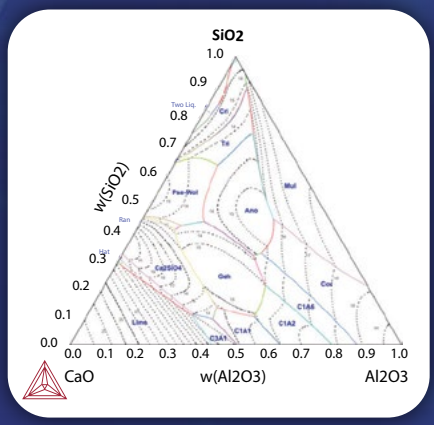
Dissolution of Mg2Si precipitate in Alloy A6401

Ti and TiAl Alloys



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

Oxides



Ternary liquidus projection in oxide systems

www.thermocalc.com info@thermocalc.com