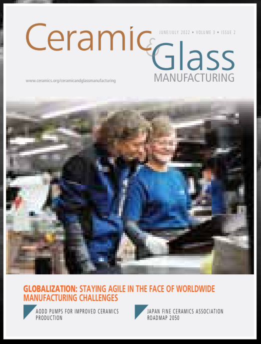
AMERICAN CERAMIC SOCIETY
bulletin
emerging ceramics & glass technology
JUNE/JULY 2022

MXenes for atomistic design of 2D nanoceramics

New issue inside:



Also– Student perspectives on hope

IYOG ushers in the Age of Glass | 2022–2023 ACerS Board members and directors

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June/July 2022 • Vol. 101 No.5

feature articles

MXenes for atomistic design of 2D nanoceramics

Since the discovery of 2D transition metal carbides and nitrides (MXenes) in 2011, research on this family of materials has led to its usage in many sectors—with future applications continuously emerging.

by Brian C. Wyatt, Anupma Thakur, and Babak Anasori

Student perspectives on hope

The challenges that students faced throughout the past few years are immense; yet, hope remained ever-present in the face of these challenges.

Chair's update on PCSA activities and welcome to the student *ACerS Bulletin* issue
by Olivia Brandt

Congressional Visits Day 2022 recap
by Yolanda Natividad

From crisis to hope—pandemic drives increase in mental health awareness and support
by Becky Steadman

Redefining the looking glass: Reconnecting glass art and science
by Brittney Hauke

Science fiction sparks 'a new hope'
by Erin Valenzuela

Toward where no earthling has gone before
by Elia Zancan

Vitrification of nuclear waste offers hope for a cleaner future
by John Bussey

With a touch of magic: Lessons learned from alchemists and historic ceramics
by Celia S. Chari

Hope in collaborations: A driving force for research
by Kartik Nemani and Brian C. Wyatt

The far-reaching impact of the Mini Materials Kit
by Nathaniel Olson and Nathaniel S. McIlwaine

Cover image

The cover depicts the accordion-like morphology of etched Ti_3C_2 MXene powder captured via field emission-scanning electron microscope. The width of the particle at the center is about 8 µm. *Credit: Babak Anasori*

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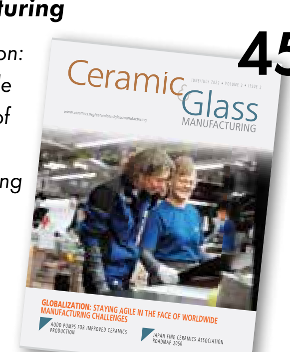
Globalization: Staying agile in the face of worldwide manufacturing challenges



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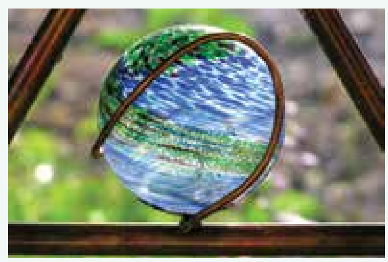
As seen on *Ceramic Tech Today...*



Credit: normanack, Flickr (CC BY 2.0)

Video: World Environment Day celebrates 50 years—how ceramic and glass materials help us live sustainably

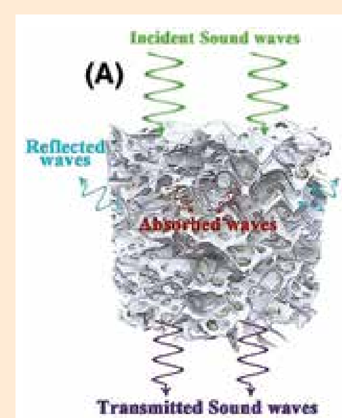
In honor of World Environment Day on June 5, we look at a few of the many important contributions by ceramic and glass scientists that move us toward a more sustainable and harmonious relationship with nature.

Read more at www.ceramics.org/WorldEnvironmentDay

Also see our ACerS journals...

Advanced graphene ceramics and their future in bone regenerative engineering
By F. Hosseini and C. Laurencin
International Journal of Applied Ceramic Technology

Enhanced sound absorption properties of porous ceramics modified by graphene oxide films
By C. He, B. Du, J. Ma, et al.
Journal of the American Ceramic Society



Improving corrosion protection of Mg alloys (AZ31B) using graphene-based hybrid coatings
By N. Afsharimani, A. Talimian, E. Merino, et al.
International Journal of Applied Glass Science

First-principles investigation of elastic and electronic properties of double transition metal carbide MXenes
By R. Jayan, A. Vashisth, and M. Islam
Journal of the American Ceramic Society

Read more at www.ceramics.org/journals

American Ceramic Society Bulletin covers news and activities of the Society and its members, includes items of interest to the ceramics community, and provides the most current information concerning all aspects of ceramic technology, including R&D, manufacturing, engineering, and marketing. The American Ceramic Society is not responsible for the accuracy of information in the editorial, articles, and advertising sections of this publication. Readers should independently evaluate the accuracy of any statement in the editorial, articles, and advertising sections of this publication. *American Ceramic Society Bulletin* (ISSN No. 0002-7812). ©2022. Printed in the United States of America. *ACerS Bulletin* is published monthly, except for February, July, and November, as a "dual-media" magazine in print and electronic formats (www.ceramics.org). Editorial and Subscription Offices: 550 Polaris Parkway, Suite 510, Westerville, OH 43082-7045. Subscription included with The American Ceramic Society membership. Nonmember print subscription rates, including online access: United States and Canada, 1 year $135; international, 1 year $150.* Rates include shipping charges. International Remail Service is standard outside of the United States and Canada. *International nonmembers also may elect to receive an electronic-only, email delivery subscription for $100. Single issues, January–October/November: member $6 per issue; nonmember $15 per issue. December issue (*ceramicSOURCE*): member $20, nonmember $40. Postage/handling for single issues: United States and Canada, $3 per item; United States and Canada Expedited (UPS 2nd day air), $8 per item; International Standard, $6 per item.

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ACSBA7, Vol. 101, No. 5, pp 1– 64. All feature articles are covered in Current Contents.

news & trends

US federal committees and agencies lay plans for spectrum management reform

Ever since telecommunications companies began rolling out their 5G networks in 2019, conflicts between federal, public, and private entities over spectrum usage have reached a fever pitch.

5G networks can operate in a higher frequency range than previous broadband standards. Though companies often claim these higher frequency ranges are "empty" for exploitation by 5G networks, the reality is that other industries and sectors already use these frequency ranges.

For example, weather satellites collect important data on water vapor in the 20–30 GHz range. In 2019, when the Federal Communications Commission (FCC) began auctioning frequencies in this range to mobile carriers preparing for 5G, the National Oceanic and Atmospheric Administration expressed strong concern about it degrading the scientific community's ability to accurately track and forecast weather patterns.

Air travel is another industry carefully tracking the rollout of 5G wireless communication services. In January 2022, as the time for AT&T and Verizon's 5G service rollout approached, airlines canceled flights due to concerns that the new network would interfere with their equipment, specifically radio altimeters, or devices that help determine a plane's altitude. In response, AT&T and Verizon agreed to delay switching on new telecom towers near key airports, and the Federal Aviation Administration is leading a push to retrofit and ultimately replace some airplane radio altimeters that could face interference from the new 5G service.

In contrast to the U.S., the 5G rollout in Europe did not cause concern among airlines because governments required a much larger buffer between the spectrum used by radar altimeters and 5G, so there was no risk of interference.

The struggle over U.S. spectrum allocations stems largely from the relationship between two federal agencies—the FCC and the National Telecommunications and Information Administration (NTIA). FCC regulates nonfederal use of the radio spectrum (including television) and interstate telecommunications (via wire and later satellite and cable). In contrast, NTIA is responsible for governmentwide federal spectrum management.

The Communications Act of 1934, as amended, assigns joint jurisdiction for spectrum management in the U.S. to FCC and NTIA. These agencies are expected to coordinate spectrum allocations to balance public and private sector interests, but communication between these two agencies often falls short of the needed cooperation.

"Two years ago [in 2020], the Democratic and Republican leaders of the House Energy and Commerce Committee asked the Government Accountability Office to review federal spectrum management, complaining it had devolved into the use of 'chaotic processes' in which federal agencies appeared to be circumventing NTIA," an FYI article explains. "The resulting GAO report, released in January, outlines steps NTIA specifically could take to reform its processes for assessing spectrum interference risks and communicating them to FCC. … A separate study that GAO released last year in response to a bipartisan request from the House Science Committee found that there is no clear guidance on how FCC and NTIA should resolve disputes."

In addition, a memorandum of understanding (MOU) between FCC and NTIA, which outlines how and how often the agencies will share data, communicate users' needs, and raise potential spectrum interference issues before allocation decisions are made, has not been updated since 2003. In January 2022, Senate Commerce Committee Ranking Member Roger Wicker (R-MS) strongly suggested that the MOU be updated because it "does not appropriately account for the dramatic changes in technology in the past 20 years."

In response to the numerous critiques, FCC and NTIA announced a new initiative called the Spectrum Coordination Initiative in February 2022. In addition to vowing to update the MOU, the new initiative requires

1. The FCC chair and NTIA head hold formal, regular meetings to conduct joint spectrum planning. The current MOU requires these officials to meet only twice each year.

2. Collaboration of FCC and NTIA to help inform development of a national spectrum strategy.

3. FCC's participation as an observer in NTIA's Commerce Spectrum Management Advisory Committee. Similarly, NTIA will participate as an observer in the FCC's Technological Advisory Council and the Communications Security, Reliability, and Interoperability Council.

In 2020, the NTIA proposed the possibility of creating a portal called the Incumbent Informing Capability (IIC). This portal would allow any federal spectrum user to submit information about when and where they would employ certain frequencies.

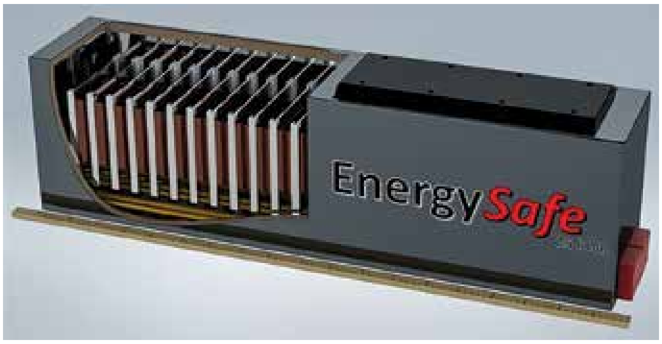
"This scheduling information would inform a spectrum coordination system, in conjunction with advanced computer databases, allowing 5G commercial network providers to adjust operations in real time and avoid harmful interference," the NTIA explained in a press release announcing the concept.

In October 2021, U.S. Representative Brett Guthrie (R-KY 2nd District) introduced the Simplifying Management, Reallocation, and Transfer of Spectrum (SMART) Act in the House, which recommends that NTIA receive a more than $100 million infusion to develop a framework to dynamically share spectrum between federal and nonfederal users. In a virtual hearing held Tuesday, May 24, by the Subcommittee on Communications and Technology of the Committee on Energy and Commerce, witnesses emphasized how this act would provide NTIA a timeline and funding authorization to realize the IIC.

Over in the Senate, Senator Roger Wicker (R-MS) introduced the Improving Spectrum Coordination Act in April 2021, which aims to reform procedures for reallocating radiofrequency bands to new users. The bill would not only require FCC and NTIA to update their MOU, but it would require revisions quadrennially to address "changing technological, procedural, and policy circumstances." The Senate Commerce, Science, and Transportation Committee originally planned to consider this bill during an executive session on Wednesday, May 25, but it ultimately was not discussed during the session. ■

Corporate Partner news

Nexceris to advance product readiness of new energy storage solution



Nexceris, a clean energy innovator with more than 25 years of focus on renewable energy, was awarded a U.S. Department of Energy Phase 2 small business innovation research contract to help modernize the U.S. energy grid. Nexceris, in partnerships with Pacific Northwest National Laboratory and BRITE Energy Innovators, will advance the product readiness of its EnergySafe product, a disruptive low-cost intraday (8–16 hours duration) energy storage solution. The project will culminate with an independent 5 kWh module demonstration at BRITE's test facility to position EnergySafe for future onsite demonstrations with industrial partners. ■

India aims to become major player in global semiconductor market

In response to the ongoing semiconductor shortage and other supply chain issues, manufacturers and government officials alike around the world are considering more closely the benefits of domestic manufacturing. In recent months, the government of India laid the groundwork to bring commercial semiconductor chip manufacturing to India for the first time.

Though defined as a lower-middle-income country by the World Bank, India has made significant progress integrating into the global economy since the 1990s and is now counted among the world's leading emerging markets. Information technology is one industry in India that particularly stands out, accounting for 8% of India's GDP in 2020. However, while India excels in providing information technology-enabled services, domestic manufacturing of electronic components remains lagging.

Semiconductor chips are a prime example. While India has done well in research and development of semiconductor chips—an India Briefing article states the Indian semiconductor design market was projected to reach US$52.6 billion in 2020—the country has few semiconductor fabrication plants and none are for commercial use.

In November 2021, India prime minister Narendra Damodardas Modi announced that India aimed to become a major global manufacturer of semiconductor chips during his keynote address at the inaugural Sydney Dialogue, hosted by The Australian Strategic Policy Institute. In his speech, Modi said the government was working on a package to push domestic semiconductor chip production.

On Dec. 15, 2021, the Indian government approved the Semicon India Program, with an outlay of INR 760 billion (>US$10 billion) for the development of a sustainable semiconductor and display manufacturing ecosystem in India. On December 30, the Indian government announced it would start receiving proposals from companies for semiconductor and display manufacturing from Jan. 1, 2022. To date, India's government has received proposals from five companies to establish electronic chip and display manufacturing plants with an investment of INR 1.53 trillion (~US$20.5 billion).

On May 1, 2022, chip consortium ISMC, a joint venture between Abu Dhabi-based Next Orbit Ventures and Israel's Tower Semiconductor, publicly announced its plans to invest up to $3 billion in India's southern Karnataka state to set up India's first commercial semiconductor manufacturing plant. (Intel announced plans to acquire ISMC partner Tower Semiconductor).

Credit: Invest in Karnataka, Twitter

Semiconductor chip consortium ISMC signed a memorandum of understanding with the government of India's southern Karnataka state to set up India's first commercial semiconductor manufacturing plant.

ISMC is not alone—Reuters reported on April 30, 2022, that Indian multinational mining giant Vedanta is in talks with several Indian states and supposedly has a planned investment outlay of $20 billion to begin its foray into semiconductor and display manufacturing. ■

Each month, we will be highlighting articles from different areas of glass science in the online blog *Ceramic Tech Today.*

Discovering the invisible: IYOG ushers in the Age of Glass

By Alicia Durán and John M. Parker

On Feb. 10–11, 2022, the United Nations International Year of Glass officially got underway when the international glass community took over the Human Rights Room in the Palace of Nations, Geneva, Switzerland, for the opening ceremony.

During the two-day event, 30 world-class speakers lectured on a multiplicity of glass-centric topics to an in-person audience of 135 glass experts, plus thousands more who joined via the United Nations Web TV. Several thousands more have since watched the session recordings, which are available at www.iyog2022.org.

The opening ceremony launched a packed program of worldwide events targeting a huge and eclectic audience. The IYOG website's events calendar currently lists 400 activities from 41 countries, with more added daily. Activities range from international congresses and trades fairs to streamed lectures and webinars, including competitions for schoolchildren, the design of a stained-glass window for a prescribed location, and equipping of primary schools with optical microscopes.

The rationale behind this International Year is not only to celebrate a material that is at the heart of society but also to focus and build on its capacity to help achieve many of the humanitarian aims embedded within the UN 2030 sustainable development goals. An inspirational video on glass and the UN goals is available on YouTube in English, Spanish, Japanese, and Portuguese at https://www.youtube.com/watch?v=A6ZEaWvlz6k.

While a small executive committee organized the opening ceremony, the world is now subdivided into 18 regions, each with its own committee for organizing local events. Between these two bodies sits a Council with representatives from: a) each region; b) subgroups responsible for education, museums/art/history, and young people that transcend geographical boundaries; and c) the main glass associations and magazines. Events planned at the national level include the issue of celebratory postage stamps, identification of specific towns with economies based around glass, setting up twinning relationships, renaming streets... The list goes on.

Funding is critical to organizing these activities. Originally, a sponsorship program was created and largely run by Patrick Gavaghan of the Australian Centre for Glass Design to generate income for the opening ceremony. However, funds raised exceeded the costs incurred, so most of the unspent monies is being made available as seed funding for new activities in various formats. Organizers can apply for seed funding by emailing fundallocation@iyog2022.org. The first call for seed funding just closed; the second call will open on July 1.

In July, the International Commission on Glass's triennial Congress in Berlin will include a major celebration of glass and the centenary of the formation of the German Society of Glass Technology. A closing ceremony in Japan in December will follow a reporting event at the UN in New York. The conference in Japan will acclaim the year's activities, emphasizing the scientific, technical, and longer-term outcomes, while New York will focus more on the organization and report success stories in achieving the UN goals.

The various events also serve as a vivid reminder of how IYOG participants are influenced by national and international events. For example, one recent lecture on Ukrainian stained glass concerned its preservation, while another talk from a museum in Lebanon explained their response to the loss of ancient glass artifacts destroyed in the chemical explosion two years ago. These more serious topics are counterbalanced by celebrations focused on fun, such as the opening and reopening of glass museums.

Six months of the year remain, and we remind you to consider attending some of the many IYOG events when planning your holidays. The legacy of our activities, like a silica glass bell, will resonate for many years to come.

About the authors

Alicia Durán is research professor for the Spanish Research Council and past president of the International Commission on Glass. John M. Parker is Emeritus Professor at The University of Sheffield. Contact Durán at aduran@icv.csic.es and Parker at j.m.parker@sheffield.ac.uk.

Group shot of attendees at the opening ceremony of the United Nations International Year of Glass, Feb. 10–11, 2022, Geneva, Switzerland.

Credit: Alicia Durán

Global markets and technologies for nanofibers

By BCC Publishing Staff

The global nanofiber market was valued at $1.8 billion in 2020 and is estimated to grow at a compound annual growth rate (CAGR) of 25.1% to reach $6.7 billion in 2026.

Nanofibers are traditionally defined as cylindrical (hollow or solid) structures having an outer diameter of less than 1,000 nanometers and an aspect ratio (i.e., the ratio between length and width) greater than 50. The high surface area offered by nanofibers, along with other physical, electrical, thermal, and mechanical properties, makes them suitable for various commercial applications (Table I).

Nanofibers can be made from various types of materials (Table II), including ceramics and glass.

- **Carbon nanofibers** can be produced via catalytic chemical vapor deposition, as well as through the combination of electrospinning of organic polymer and thermal treatment. Carbon nanofibers exhibit high specific surface area, flexibility, and super strength, which allows them to be used in electrode materials for energy storage devices, as a hybrid-type filler in carbon-fiber-reinforced plastics, and as bone tissue scaffolding.
- **Ceramic nanofibers** such as alumina, zirconia, and titania can be produced via magnetron sputtering, solution blowing (i.e., air jet spinning), laser spinning, chemical vapor deposition, template synthesis, phase separation, hydrothermal treatment, and electrospinning. Electrospun ceramic nanofibers display unprecedented properties, including high surface area, length, thermomechanical properties, and hierarchically porous structure. These properties make them candidates for a wide range of applications, including tissue-engineering, sensors, water remediation, energy storage, electromagnetic shielding, and thermal insulation.
- **Glass nanofibers** are typically produced using laser electrospinning. A new production method was recently introduced that produces endless, continuous, solid, and separated glass nanofibers from the melt of a solid preform without requiring a crucible. The continuous fiberizing by laser melting and supersonic dragging (Cofiblas) method leads to glass fibers with controlled and uniform diameters. Unlike laser spinning, it achieves total control of the fiber diameter and increases productivity.

Table 1. Global nanofiber market, by application, through 2026 ($ millions)

Application	2020	2021	2026	CAGR % 2021–2026
Life science	617.3	772.2	2,766.1	29.1
Mechanical, chemical, and environmental	724.8	864.4	2,548.1	24.1
Energy	193.8	225.5	587.8	21.1
Electronics and optoelectronics	154.8	182.8	510.2	22.8
Consumer	41.4	46.2	97.7	16.2
Transportation	34.0	39.2	96.4	19.7
Sensors and others	59.9	64.8	114.9	12.1
Total	1,826.1	2,195.0	6,721.5	25.1

Table 2. North American nanofiber market, by material type, through 2026 ($ millions)

Material type	2020	2021	2026	CAGR % 2021–2026
Polymers	550.1	691.2	2,353.3	27.8
Carbon	96.9	106.0	190.1	12.4
Metals and alloys	56.8	64.3	137.4	16.4
Ceramics and glass	35.9	37.7	55.5	8.0
Composites	26.4	31.3	83.3	21.6
Semiconductors	11.8	13.8	33.9	19.7
Total	777.9	944.3	2,853.6	24.8

Energy applications will be the main driver for carbon nanofiber market growth, accounting for 32.1% of the total carbon nanofiber market in 2026 (corresponding to revenues of $142.4 million). In contrast, applications in the mechanical, chemical, and environmental sector will be the main driver for ceramic and glass nanofiber market growth, accounting for a combined 52.9% share of the market (corresponding to revenues of $65.0 million).

A significant amount of research work on nanotechnology and a rise in the commercialization of products containing engineered nanomaterials (particularly nanofibers) is currently taking pace in the Asia-Pacific region. Several countries in the region have declared nanotechnology as a strategic sector of technological and scientific development.

About the author

BCC Publishing Staff provides comprehensive analyses of global market sizing, forecasting, and industry intelligence, covering markets where advances in science and technology are improving the quality, standard, and sustainability of businesses, economies, and lives. Contact the staff at Helia.Jalili@bccresearch.com.

Resource

BCC Publishing Staff, "Global markets and technologies for nanofibers" BCC Research Report NAN043F, April 2022. www.bccresearch.com.

acers spotlight

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Welcome new ACerS Corporate Partner

ACerS is pleased to welcome its newest Corporate Partner

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Refratechnik North America, Inc.

To learn about the benefits of ACerS Corporate Partnership, contact Kevin Thompson, industry relations director, at (614) 794-5894 or kthompson@ceramics.org. ■

ACerS 2022 Society awardees announced

Congratulations to the latest group of Society awardees! The list of 2022 awardees is available at https://bit.ly/2022societyawards. Bios and photos of the 2022 awardees will be posted online over the next few months, and they will be featured in the September 2022 issue of the *Bulletin*. The awards will be presented October 10 at ACerS Honors and Awards Banquet during ACerS Annual Meeting at MS&T in Pittsburgh, Pa. Be sure to purchase your banquet tickets before the meeting. ■

Ceramic Tech Chat: Christopher Berndt

Hosted by ACerS Bulletin editors, Ceramic Tech Chat talks with ACerS members to learn about their unique and personal stories of how they found their way to careers in ceramics. New episodes publish the second Wednesday of each month.

In the April episode of Ceramic Tech Chat, Christopher Berndt, Distinguished Professor of Surface Science and Engineering at Swinburne University of Technology, describes the use of thermal spray technologies to coat surfaces, the challenges companies face implementing these technologies on an industrial scale, and what is in store for the future of this field. Check out a preview from his episode, which features Berndt offering advice to young material scientists considering a career in surface engineering.

"The advice should be, first of all, do not limit yourself just to thermal spray. Think about the big picture of materials science and engineering and apply those principles to ceramic technology or thermal spray. Because if they do not have that very strong grounding in phase equilibria or mechanical testing, you can still get into the area, but you're going to have to somehow pick up those skills in your own time. So, ... early career professionals need to be very open minded."

Listen to Berndt's whole interview—and all our other Ceramic Tech Chat episodes—at http://ceramictechchat.ceramics.org/974767. ■

John Mauro appointed next editor-in-chief of the *Journal of the American Ceramic Society*

Mauro

ACerS president Beth Dickey announced that John C. Mauro will succeed William G. Fahrenholtz as editor-in-chief of the *Journal of the American Ceramic Society*. Fahrenholtz will step down in December after six years as editor-in-chief. Mauro's five-year appointment begins Jan. 1, 2023. As editor-in-chief, Mauro will serve as principal architect of the scientific content of *JACerS* and grow its impact worldwide. He will lead a team of editors and associate editors.

"The landscape for scholarly publishing is constantly shifting, and John has an exciting vision for the *Journal* and a comprehensive knowledge about the future of publishing," Dickey says.

"Bill's appointment began a significant investment in *JACerS* by the Society. He led the expansion of the editor corps and implemented procedures that greatly improved the end-to-end efficiency of the publishing process. We look forward to working with John as he leads *JACerS* to the next level" says Mark Mecklenborg, ACerS executive director.

Mauro says, "The American Ceramic Society has been my professional home now for nearly 25 years, and it is a great privilege to serve as editor-in-chief for our flagship journal. I will strive to continue the excellent progress of *JACerS* to attract the highest-quality, highest-impact manuscripts in the ceramic and glass sciences."

Mauro is a Dorothy Pate Enright Professor in the Department of Materials Science and Engineering and associate head for graduate education at The Pennsylvania State University (University Park, Pa.). He graduated from Alfred University with a B.S. in glass engineering science and B.A. in computer science (2001), and he earned his Ph.D. in glass science in 2006, also at Alfred University.

A world-recognized expert in glass science, he worked 18 years at Corning International (Corning, N.Y.) prior to joining the Penn State faculty. He invented or was co-inventor of three generations of Corning Gorilla Glass products, used on more than two billion devices worldwide. He authored or co-authored more than 300 peer-reviewed journal articles (many in *JACerS*), which have garnered more than 13,000 citations. He is an ACerS Fellow, member of the National Academy of Engineering and the National Academy of Inventors, and former chair of ACerS Glass & Optical Materials Division. He has been a *JACerS* editor since 2017 and was an associate editor 2012–2017. He is also an associate editor of *International Journal of Applied Glass Science*.

Volunteer spotlight

ACerS Volunteer Spotlight profiles a member who demonstrates outstanding service to the Society.

Kundu

Rishabh Kundu is a graduate student in the Institute of Materials Science at the Technical University of Darmstadt, Germany. He received his bachelor's degree in ceramic engineering from the National Institute of Technology, Rourkela (NIT-RKL), India.

Kundu has authored/co-authored five research papers in peer-reviewed esteemed international journals. He was active in the Indian Ceramic Society's student chapter at NIT-RKL, serving as vice-chair and a senior mentor.

An ACerS member since 2021, he is active as a Super Member in the online ACerS Member Community and is currently the top contributor. He also developed a global logo competition for the Energy Materials and Systems Division (EMSD) and has served as a guest columnist for the *ACerS Bulletin*.

Kundu was awarded the Student Initiative Grant 2021 by the EMSD to support his self-motivated scientific and outreach pursuits. Currently, he serves as a member of the Special Projects Committee of the Manufacturing Division.

We extend our deep appreciation to Kundu for his service to our Society!

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Meet the 2022–2023 officers and Board members

President-elect


Bordia

RAJENDRA KUMAR BORDIA
George J. Bishop, III Professor of Ceramic and Materials Engineering
Department of Materials Science & Engineering
Clemson University
Clemson, S.C.

I have deep reverence and gratitude for The American Ceramic Society, and commitment to its mission. Having volunteered at all levels in the Society (Division, professional meetings, technical publications, Board and member recognition) I am well aware of the value of the Society to our profession and the Society's members. I am actively involved in ceramics research and teaching, including participation in domestic and international research collaborations and technical meetings. Finally, I have managed and led large organizations, which requires working with and engagement of both volunteers and professional staff members (e.g., academic departments and the current NSF-funded MADE in SC award).

Our Society's Board must have a singular focus on member services for the diverse global membership. If elected, my focus will be on enhancing the services for students, junior professionals, nonacademic, and international members. The Society's Divisions, Classes, Sections, and Chapters are conduits for serving the membership, and they must be strengthened by the Board to serve their members and provide opportunities for engagement and professional development. The Society provides three primary services: publications, meetings, and opportunities for leadership and professional development.

The Board must ensure that publications and meetings continue to meet the evolving needs of our discipline. The Board must be supportive of and proactively identify new approaches and platforms to engage and provide professional development opportunities for students, junior professionals, nonacademic, and international members. Specific focal areas will include international and domestic partnerships and strategic use of social media and web-based platforms.

Directors


Cesarano

JOSEPH CESARANO III
President and founder
Robocasting Enterprises LLC
Albuquerque, N.M.

I have been a participating member of ACerS since 1983 as a student, author, reviewer, presenter, symposium organizer, instructor, and corporate member. I am not sure how many meetings I have attended or how many presentations (invited and otherwise) I have either given or co-authored representing Alfred University, the University of Washington, and Sandia National Laboratories. It must be close to 100. However, since 2007, I have been a small business owner that manufactures ceramics and exhibited several times at the annual meeting, the Daytona Beach ICACC meeting, and the Ceramics Expo.

As such, I believe my journey from student to scientist to entrepreneur has provided first-hand recognition of the importance of the Society's responsiveness to needs of all members, including students, academicians, researchers, engineers, technical sales reps, business leaders, suppliers, and customers (public and private). The value of a Society event or publication is perceived very differently by a researcher than a manufacturer participating in an exposition. Both need satisfaction for the Society to be healthy and vibrant.

With my experiences, I believe I can effectively represent the interest of most of the Society's membership and provide perspective and insight to the Board as discussions

FOR MORE
INFORMATION:

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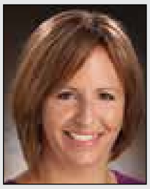
are conducted regarding the current state of the Society and its future direction. Summarily, I hope to assist in further increasing the perceived value of Society membership to all.

Equally important is the need to focus on future members and continuous improvement and expansion of outreach activities the Society provides to excite, educate, and inspire high-school students to pursue career opportunities in ceramics and glass. To secure the future health of our Society, growth in student enrollment in ceramic-related majors is a necessity, and my passion is to contribute to improved strategic plans for reaching out to the next generation of members still in high school.

Ceramic and glass engineering RULES!!!

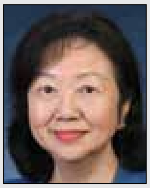


Reigel

MARISSA REIGEL

R&D execution manager
Savannah River National Laboratory
Aiken, S.C.

I have served as a volunteer in ACerS in several capacities, mostly through educational and professional development activities. I am passionate about providing students and young professionals with the technical and professional development tools needed to succeed. ACerS is the society for these professionals to grow and become leaders in ceramic and glass industries. I am also heavily involved with committees at ASM. I believe that engaging in the activities of other societies and the associated personal connections that develop among the major materials societies is crucial for the future of ACerS. It would be an honor to be part of the Board of Directors and help set ACerS' strategic direction to ensure that it continues to be the resource for technical and professional growth in materials science and specifically glass and ceramics. As a Board member, I will contribute vision and energy to help propel ACerS into the next decade and continue its growth. The strength of ACerS is in its Divisions and technical publications as well as its role in ABET accreditation. I can contribute to the Board by providing input and direction on how to continue the technical and professional growth of the young professional membership as well as retain student members when they transition into industry. A key challenge for the Board is to position ACerS to attract new members while continuing to engage, involve, and empower current members. I have the drive and creativity to help shape the strategic direction to meet this challenge.



Wong-Ng

WINNIE WONG-NG

Staff chemist
National Institute of Standards and Technology
Gaithersburg, Md.

I am honored to serve on the ACerS Board of Directors. Since joining ACerS, I have enjoyed serving our members through efforts on various ACerS and Electronics Division committees. I pledge to commit my best efforts to fulfilling the responsibilities of the office. I can foresee my contributions in several areas, including

1. Publication activities. My knowledge of phase diagrams, diffraction databases, and crystallography could compliment the expertise of the existing board.

2. Diversity and inclusivity. My experience working at NIST as a member of the diversity council team and as the president of the Association of NIST Asian Pacific Americans can help the BOD on diversity-related activities.

3. Interorganizational collaborations. My experience in leadership positions for other scientific organizations will help establish collaborations with other societies, which could lead to potential membership increase.

As ACerS prepares strategic plans for the future, I believe as a BOD team member and leader with relatively long-term knowledge of ACerS operations, I can assist ACerS to further grow its stature by addressing critical challenges. These challenges include retaining and attracting members, keeping abreast of the latest technological advances, maintaining our institutional health through promotion of ceramics/glass education, safeguarding financial stability, embracing diversity and equity, and establishing a well-planned outreach program to augment our membership and enhance our visibility. ■

more SOCIETY DIVISION SECTION CHAPTER NEWS

2022–2023 ACerS officers

The new slate of ACerS officers has been determined. There were no contested offices and no write-in candidates, automatically making all nominees "elected." ACerS rules eliminate the need to prepare a ballot or hold an election when only one name is put forward for each office. The new term will begin Oct. 12, 2022, at the conclusion of ACerS Annual Meeting at MS&T.

ACerS President-elect

To serve a one-year term from Oct. 12, 2022, to October 2023

Rajendra Bordia

ACerS Board of Directors

To serve three-year terms from Oct. 12, 2022, to October 2025

Joseph Cesarano III
Marissa Reigel
Winnie Wong-Ng

Division and Class Officers

To serve a one-year term Oct. 12, 2022, to October 2023, unless otherwise noted

Art, Archaeology and Conservation Science Division

Chair: **Jamie Weaver**
Vice chair: **Christina Bisulca**
Secretary: **Fumie Iizuka**
Treasurer: **Tami Clare**
Trustee: **Darryl Butt**

Basic Science Division

Chair: **Wolfgang Rheinheimer**
Chair-elect: **Edwin García**
Vice chair: **Amanda Krause**
Secretary: **Ricardo Castro**
Secretary-elect: **Fei Peng**

Bioceramics Division

Chair: **Bikramjit Basu**
Chair-elect: **Kalpana Katti**
Vice chair: **Annabel Braem**
Secretary: **Hrishikesh Kamat**

Cements Division

Chair: **Dimitri Feys**
Chair-elect: **Wil V. Srubar III**
Secretary: **Prannoy Suraneni**
Trustee: **Jeffrey Thomas**

Education and Professional Development Council

Co-chair: **Steven Naleway**, 2022–2024
Co-chair: **Krista Carlson**, 2021–2023

Electronics Division

Chair: **Jenny Andrew**
Chair-elect: **Ed Gorzkowski**
Vice chair: **Matjaz Spreitzer**
Secretary: **Elizabeth Paisley**
Secretary-elect: **Mina Yoon**
Trustee: **Geoff Brennecka**

Energy Materials and Systems Division

Division chair: **Krista Carlson**
Vice chair: **Eva Hemmer**
Secretary: **Yang Bai**
Program committee chair: **Charmayne Lonergan**

Engineering Ceramics Division

Chair: **Palani Balaya**
Chair-elect: **Young-Wook Kim**
Vice chair/Treasurer: **Jie Zhang**
Secretary: **Amjad Almansour**
Trustees: **Hisayuki Suematsu** and **Valerie Wiesner**
Parliamentarian: **Manabu Fukushima**

Glass & Optical Materials Division

Chair: **Joseph Ryan**
Chair-elect: **Irene Peterson**
Vice chair: **Michelle Korwin-Edson**
Secretary: **Mathieu Bauchy**

Manufacturing Division

Chair: **Ashley Hampton**
Chair-elect: **Joseph Szabo**
Vice chair: **Sarah Whipkey**
Secretary: **Bai Cui**
Counselor: **William Carty**

Refractory Ceramics Division *(term begins March 2022)*

Chair: **Kelley Wilkerson**
Vice chair: **Robert Hunter**
Secretary: **Austin Scheer**
Program chair: **John Waters**
Trustee: **Dana Goski**

Structural Clay Products Division

Chair: **Holly Rohrer**
Chair-elect: **Jim Krueger**
Vice chair: **Bryce Switzer**
Secretary: **TBD**
Trustee: **Jed Lee** ■

IN MEMORIAM

Wolfgang Kroenert
William Longacre
George Peckham
Daniel Shanefield
William Tope

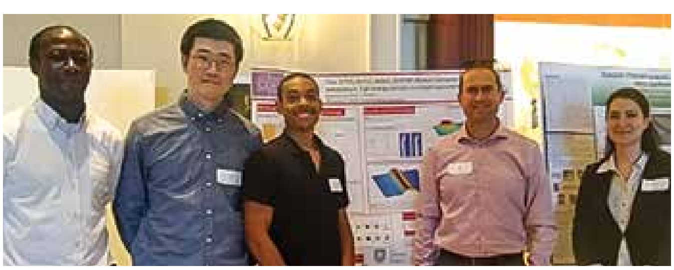
Some detailed obituaries can also be found on the ACerS website, www.ceramics.org/in-memoriam.

ACerS Sections celebrate spring with full schedule of networking events

◄ The ACerS Dayton/Cincinnati/Northern Kentucky Section and ACS Dayton hosted a networking event at the Dayton Dragons game on April 24, 2022. ■

On March 26, 2022, members of Dayton/Cincinnati/Northern Kentucky Section enjoyed a scavenger hunt at the Dayton Art Institute followed by a social hour at the Dayton Beer company. ■ ►

The Northern California Section hosted its first in-person event on April 29, 2022. Section members enjoyed the "A Life in Clay" exhibit at the Oakland Museum of California, followed by dinner at Peony Seafood Restaurant. ■



The ACerS Carolinas Section hosted a tour, networking, and student poster session at the University of North Carolina at Charlotte on May 10, 2022. Graduate students who attended were offered a complimentary Global Graduate Researcher Network membership courtesy of the Section. ■

ACerS Southern California Section virtually hosts ACerS President Beth Dickey

ACerS President Beth Dickey virtually presented "Point defect migration in metal oxides" to the Southern California Section on May 2, 2022.

Over 30 ACerS members and nonmembers gathered at the California Institute of Technology to watch the presentation and network. Graduate students who attended were offered a complimentary Global Graduate Researcher Network membership courtesy of the Section. ■

more SOCIETY DIVISION SECTION CHAPTER NEWS

Welcome to new ACerS India Chapter leadership

Secretary: **CD Madhusoodan**, Bharat Heavy Electricals Limited

Treasurer: **Preeti Kumari**, IIT (BHU)

Madhusoodan and Kumari join India Chapter chair L.K. Sharma as leaders of the India Chapter.

AWARDS AND DEADLINES

MS&T22 registration for ACerS Distinguished Life, Senior, and Emeritus members

ACerS is again offering complimentary to ACerS Annual Meeting and MS&T registration for Distinguished Life Members and reduced registration for Senior and Emeritus members. These special offers are only available through ACerS and are not offered on the MS&T registration site. Registration forms are available at www.bit.ly/MST22DLMEmeritus and should be submitted by **Aug. 31, 2022**, to Erica Zimmerman at ezimmerman@ceramics.org.

Nominations for Varshneya Frontiers of Glass Lectures due September 1

The two Darshana and Arun **Varshneya Frontiers of Glass lectures** will be presented at the GOMD Annual Meeting, June 4–9, 2023, in New Orleans, La.

The Frontiers of Glass Science and the Frontiers of Glass Technology lectures are designed to encourage scientific and technical dialog in glass topics of significance that define new horizons, highlight new research concepts, or demonstrate the potential to develop products and processes for the benefit of humankind.

Please submit nominations for individuals who have helped to define new horizons in glass science and technology to Erica Zimmerman by **Sept. 1, 2022**. Additional information is available at www.bit.ly/VarshneyaLectures.

ACerS/BSD Ceramographic exhibit and competition

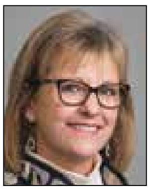
It is time to start working on your entry for the 2022 Ceramographic Exhibit & Competition, organized by the ACerS Basic Science Division. This unique competition, to be held at MS&T22 in October in Pittsburgh, Pa., is an annual poster exhibit that promotes the use of microscopy and microanalysis as tools in the scientific investigation of ceramic materials. The Roland B. Snow award is presented to the Best of Show winner of the competition. Winning entries are featured on the back covers of the *Journal of the American Ceramic Society*. Find out more about rules of entry at http://ceramics.org/?awards=ceramographic-competition-and-roland-b-snow-award.

FOR MORE INFORMATION:

ceramics.org/members/awards

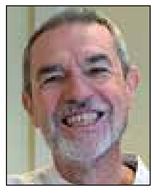
Names in the news

Members—Would you like to be included in the Bulletin's Names in the News? Please send a current head shot along with the link to the article to mmartin@ceramics.org. The deadline is the 30th of each month.



Richardson

Kathleen Richardson, Pegasus Professor of Optics and Materials Science and Engineering and a Florida Photonics Center of Excellence (FPCE), was named as the University of Central Florida's Trustee Chair Professor.



Zanotto

Edgar D Zanotto, CerTEV-DEMa/UFSCar, Brazil, was invited as part of the UN International Year of Glass as an "Excellence Chair" visitor to the Université Libre de Bruxelles (ULB), Belgium. ■

more AWARDS AND DEADLINES

Division	Award	Nomination Deadline	Contacts
GOMD	Alfred R. Cooper Scholars	June 13	Steve Martin swmartin@iastate.edu
ECD	Jubilee Global Diversity	July 1	Michael Halbig michael.c.halbig@nasa.gov
ECD	James I. Mueller Lecture	July 1	Hisayuki Suematsu suematsu@vos.nagaokaut.ac.jp
ECD	Global Young Investigator	July 1	Young-Wook Kim ywkim@uos.ac.kr
ECD	Bridge Building	July 1	Palani Balaya mpepb@nus.edu.sg
EMSD	Outstanding Student Researcher	July 31	Yang Bai yang.bai@oulu.fi
BSD	Graduate Excellence in Materials Science (GEMS)	Aug. 12	John Blendell blendell@purdue.edu
BSD	Roland B. Snow/Ceramographic Competition	Sept. 30	Klaus van Benthem benthem@ucdavis.edu

STUDENTS AND OUTREACH

ACerS GGRN for young ceramic and glass researchers

Put yourself on the path toward post-graduate success with ACerS Global Graduate Researcher Network! ACerS GGRN is a network of ACerS that addresses the professional and career development needs of graduate-level research students who have a primary interest in ceramics and glass.

GGRN aims to help graduate students

- Engage with The American Ceramic Society,
- Access professional development tools, and
- Build a network of peers and contacts within the ceramic and glass community.

Are you a current graduate student who could benefit from additional networking within the ceramic and glass community? Visit www.ceramics.org/ggrn to learn what GGRN can do for you, or contact Yolanda Natividad, ACerS membership engagement manager, at ynatividad@ceramics.org.

Complimentary membership for recent graduates and new members

Did you know that ACerS offers a one-year complimentary Associate membership for those who have recently completed their studies with plans to enter the workforce, and also for individuals that have never before been ACerS members?

ACerS is a truly global community, and an Associate membership can connect you to more than 8,000 professionals from more than 75 countries. More than 35% of our members live and work outside North America. They collaborate and inspire one another through participation in Divisions, Chapters, Sections, and technical interest groups. Learn more about Associate membership at http://www.ceramics.org/associate. Be sure to share this information with your colleagues who are not yet enjoying the many benefits of ACerS membership! For more information or questions, please contact Yolanda Natividad, ACerS membership engagement manager, at ynatividad@ceramics.org.

FOR MORE INFORMATION:

www.ceramics.org/students

Description
Recognizes undergraduate students who demonstrated excellence in research, engineering, and/or study in glass science or technology.
Recognizes exceptional early- to mid-career professionals who are women and/or underrepresented minorities (i.e., based on race, ethnicity, nationality, and/or geographic location) in the area of ceramic science and engineering.
Recognizes individuals who, like James I. Mueller, made contributions to the ECD and the field of engineering ceramics.
Recognizes the outstanding young ceramic engineer and scientist whose achievements are significant to the profession and to the general welfare of the global community.
Recognizes individuals outside of the United States who made outstanding contributions to engineering ceramics.
Recognizes exemplary student research related to the mission of the Energy Materials and Systems Division.
Recognizes the outstanding achievements of graduate students in materials science and engineering. Open to all graduate students who are making an oral presentation in any symposium or session at MS&T.
An annual poster exhibit to promote the use of microscopy and microanalysis as tools in the scientific investigation of ceramic materials.

CERAMICANDGLASSINDUSTRY FOUNDATION

CGIF hosts first teacher training workshop of 2022

On Saturday, April 23, 2022, the Ceramic and Glass Industry Foundation (CGIF) hosted their first of five teacher training events for 2022. The workshop was located at Clark Hall in Gahanna, Ohio, and lasted for seven hours. During this time, middle and high school teachers had the opportunity to perform hands-on experiments of the nine lessons in the Materials Science Classroom Kit, chat with professionals at an industry luncheon, and earn continuing education units. The event was a huge success, hosting teachers across disciplines from chemistry, engineering, and the arts.

Credit: ACerS

We want to send a special thanks to our volunteers Manoj Choudhary, Ashley Hampton, Tim Powers, Brian Rayner, and Jing Yang for attending the industry luncheon and speaking with teachers about careers in ceramic and glass industries.

CGIF will host teacher training events throughout Ohio in 2022, so if you are interested in sponsorship or volunteering for an event, contact Amanda Engen at aengen@ceramics.org to learn about available opportunities.

This event was made possible through generous donations to CGIF. If you would like to support the next generation of ceramic and glass professionals, visit https://myacers.ceramics.org/donate. ■

CGIF debuts new glass lesson at COSI Science Festival

The Ceramic and Glass Industry Foundation participated in the fourth annual Big Science Celebration at COSI in Columbus, Ohio, on Saturday, May 7, to round off the weeklong 2022 COSI Science Festival.

This four-day festival, which aims to inspire curiosity and exploration of science in learners of all ages, took place in person after COSI hosted virtual science festival events during the last two years.

The first three days of the festival took place at local community centers, libraries, schools, businesses, parks, and even bars to reach a variety of learners where they live, work, and lounge. The final Big Science Celebration took place from 11 a.m. to 4 p.m. with booths for nonprofits, community partners, local businesses, and educational institutions, including Battelle, Honda, CD 92.9 FM radio station, and more.

Credit: ACerS

PCSA student hands a water-based microbead to a young scientist at COSI.

CGIF, along with members of the ACerS President's Council of Student Advisors Outreach Committee, hosted an interactive booth with two hands-on science experiments for families, teachers, and young scientists. In celebration of the International Year of Glass, both experiments demonstrated the unique properties of glass.

The candy fiber pull experiment is an established activity that shows the nature of fiber optics. A new experiment debuted at this event used water pods to represent bioactive glass microbead encapsulation, which is typically used for drug delivery in pharmaceutical and medical industries.

The new experiment is under development by Casey Schwarz and her team at Ursinus College in Pennsylvania. Schwarz is an assistant professor of physics who also works with outreach programs at middle and high schools.

CGIF continually strives to create innovative teaching resources to expand materials science education in the community to attract the next generation of ceramic and glass professionals. If you would like to support CGIF, visit https://myacers.ceramics.org/donate. ■

Tile manufacturers face clay shortages due to war in Ukraine


Credit: UATV English, YouTube

A craftswoman from the Ukrainian city of Lviv turns clay from Donbas into unique tiles, which are used to decorate buildings across Europe.

As the war in Ukraine enters its third month, energy markets remain a focus of international discussion as governments continue imposing sanctions on Russian oil and gas. These sanctions contribute to Europe's ongoing surge in natural gas prices, which is straining energy-intensive industries such as ceramics and glass.

These disruptions in the energy market are not the only market forces affecting the ceramics industry. The war in Ukraine is also driving a shortage in supplies of Ukrainian clay.

Though the word "clay" may conjure images of artists hunched over pottery wheels, clay is critical to diverse end applications. Besides traditional ceramic products such as tiles and refractories, clay minerals are used in products from paper, paints, and coatings to polymer composites, cosmetics, and pharmaceuticals as well.

Since the 1990s, Ukrainian clay gained a reputation around the world for its purity and good consistency. There are currently around 40 recognized refractory and ball clay deposits in Ukraine amounting to more than 600 million tonnes in resources, with most deposits concentrated in the Donbas region, near Donetsk, eastern Ukraine, according to an IMFORMED article.

Based on export data, almost 5 million tonnes of ball clay were exported by Ukraine in 2019, accounting for 81% of all such exports. The main export destinations were the ceramic tile-producing centers of Spain and Italy, as well as Poland and Turkey.

Because of the war, Ukrainian suppliers currently are unable to export their clay. European tile manufacturers estimate their reserves of Ukrainian clay will run out in about three months.

In a *Fortune* article, Dmitry Kostornichenko, sales and logistics chief of VESCO, one of the biggest clay producers globally and number-one supplier to European tile manufacturers, says the assortment of tiles available for purchase will be the clearest indicator for consumers that reserves ran out. There will be shortages of very white and large-format tiles, which depend on the clay kaolin, and remaining tiles will only be available in darker colors and of lower quality.

Modifying formulations to reduce dependence on Ukrainian ball clay is one solution that tile manufacturers are considering, "but this is extremely challenging given the special qualities of the Ukrainian material now established in plant production, quality and logistical issues with alternative sources, and a lack of planning to use domestic resources," the IMFORMED article explains.

However, with few other options available, "I suspect this market disruption will result in a major reformulation of tile body formulation and the question remains will 'red' become the new 'white'," says Brendan Clifford, co-CEO of Portugal-based Mota Ceramic Solutions, in the IMFORMED article. ■

research briefs

Forming methods influence the microstructure of flash-sintered ceramics

Researchers from the University of São Paulo and Federal University of São Carlos in Brazil demonstrated that forming method can influence the final microstructure of flash-sintered ceramics.

Flash sintering is a newer ceramic processing technique that allows for lower temperatures. In this process, an electric field is applied to the ceramic during sintering. This combination of heat and electric field causes an abrupt increase in the current flowing through the material, and the thermal effect of the current allows the ceramic to fully densify in a few seconds.

The low furnace temperatures and short processing time required for flash sintering are the most widely recognized benefits of this process. However, there is also one widely recognized drawback—microstructural heterogeneity of the final ceramic, which can negatively impact its mechanical, chemical, and thermal behaviors.

This heterogeneity primarily originates from different thermal gradients that develop throughout the material during the flash sintering process. These gradients lead to different grain growth between regions, resulting in grain size differences.

Studies showed microstructural heterogeneity may be influenced by the ceramic's geometry, which makes certain areas more susceptible to becoming hotspots during the flash sintering process. Because geometry is determined in part by the forming method used to fabricate a material, does forming method perhaps influence the final microstructure of a flash-sintered ceramic?

To investigate this hypothesis, the researchers of the recent study evaluated the influence of three different forming methods—uniaxial and isostatic pressings and slip casting—on the densification and microstructure of cylindrical flash sintered 3 mol% yttria-stabilized zirconia (3YSZ) ceramics.

They chose these three methods based on the known differences in geometry of materials formed by each method. In uniaxial and isostatic pressing, methods that are based on mechanical pressure, strain gradients can form throughout the material. For uniaxial pressing, these gradients are observed among the powder particles and between powder particles and the die walls, while for isostatic pressing, a strain gradient is observed only among the powder particles. Slip casting, which does not require mechanical pressure, results in a material with a fairly uniform density gradient.


Credit: Craft Festival, YouTube

Example of slip casting a ceramic mug. A new study found forming method influences the microstructure of flash-sintered ceramics.

After obtaining samples from each forming method, the researchers sintered the green ceramics using either flash sintering or conventional sintering for comparison.

Analysis of the green and final samples revealed that irrespective of forming method used, all conventionally and flash-sintered ceramics presented high final densities, though densities of conventionally sintered ceramics were slightly higher.

However, there were significant differences in the microstructures of the flash-sintered ceramics formed by each method. Samples prepared by uniaxial pressing had higher microstructure heterogeneity, while isostatically pressed specimens showed better homogeneity than the uniaxially pressed ones. Overall, though, the slip-cast ceramics presented the best microstructure homogeneity for the flash-sintered samples, and they had average grain size similar to the conventionally sintered samples (which presented microstructure homogeneity regardless of forming method).

"Thus, we concluded that the green density gradient (heterogeneous powder packing) produced by the different forming methods plays a significant role in the current passage during flash sintering, which can influence the heat dissipation within the specimen," the researchers conclude.

The paper, published in *Materialia*, is "Influence of forming methods on the microstructure of 3YSZ flash-sintered ceramics" (DOI: 10.1016/j.mtla.2022.101419). ■

Research News

Flash Joule heating process recycles plastic from vehicles into high-value graphene

Rice University chemists and Ford Motor Company researchers turned plastic parts from "end-of-life" vehicles into graphene via the university's flash Joule heating process. This graphene can be reused to make enhanced polyurethane foam for new vehicles. Tests showed the graphene-infused foam with only 0.1% by weight or less of graphene had a 34% increase in tensile strength and a 25% increase in low-frequency noise absorption. For more information, visit https://news.rice.edu. ■

Effect of thermal ageing on microstructure and elastic properties of ytterbium silicates

Researchers from the University of Manchester examined the effect of thermal ageing on microstructural characteristics and elastic properties of ytterbium-based silicates.

Ytterbium-based silicates are a current generation of environmental barrier coating materials that demonstrate much promise due to their high temperature stability and low steam volatility capabilities. Ytterbium disilicate and ytterbium monosilicate specifically are being studied due to their stability at temperatures below 1,750°C and higher damage tolerance behaviors compared to other rare earth silicates.

Thermochemical and thermomechanical stability of both ytterbium disilicate and ytterbium monosilicate in aerospace engine working environments are extensively reported. However, most of the studies were conducted on coatings processed using plasma spray techniques that result in complex coating microstructures.

"Therefore, there is a lack of fundamental studies in the literature about the structural stability of these materials under long-term thermal exposure at high operating temperatures," the researchers write.

They looked to examine the effect of thermal ageing on microstructural characteristics and elastic properties of as-sintered ytterbium disilicate, ytterbium monosilicate, and ytterbium disilicate/monosilicate composites.

Based on experiments, they drew several conclusions about the behavior of these ytterbium silicates, including

- **Microstructure characteristics**: Thermal ageing at 1,350°C resulted in significant increase of grain size and relative density for the ytterbium disilicate. However, ytterbium monosilicate did not exhibit an apparent change in microstructure characteristics and showed insignificant grain growth, implying higher structural stability of this silicate.
- **Elastic properties**: The change in elastic properties as a function of thermal ageing time followed a similar trend as the microstructural characteristics. Ytterbium disilicate experienced a high degree of densification, resulting in an about 10% increase of Young's modulus up to 110 hours of heat treatment, while neither the elastic properties nor the density of ytterbium monosilicate changed in this same period.
- **Behavior of ytterbium silicate composites**: Sintering behavior of the ytterbium disilicate/monosilicate composites showed that addition of ytterbium monosilicate impeded the grain growth rates and contributed to stabilization of the elastic properties. Plus, a crack healing phenomenon was observed in the composite with 22 wt.% ytterbium monosilicate due to microthermal stress-promoted diffusion on crack surfaces and grain boundaries.

"The findings of this study do not only lay the groundwork for high temperature stability of [ytterbium] based silicates for the design and application of EBCs, but also demonstrates that [ytterbium disilicate/monosilicate] composites could be a prospective material system to heal the cracks and increase the lifetime of EBCs," the researchers conclude.

The paper, published in *Ceramics International*, is "Study on sintering behaviour of ytterbium disilicate and ytterbium monosilicate for environmental barrier coating applications" (DOI: 10.1016/j.ceramint.2021.12.344). ■

Credit: Dirk-Jan Kraan, Flickr (CC BY-NC 2.0)

An Airbus A320neo, which contains a ceramic matrix composite turbine shroud in its engines. Research on developing new environmental barrier coatings to protect these composite shrouds from undesirable reactions is an active area of study.

Mullite precursor method may be a game changer for fabricating ceramic matrix composites

Researchers from the Indian Space Research Organization and Indian Institute of Space Science and Technology developed a one-step process for synthesizing mullite precursors that could lower the sintering temperatures needed for fabricating oxide–oxide ceramic matrix composites.

Oxide–oxide CMCs are being considered for use in jet engine components due to their ability to withstand oxidative corrosion for long duration flights while maintaining their shape without cracking. However, conventional processing techniques for oxide composites require high temperatures and pressures, which damage the oxide fiber and limits the composite's application to 1,200°C.

To address this issue, the Indian researchers developed a one-step process for synthesizing mullite precursors (aluminosiloxanes), which involves co-hydrolysis and condensation of high-purity aluminum trisecbutoxide and tetraethoxysilane in the presence of concentrated hydrochloric acid in a nonpolar solvent.

The research revealed that

- A homogenous distribution of silicon and aluminum helps form mullite at a lower temperature;
- Mullite formation shifts to a lower temperature with an increase in aluminum content in the precursor;
- By adjusting the aluminum/silicon ratio of the precursors, the composition can be controlled between a silica-rich mullite phase and near-stoichiometric mullite phase;
- The ceramic content ranges from 65–80.6 wt.%, a prerequisite for a suitable matrix precursor; and
- Resin viscosity is easily controlled by adjusting how much solvent is evaporated, allowing polymer infiltration and pyrolysis fabrication of composites.

If this process is scaled to production levels, the lower sintering temperature will help prevent fiber damage. And the ability to tailor the ceramic composition makes a wider range of applications possible for jet engines.

The paper, published in *Ceramics International*, is "Low temperature mullite forming pre-ceramic resins of high ceramic yield for oxide matrix composites" (DOI: 10.1016/j.ceramint.2022.03.113). ■

Revealing secrets of the past—nanoscale engineering gave historic glaze its iridescence

A group led by researchers from the California Institute of Technology used advanced analytical techniques to show how nanoscale engineering gave Böttger luster, a historic purple overglaze, its distinctive iridescence.

The history of Böttger luster traces to the early 18th century and the development of porcelain outside of China. In the 17th century, Chinese porcelain was widely sought after by European aristocrats. However, the recipe was closely guarded by Chinese potters, so Europeans were unable to create porcelain themselves.

In 1702, Augustus II "the Strong" (Elector of Saxon, King of Poland, and Grand Duke of Lithuania) summoned alchemist Johann Friedrich Böttger to his palace and ordered him to discover the secret to creating porcelain. After a series of failed experiments, unsuccessful attempts to flee, and forceful recaptures, Böttger successfully produced the first continental European hard-paste porcelain, which was distinct from contemporary porcelain formulations.

In 1710, August II established the Meissen manufactory, located near Dresden in present-day Germany, to continue producing this European porcelain. Alchemists at the manufactory initially struggled to produce overglaze polychrome decorations that were compatible with the required high firing temperatures, but they ultimately developed the Böttger luster iridescent overglaze that is famous today.

Like other historical red and purple glazes, Böttger luster gets its color from gold particles within the glaze. However, while alchemists of the time were aware that gold produced reddish/purplish colors, the ability to visualize the particles and investigate the nanoscience at work did not occur until the early 20th century with the development of the ultramicroscope by Nobel laureates Richard Zsigmondy and Henry Siedentoph.

In an email, Katherine T. Faber, Simon Ramo Professor of Materials Science at the California Institute of Technology and adjunct professor of materials science and engineering at Northwestern University, explains that the decision to understand the nanoscience behind Böttger luster is due to an observation by coauthor Anikó Bezur, Wallace S. Wilson director of the Technical Studies Laboratory at Yale University's Institute for the Preservation of Cultural Heritage.


Credit: Celia Chari

18th century Meissen teapot (Art Institute of Chicago) with Böttger luster (top) and Purple of Cassius enamel (bottom) noted with cross-sectional maps of gold nanoparticle signatures from energy dispersive X-ray spectroscopy.

Bezur was working at the Art Institute of Chicago when the investigation started. She was studying Meissen porcelains with respect to Du Paquier porcelains made in Vienna when she became curious as to why Böttger luster, unlike other historical gold-based glazes, was iridescent. She teamed up with Faber and the others through NU-ACCESS, a collaboration between Northwestern University and the Art Institute of Chicago.

To understand the mechanics behind Böttger luster's iridescence, the researchers compared it to Purple of Cassius, another gold-based purple colorant used at the Meissen manufactory that is non-iridescent. First, they analyzed historical samples of the two glazes using several spectroscopy and microscopy methods to reveal the glazes' composition and structure. Then, they experimentally synthesized Böttger luster in hopes of replicating the distinct optical effects.

Through these experiments, they showed that the distinct optical properties of Böttger luster and Purple of Cassius are due to the different ways gold is applied to each glaze.

"In Böttger luster, as with other types of lusterware, the metal nanoparticles develop in the top glaze through a firing step that allows metal ions to diffuse, nucleate, and grow into particles of several sizes inside the glaze. In Purple of Cassius, the gold nanoparticles are precipitated using tin(II) chloride prior to being incorporated into the leaded frit that is applied to create an overglaze enamel, providing a more homogenous particle dispersion and smaller particle sizes," they write.

The paper, published in *Proceedings of the National Academy of Sciences*, is "Nanoscale engineering of gold particles in 18th century Böttger lusters and glazes" (DOI: 10.1073/pnas.2120753119). ■

Metalens may simplify generation and control of vacuum UV light

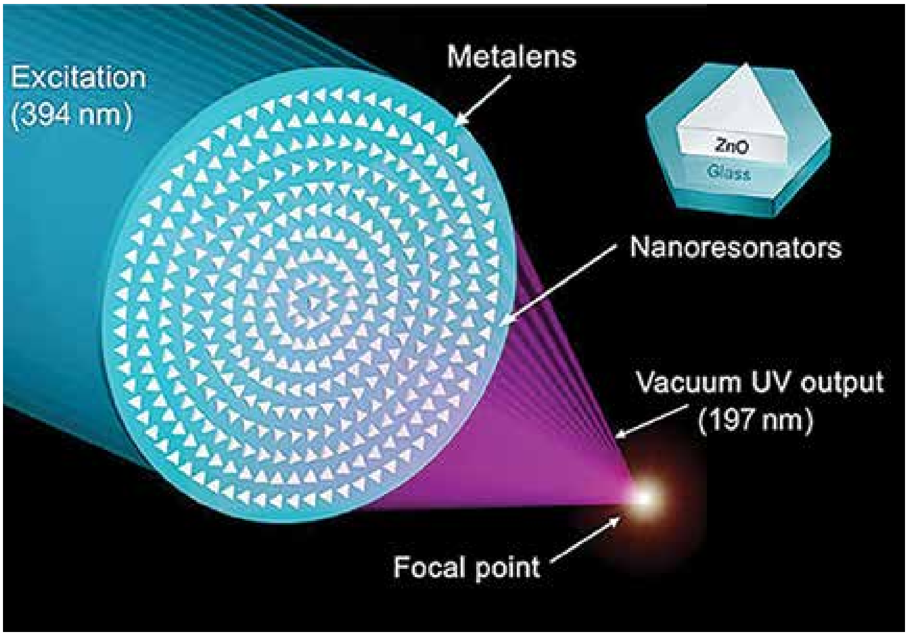
Researchers led by Rice University, along with colleagues in Taiwan and Hong Kong, developed a metalens that can both generate and manipulate vacuum ultraviolet light.

Vacuum UV light refers to the region of the UV radiation spectrum with the shortest wavelengths (<200 nm). These wavelengths are readily absorbed by many gases in the atmosphere, which makes vacuum UV light useful as a disinfectant by triggering beneficial photochemical reactions. It is also useful in nanoscale processing for this same reason.

The use of vacuum UV light in these applications is limited, however, due to the difficulty of generating and manipulating this shortest of UV wavelengths. Vacuum UV light is typically generated by nonlinear processes in gases, which is not the most convenient or easily integrated approach.

Additionally, once vacuum UV light is generated, focusing it is difficult because almost all types of glass used for conventional lenses will absorb this light. The few vacuum-UV-transmittable materials used for lenses, such as CaF_2 and MgF_2, are comparably fragile, placing practical limits on thin lens fabrication and design.

So, "New approaches to both VUV [vacuum UV] light generation and manipulation are clearly needed to advance our utilization of this region of the electromagnetic spectrum," the Rice-led researchers write in their recent open-access paper.



Credit: M. Semmlinger, Rice University

A new metalens developed by Rice University photonics researchers can both generate and manipulate vacuum UV light.

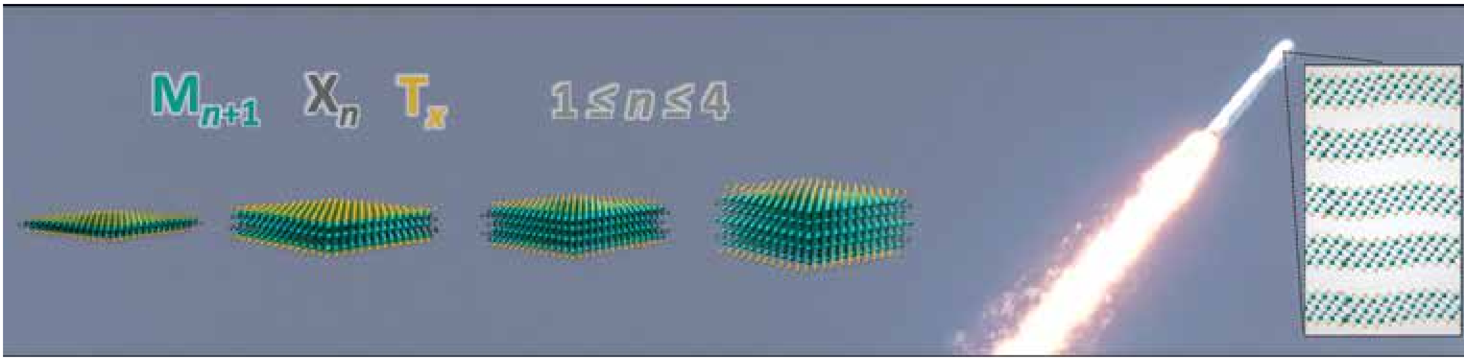
In 2018, the researchers demonstrated that a metasurface made from zinc oxide can convert UVA light (wavelengths in the region 320–400 nm) into vacuum UV light through a frequency-doubling process called second-harmonic generation. Now, their new work explores whether a metalens made from the same material would be able to both generate and manipulate vacuum UV light.

The researchers used finite-element analysis to design and simulate the metalens' performance before patterning the actual sheet of transparent zinc oxide using electron beam lithography and reactive ion etching. The pattern consists of concentric circles studded with tiny triangles.

Like the metasurface, the metalens successfully converted 394-nanometer UVA light into 197-nanometer vacuum UV light. In addition, the metalens focused its 197-nanometer output onto a spot measuring 1.7 microns in diameter, increasing the power density of the light output by 21 times.

Though it is too early to say whether the technology can compete with state-of-the-art vacuum UV systems, Naomi Halas, Stanley C. Moore Professor of Electrical and Computer Engineering and director of Rice's Smalley-Curl Institute, says this work is particularly promising in light of recent demonstrations that chip manufacturers can scale up production of metasurfaces with CMOS-compatible processes.

The open-access paper, published in *Science Advances*, is "Vacuum ultraviolet nonlinear metalens" (DOI: 10.1126/sciadv.abn5644). ■



Credit: Wyatt, Thakur, and Anasori

MXenes for atomistic design of 2D nanoceramics

By Brian C. Wyatt, Anupma Thakur, and Babak Anasori

Since the discovery of 2D transition metal carbides and nitrides (MXenes) in 2011, research on this family of materials has led to its usage in many sectors—with future applications continuously emerging.

For the last 100-some years, scientists have identified transition metal carbides, nitrides, and carbonitrides as ideal ceramic materials for applications requiring mechanically hard, electrically conductive, chemically stable, and ultrahigh-temperature properties.

In the mid-1900s, advances in transition metal carbides and nitrides expanded to ternary phases of transition metal carbides and nitrides, known more commonly today as MAX phases. MAX phases, denoted by their chemical formula $M_{n+1}AX_n$ (n = 1 to 4), have a wide range of chemical diversity.[1] M represents n+1 layers of transition metals from groups 3–6 of the 3d-5d block of the periodic table. X represents carbon and/or nitrogen, which occupy the octahedral interstitial sites of the M layers. The $M_{n+1}X_n$ layers are interleaved with A-group elements, commonly from groups 13–16 of the periodic table.[2]

Research on MAX phases from the 1990s to early 2010s focused on high-temperature oxidation resistance, damage and corrosion tolerance, and self-healing capabilities.[1] However, in 2011, investigation of the selective etching effect of hydrofluoric acid on the A-layers in MAX phases led to the discovery of a new field of layered 2D transition metal carbides and nitrides, known today as MXenes (Figure 1).[3]

Today, MXenes are an ever-expanding field of 2D transition metal carbides and nitrides that are commonly derived from their MAX phase precursors, such as $Ti_3C_2T_x$ from Ti_3AlC_2, through selective etching of the A layers in MAX phases to yield their $M_{n+1}X_nT_x$ layers. Because of the top-down synthesis process, MXenes derive their chemistry and structure from their respective MAX phase. The selective etching results in the formation of surface groups (shown as T_x) from their etching environment, which are commonly –O, –F, and –(OH).

As a derivative 2D material of MAX phases, MXenes also demonstrate a wide range of chemical and structural diversity, which leads to a range of impressive material behaviors, including electrical conductivity (up to 24,000 S/cm), mechanical stiffness (up to 386 ± 13 GPa), solution processibility (negative zeta potential of about –40 mV in aqueous solutions), electromagnetic interference shielding (up to 116 dB for total shielding effectiveness),[4] catalytic activity,[5] tribological behavior (6-fold reduction in coefficient of friction as a coating),[6] and high-temperature stability in its hexagonal structure in inert environments (up to 800°C).[7]

As a result of these impressive properties, MXenes have seen an outpour of attention from the materials science community, with over 7,000 publications with the word *MXene* in their titles, as of June 2022 on Web of Science. The bulk of attention on MXenes from 2011 through 2015 focused on energy storage capabilities as a layered 2D nanomaterial, and the interest in energy storage is still expanding.[8] However, increased attention in recent years focused on MXenes in other applications, including electrocatalysis, electromagnetic interference shielding, mechanical and tribological reinforcements, biomedical, and (very recently) as ultrahigh-temperature environment materials.

MXenes in electrocatalysis

Since the 1970s, scientists explored 3D grains of transition metal carbides and nitrides as alternatives for noble metals for electrocatalysis, such as hydrogen evolution reaction (HER), owing to their advantageous properties, namely high electrical conductivity, mechanical and chemical stability, and high melting point. In 1973, tungsten carbide was reported to have platinum-like catalytic behavior, which accelerated the development of tungsten carbide potential electrochemical properties.[9] This discovery opened new avenues for researching and designing catalysts with platinum-like characteristics made of transition metal carbides and nitrides for electrocatalysis.

With their similar bonding behavior, 2D MXenes were also employed successfully in electrocatalysis due to their high electronic conductivity, hydrophilic nature, chemical stability, and high surface area, which is electrochemically active.[5] In 2016, two reports, including a theoretical study on oxygen-terminated V_2C MXene and an experimental study on Mo_2CT_x and Ti_2CT_x, pointed toward superior HER activity of MXenes.[10,11] These findings demonstrated that Mo_2CT_x exhibits higher HER activity with lower overpotential than Ti_2CT_x toward HER. It was also shown that MXenes' basal planes (2D sheet surfaces) are catalytically active toward HER.[11]

The large available basal surface area for catalytic activity paired with the chemical diversity of 2D MXenes lends promise to MXenes for use in future energy conversion applications, such as substituting platinum-based catalysts for efficient HER catalysis.

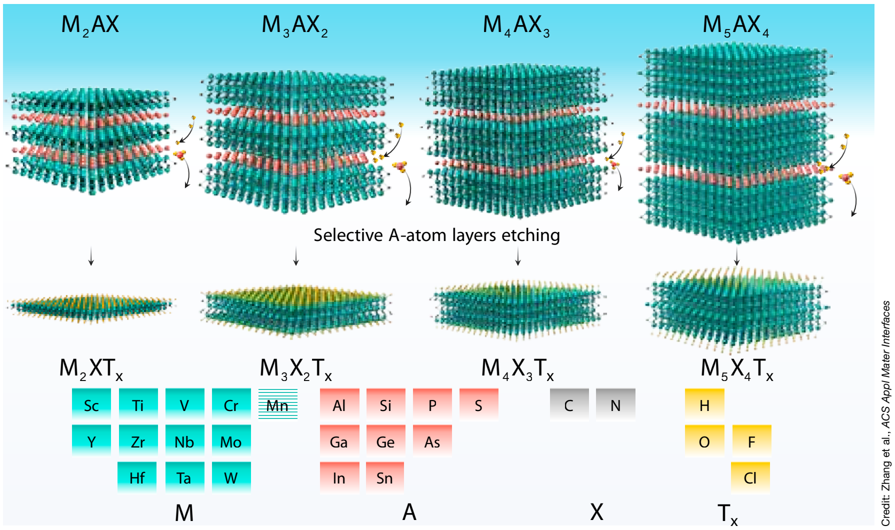


Figure 1. The large compositional and structural family of MXenes ($M_{n+1}X_nT_x$), which is derived from their MAX phase precursor ($M_{n+1}AX_n$).

MXenes for EMI shielding

In the general transition metal carbides field, electromagnetic interference (EMI) shielding is sparsely reported compared to their mechanical stiffness, wear and corrosion resistance, and high-temperature behaviors. The lack of EMI shielding studies is despite the high electrical conductivity of bulk transition metal carbides and nitrides and possibly due to the difficulties of ultrathin film fabrication (such as foil fabrication) from these hard and high-melting point carbides and nitrides.

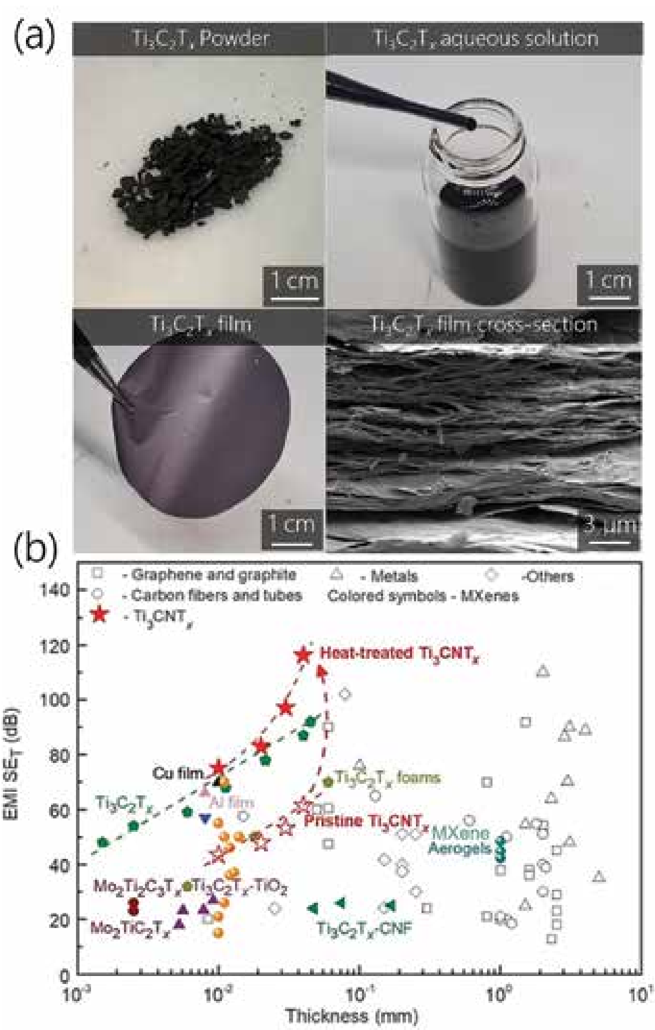
However, thanks to MXenes' 2D structure, the EMI shielding of MXenes of different morphologies expanded to become a major application area, as MXenes can be fabricated as multilayer powder, aqueous solutions, or thin stacked films (Figure 2a).[4,12] A 50-nm-thick film of $Ti_3C_2T_x$ (about 24 sheets) showed an electromagnetic shielding capability of about 99% EMI shielding, which leads to an effective shielding of more than 3 million dB•cm^2/g.[12] While the electrical conductivity of MXenes is lower than copper and aluminum films, MXene EMI shielding effectiveness (EMI SE) is on par or even higher than those of copper and aluminum (Figure 2b).

Both reflection and absorbance mechanisms may contribute to the EMI shielding property of MXenes. Reflection is predicted to result from abundant free electrons on MXenes surfaces due to T_x and surface M layers, while absorbance is thought to come from energy transfer to the internal high electron density MXene lattice structure. The absorbance contribution of EMI shielding can be improved by using nitrogen with carbon as mixed elements in the X layers (Ti_3CNT_x MXene), as it is speculated that the added valence electron of nitrogen in Ti_3CNT_x results in increased absorbance of incident electromagnetic waves, leading to a larger EMI shielding effectiveness as compared to $Ti_3C_2T_x$ (Figure 2b).[12]

The EMI SE behavior of Ti_3CNT_x compared to $Ti_3C_2T_x$ illustrates the potential for compositional tuning of MXenes toward application-based design, as the top-down synthesis from their respective chemically diverse MAX phases permits a large range of potential compositions of MXenes available for synthesis. In addition to the chemical diversity, the solution processibility of MXenes allows simple processes to be used, such as vacuum filtration or paint-brush style spray-coating, to form flexible structures that can be used for EMI shielding and wireless communications.[13,14] The combination of this compositional space and solution processibility results in a wide range of potential choices in chemistry and simplistic processing to form EMI shielding and EM antennas for use in next-generation electronics.

MXenes as mechanical and tribological materials

For those familiar with traditional carbide and nitride ceramics, stiff mechanical behavior and high wear resistance are key features of these ceramic materials. Bonding interactions in MXene between M and X structure dominate the mechanical behavior of MXene flakes. These M and X interactions in MXenes



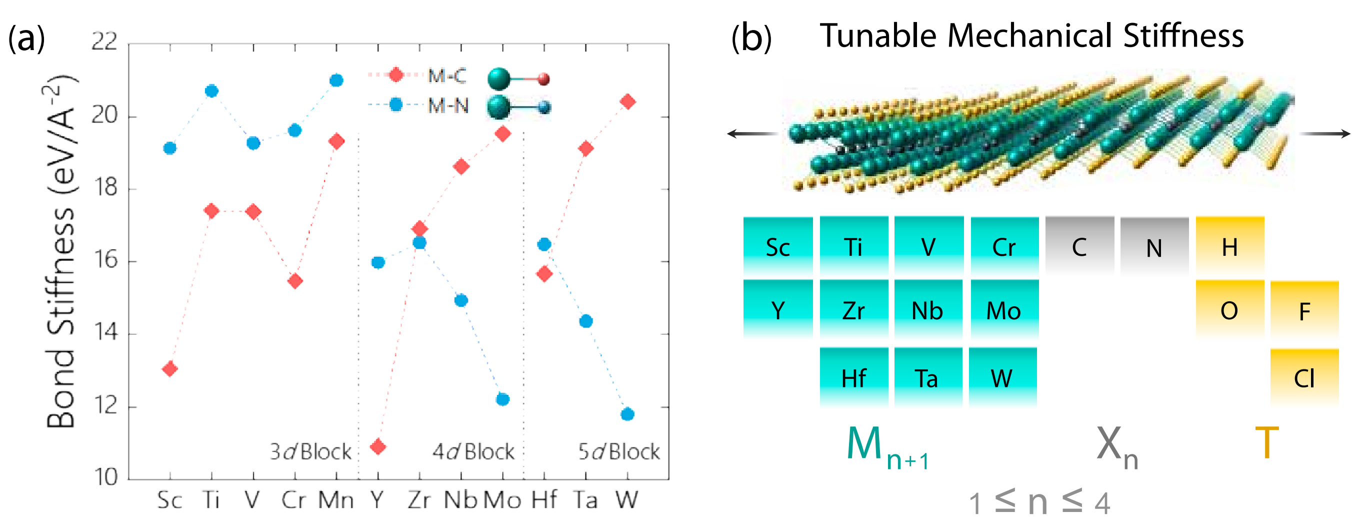
Credit: (a) Wyatt, Thakur, and Anasori; (b) Iqbal et al., *Science*

Figure 2. (a) Different MXene morphologies and (b) EMI shielding effectiveness of different MXene compositions as related to film thickness. Panel (b) reprinted with permission from Reference 14.

are mixed ionic/covalent/metallic bonded systems with different bond stiffnesses depending on the M and X chemistry and *n* number layering of $M_{n+1}X_n$. In short, bonded compositions such as molybdenum to carbon and tungsten to carbon have the stiffest bonds of carbide compositions while early transition metals, such as scandium to nitrogen or titanium to nitrogen, are the stiffest bonds of nitrides. This chemistry-dependent mechanical behavior of M–X implies MXene mechanical behavior is tunable by composition (Figure 3a).[15]

In addition, MXenes with a higher *n* have the highest in-plane stiffness due to the decreasing effect of the surface M layer on the mechanical behavior, for example, about 150 N/m for Ti_2C as compared to about 350 N/m for Ti_4C_3.[15] Similarly, T_x groups on the surface of MXenes influence their mechanical behavior even further, as O_2-terminated MXenes are shown to have the highest in-plane mechanical stiffness of all other common surface groups due to the affinity of oxygen with transition metals. The mechanical behavior has exhibited the highest experimentally observed elastic moduli of all solution-processable nanomaterials to date for $Ti_3C_2T_x$ and $Nb_4C_3T_x$ at 330 ± 30 GPa and 386 ± 13 GPa, respectively.[15]

The capability of tuning the interior M–X chemistry of MXenes and the T_x surface groups based on MAX synthesis and selective etching (Figure 3b) yields a range of choices to experimentally determine the effects of composition, structure, and defects on the bonding behavior of transition metal carbides and nitrides at the nanoscale. Additionally, MXenes stiff in-plane mechanical properties are paired with very weak van der Waals interlayer interactions between MXene sheets, which makes them an incredibly stiff and tunable reinforcement materials. This information can be used to develop strong, stiff nanomaterials as additives for metal or ceramic matrices, and it can also inform design decisions of bulk transition metal carbide and nitride systems based on fundamental understanding.



Credit: (a) Wyatt et al., *Advanced Materials*; (b) Wyatt, Thakur, and Anasori

Figure 3. Tunability of the mechanical behavior of MXenes based on compositions, where various bond pairings shown in (a) can be chosen to affect the mechanical behavior of MXenes based on their possible chemistry and structure (b). Panel (a) reprinted with permission from Reference 16.

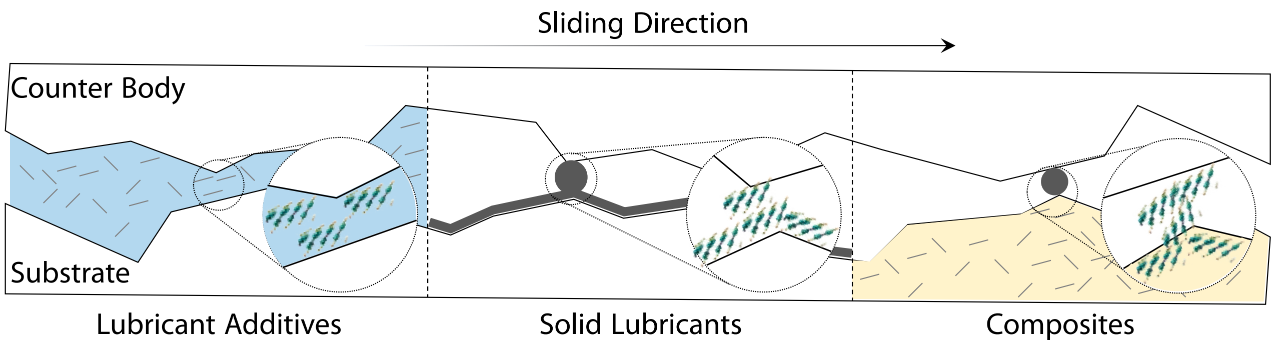


Figure 4. Example uses of MXenes in tribological applications including in lubricant additives, solid lubricant films, and composite additives. Reprinted with permission from Reference 16.

Just as ceramic materials shown significant wear resistance under sliding force conditions, MXenes show promise as wear-resistant materials with an additional property of very low coefficient of friction (COF) in many uses ranging from lubricant additives, solid lubricants, and composite additives, outperforming even state-of-the-art nanomaterial choices (Figure 4).[6,15] MXenes owe their impressive performance in tribological applications to their strong in-plane mechanical behavior paired with their comparatively weak out-of-plane van der Waals interlayer interactions. Their low COF can be attributed partly to the low energy barrier from T_x–T_x interactions toward interlayer sliding. Computational studies reported that Ti_2CO_2 has a sliding barrier of 0.017 eV while bare Ti_2C (with no surface terminations) has a sliding barrier of 0.237 eV, which corresponds to COFs of 0.24–0.27 for bare titanium-based MXenes while O-terminated titanium-based MXenes have COFs of 0.10–0.14.[16]

The effect of M element and n values on the surface groups also showed an effect on the frictional behavior, as $Ti_3C_2T_x$ and Nb_2CT_x terminated with O_2 have surface dipole moment densities of 0.020 eV/Å and 0.011 eV/Å, respectively, which leads to lower adhesion forces and frictional forces for Nb_2CT_x compared to $Ti_3C_2T_x$.[17] Their potential to improve mechanical wear resistance can be attributed to their strong in-plane mechanical bonding,[15] which may improve average service life of MXene-coated bearings by 30% and 55% compared to similarly MoS_2-coated and diamond-like carbon-coated bearings, respectively.[18] These material behaviors illustrate that MXenes are ideal and tunable nanoceramics for use in high-wear and high-friction environments, which can lead to development of new low-friction equipment components or even triboelectric nanogenerators of energy.[19]

MXenes in extreme environments

Similar to their bulk transition metal carbide and nitride counterparts, MXenes' interior transition metal carbide/nitride core lends the potential of their use in extreme conditions, such as ultrahigh-temperature environments. Although MXenes display detrimental oxidation behavior in water or oxygen-containing environments,[20] carbide MXenes form ultrahigh-temperature nanolamellar carbides that are highly stable in inert high temperature environments (>1,500 °C).

This high-temperature phase transition of carbide MXenes to stable nanolamellar carbides in inert environments takes place in four main regimes (Figure 5), which occur in order of 1) loss of adsorbed species on the surface of each 2D sheet from room temperature to about 300 °C; 2) loss of surface T_x groups at temperatures up to 800 °C, followed by 3) beginning diffusion of atoms onto the surface to result in phase transformation of MXene from its hexagonal crystal structure to more stable nanolamellar carbides (titanium–carbide layers on top of Ti_3C_2, for example); and 4) complete phase transformation of MXenes to a stable nanolamellar carbide.[7]

The extensive range of compositions of transition metals, carbon/nitrogen, and structural configurations of MXenes lends significant possibilities and engineering control of high-temperature phase behavior of MXenes. Additionally, MXenes' solution processibility and their inherent negative zeta potential allow the addition of MXenes as additives and reinforcement materials in metal or ceramic composites (Figure 6a). The ease of film and coating fabrication make MXenes a unique

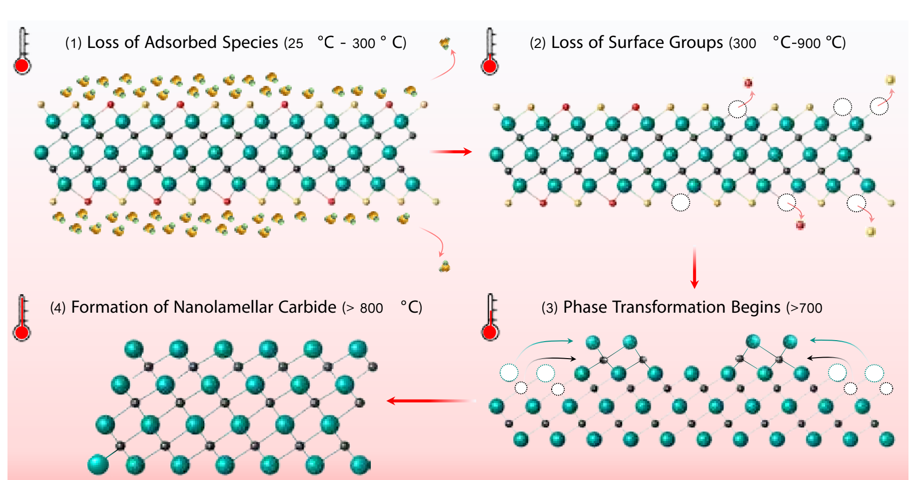


Figure 5. High-temperature phase behavior of MXenes, showing the four-stage behavior of MXenes in inert environments.

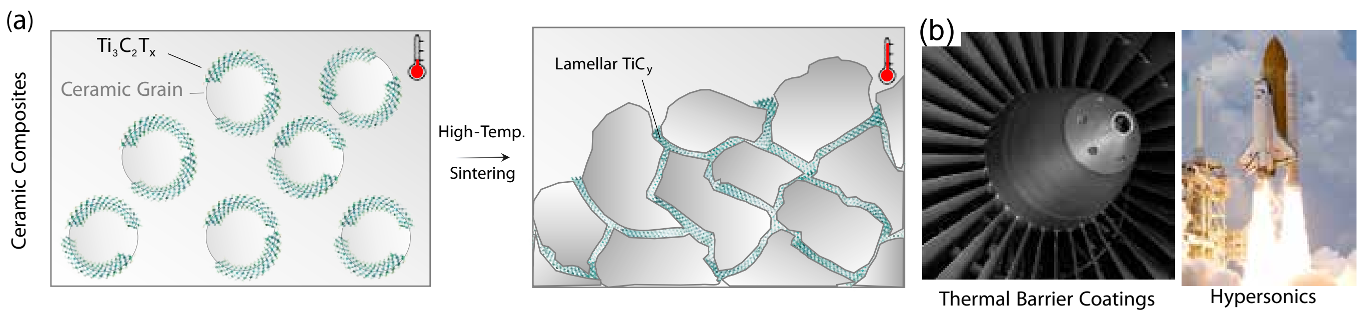


Figure 6. Future uses of MXenes as (a) additives in ultrahigh-temperature ceramics (UHTCs), can see MXenes used as strong binder materials in future extreme environment applications, such as (b) thermal barrier coatings on turbine blades and hypersonic travel. Adapted from Reference 21.

precursor for ultrahigh-temperature coatings (Figure 6b).[21] MXenes as precursors for extreme environment materials holds promise for MXene use in hypersonics, space exploration, nuclear reactors, and other extreme environment applications.

Conclusion

The future for MXenes as an engineerable 2D nanoceramic material is bright because of their impressive electrochemical, electrical, EMI, mechanical, tribological, and ultrahigh-temperature behaviors. The wide range of chemical diversity, crystal structures, potential morphologies, and high surface area to volume ratio means that MXenes have the potential to be the premier building block of ceramics engineers in future demanding engineering challenges.

Future fundamental research exploring MXenes as nanoceramic building blocks will be needed to capitalize on MXenes' as strong, ultrahigh-temperature reinforcements or thin-film materials that offer new materials solutions over traditional macroscale ceramics for use in future electronics, space exploration, or defense applications. With the addition of MXenes as a viable nanoceramic material, the future for the field of ceramic engineering is at the nanoscale.

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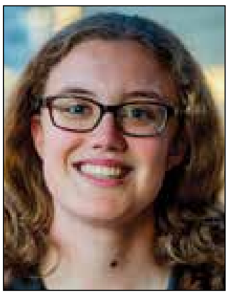
Chair's update on PCSA activities and welcome to the student *ACerS Bulletin* issue



By Olivia Brandt, PCSA Chair

2021–2022 PCSA delegates at the PCSA annual meeting in October 2021.

The challenges that students faced throughout the past few years are immense; yet, hope remained ever-present in the face of these challenges.

The hope of returning to in-person gatherings and meetings. The hope of reconnecting with friends, colleagues, and loved ones separated by travel restrictions and quarantines.

This year's student issue of the *Bulletin* aims to provide perspectives from students on their hopes. As students, we are often told we are the future, and thus we embody society's hopes for the future. Yet as materials scientists and engineers, we carry hopes of our own as well—hopes that our research will be meaningful, hopes for how we can learn from the past, and hopes for the future to come. We have used this hope to overcome obstacles, break down barriers, and better the world in ways both large and small.

For me, as chair of the ACerS President's Council of Student Advisors (PCSA), my hopes lie in leading the next generation of student leaders to reach their fullest potentials. The PCSA currently comprises 44 delegates, representing 29 universities and eight countries.

When the PCSA began its term last October during ACerS Annual Meeting at MS&T21, hopes were high—delegates met face to face at what was for many their first in-person conference in more than a year and half, and for some their first conference ever. With this hope, the PCSA delegates produced a vision for the 2021–2022 term centered on cultivating an internal environment that encourages leadership and creativity, plus strengthening and expanding external partnerships and connections. Our committees are hard at work bringing this vision of the PCSA to life.

- **The Outreach Committee** is working to improve upon previous classroom outreach efforts, which includes wider distribution of both the mini and full-size Materials Science Classroom Kits as well as increasing collaboration with local community organization starting STEM outreach.
- **The External Partnerships Committee** is working toward increasing international connections. The biggest initiative underway is the student mentoring program (https://ceramics.org/mentorship), which has more than 50 mentor–mentee pairs. Additionally, this committee hosted an activity that promotes connection between ACerS and ECerS students at the Winter Workshop, which is held between ICACC and EMA every year.
- **The Communications Committee** is continuing to expand connections through engaging social media content that focuses on interesting aspects of ceramics and glass science, such as the science behind glassware.
- **The Programing Committee** is finding new ways of engaging with students through virtual competitions and virtual career panels at conferences such as EMA and ICACC.
- **The Recruitment Committee** is looking toward the future as they select the next PCSA delegates, who they hope will continue improving diversity and inclusion within the PCSA, which, in turn, helps to diversify ACerS.

There are so many things to be hopeful for—from the hope that a research hypothesis is met; to the hope that knowledge gained in a classroom STEM activity opens the eyes of younger students; to the hope for a safer, more tolerant world. Hope is something that is constant, but it is not something that should be taken for granted. We must never forget to celebrate hope.

Olivia Brandt is a Ph.D. candidate at Purdue University studying under professors Rodney Trice and Jeffrey Youngblood. As the 2021–2022 chair of the PCSA, Olivia's vision is to effectively collaborate with the PCSA committees to achieve their key, strategic goals for the 2021–2022 term. ■

Congressional Visits Day 2022 recap

By Yolanda Natividad
ACerS Liaison to the Material Advantage Student Program

The Material Advantage Student Program's Virtual Congressional Visits Day (CVD) was held this year from May 17–19, 2022. The CVD is an annual event that gives students an opportunity to visit Washington, D.C. to educate congressional decision makers about the importance of funding for basic science, engineering, and technology. While we again were unable to physically be in D.C. this year, we did put together a virtual CVD program for Material Advantage students.

The CVD experience began with a virtual welcome event on May 17, featuring talks by Sean Gallagher, senior government relations officer at the American Association for the Advancement of Science, and Meg Thompson, cofounder and partner of Federal Science Partners.

After the talks concluded, students were provided with a chance to go into breakout rooms to further organize their teams and to do some role-play in advance of their appointments in the following days.

Students and faculty from the following universities registered for this year's Material Advantage Virtual CVD event:

Colorado School of Mines
Drexel University
Iowa State University
Michigan Technological University
Missouri S&T
The Pennsylvania State University
San Jose State University
The Ohio State University
University of Arizona
University of Maryland, College Park
University of Tennessee, Knoxville
Washington State University

Continued thanks to David Bahr, head and professor of materials engineering at Purdue University, and Iver Anderson, senior metallurgist at Ames Laboratory and adjunct professor in the materials science and engineering department at Iowa State University, for conducting the training on how to visit with legislators and for their assistance over the years in helping to coordinate CVD. Bahr and Anderson both serve on the Material Advantage Committee, the advisory committee that provides recommendations and feedback about the program to the four partnering organization's leadership.

Credit: Christopher Walker, University of Tennessee - Knoxville

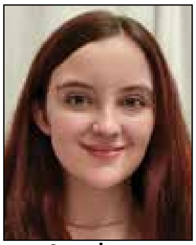
We hope to be back in-person in D.C. for the 2023 CVD event. If you are a student and did not get a chance to participate this year, make sure that you plan to register EARLY for the 2023 CVD event. Or if you are a professor/faculty advisor, make sure to plan on gathering a group together from your university.

For future updates, visit the Material Advantage website at www.materialadvantage.org. It is an opportunity that you will not want to miss! ■

MATERIAL™ ADVANTAGE
The Student Program for Materials Science and Engineering
The American Ceramic Society www.ceramics.org | AIST Association for Iron & Steel Technology | ASM International | TMS The Minerals, Metals & Materials Society

From crisis to hope—pandemic drives increase in mental health awareness and support

By Becky Steadman



Steadman

Among the many hardships we've faced the past two years due to the COVID-19 pandemic, its toll on student mental health is one consequence that has caused concern among parents, educators, and students alike.

As students, we often feel pressured to uphold people's dreams and expectations for the future society. But when the pandemic hit, job offers were withdrawn, graduations were cancelled, and connections were lost—yet the pressure remained.

As a result, many students experienced a decline in mental health. A survey by Student Minds, a U.K.-based student mental health charity, found that between March 2020 to 2021, 74% of students reported COVID-19 had a negative impact on their mental health and wellbeing at university.[1] A survey by *The Washington Post* supported these findings when it found nearly 73% of U.S. students reported moderate or serious psychological distress.[2]

However, as the number of students struggling with mental health increased, support services for students did not keep pace. That same survey by Student Minds found that while 65% of students said they needed additional support, just 19% got the help they needed.[1]

In response, students worked to raise awareness of the burgeoning mental health crisis. For example, Foothills University in California created a Mental Wellness Ambassadors program run by student representatives who aim to reduce social stigma and raise awareness of mental health resources.[3] Students also began to advocate for new policies and mental health programs at their universities. For example, a common request was the implementation of a "no detriment" or "safety net" policy,[4] which would ensure a student's education remained unaffected as they took exams from home in an unfamiliar format, away from in-person professional and personal support systems.

Resource list—Student mental health organizations

Organization	Website	Description
Student Minds	https://www.studentminds.org.uk	U.K.-based student mental health charity dedicated to raising awareness and providing support for students across the U.K.
JED Foundation	https://jedfoundation.org	U.S.-based nonprofit aimed at providing resources to young adults to better understand mental health issues and also crisis hotlines for those in need.
Crisis Text Line	https://www.crisistextline.org	Global nonprofit providing free mental health texting service. Available 24/7 throughout the U.S., Canada, U.K., and Ireland.
The Trevor project	https://www.thetrevorproject.org	U.S.-based nonprofit that is the world's largest suicide prevention and crisis intervention organization for LGBTQ+ young people.
Samaritans	https://www.samaritans.org	U.K.-based crisis line for all ages, focusing on suicide prevention.
Switchboard LGBT+ helpline	https://switchboard.lgbt/how-we-can-help	U.K.-based charity supporting those in the LGBTQ+ community struggling with mental health.
Active Minds	https://www.activeminds.org	U.S.-based nonprofit dedicated to promoting mental health, especially among young adults, via peer-to-peer dialogue and interaction.

Universities acted as well, with many investing in online "telehealth" services to expand student access to mental health professionals. For example, the University of West Virginia established a partnership with online and mobile therapy company Talkspace, and Belmont University in Tennessee purchased the telehealth support platform TimelyCare.[5]

National charities such as the JED Foundation and Student Minds also provided aid to universities in the form of crisis hotlines and educational resources for students. You can learn more about these organizations and others in the accompanying resource list above.

As someone who began a Ph.D. program in 2020, I know all too well the despair the pandemic wrought for students. But I also know the hope that is growing among students that universities will begin taking mental health of students more seriously, even after the pandemic. As lockdowns end and life slowly transitions back to in-person gatherings, universities continue to implement plans to support and acknowledge those working on their mental health.

As a society, we should remember the challenges we faced during the pandemic and address them with concern, understanding, and respect. Only by helping our peers can we create a bedrock of knowledge and trust for others to build on.

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Becky Steadman is a second-year Ph.D. student at the University of Birmingham. Her research focuses on creating multifunctional ceramic matrix composite for aerospace applications. Becky enjoys reading fantasy novels, doing yoga, and visiting her friends' villages in Animal Crossing. ■

Redefining the looking glass: Reconnecting glass art and science

By Brittney Hauke

Hauke

The International Year of Glass (IYoG) could not have come at a better time; for me personally, the last two years have challenged my ability to focus on research. But having an international celebration for the material I love provides a great chance to step back and remind myself why I study glass, reflect on how far we have come, and look forward to the future of this field.

As an artist as well as a scientist, I especially appreciate the emphasis of glass art in the IYoG celebrations. Reintroduction of the arts into STEM fields has gained in popularity as a way to increase student interest in science and engineering and to improve problem solving skills.[1] I say "reintroduction" because for most of history, art and science were studied together: think Leonardo da Vinci and the concept of the "Renaissance man." The supposed dichotomy between glass art and science is a relatively recent perspective.[2]

Art and science are mutually beneficial for several reasons. For one, solving scientific problems often requires creativity, but creativity is a difficult concept to teach and is often not emphasized to STEM students. The introduction of art into STEM classes is a great way to develop this ability.

Similarly, many artists stand to gain from scientists, both in terms of how scientists conduct experiments and the resulting material knowledge. In my own artist endeavors, I found that documenting my experiments in the format of a laboratory notebook helps me clarify my processes and come up with new ideas. In addition, learning about the structure–property relationships of different materials allows artists to arrive at desired artistic results more directly than traditional trial-and-error endeavors.

Art is also a great way to reach new audiences and teach them about science. Glass is a particularly good material for education because in addition to being readily present in our everyday lives, it easily captures out attention; from there it is simple to start teaching about the science and history of glass and what it holds for our future. The Corning Museum of Glass is a great example of using art as a bridge to science outreach.[3] The museum blends the technological and artistic histories of glass into an amazing learning experience, while also spotlighting contemporary artists.

Regarding the combination of glass art and science in the classroom, Márcia Vilarigues of Universidade NOVA de Lisboa recently gave a good overview of this topic in a talk at the IYoG opening ceremony titled "Education in glass art and science—challenges of transdisciplinarity," which you can view online.[4] Some of the challenges she discussed are ones I have experienced personally in the materials science and engineering department at Penn State, where we are working to overhaul our glass blowing studio to make it more portable for outreach events.

Credit: Brittney Hauke

An example of combining art and science from the author's senior art exhibition at Coe College in Cedar Rapids, Iowa. Vanadium tellurite glass used for research was remelted on the bottom of a glazed ceramic bowl.

Even though I have experimented with many different mediums as an artist, my relationship with glass art is just beginning. I have a little experience with flameworking and just finished an introductory class on stained glass. This summer, I hope to learn how to blow glass once our studio space reopens. I am excited to work with glass in new ways, and I hope that it gives me more innovative ideas and appreciation for my research.

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Brittney Hauke is a third-year Ph.D. candidate in materials science and engineering at The Pennsylvania State University studying glass relaxation. In her free time, she enjoys creating art in a variety of mediums, playing board games and video games, and reading. You can also find her in the gym on the rock-climbing wall or lifting weights.

Student perspectives

Science fiction sparks 'a new hope'

By Erin Valenzuela

Valenzuela

While curiosity is a trait we all share, the strength of our wonder tends to fade the older we grow. Yet if we can hold on to that childhood excitement, it can help us advance research into realms previously unexplored. In my opinion, science fiction is an excellent way to spark that inspiration in adults.

Science fiction films account for many key moments in my childhood, with some films deemed a rite of passage by certain family members. As a child, I would sit, think, imagine, and question what and how the social themes within sci-fi might trickle through and grow during my lifetime. Now, as a full-time researcher, I see a real and direct influence by sci-fi science on today's cutting-edge technological accomplishments.

While some of these advancements were pursued for pleasure—do people really need personal jetpacks?—others such as "waldo" remote manipulator arms[1] and language translators[2] were developed out of necessity or a hope for a more collaborative and sustainable future.

Sometimes these sci-fi-inspired discoveries reach beyond their original purpose to benefit other fields. As a personal example, I have always been interested in the space exploration industry, in part due to my love of Star Wars. Yet after working the past three years on aerospace ceramics for supersonic speeds—like those surely used on the T-65B X-wing starfighter—I started to develop a research identity that stretches across and beyond aerospace. What started out as a supersonic aerospace ceramic could also be developed into a ceramic for wind turbine blades,[3] materials for the developing nuclear energy field,[4] and much more.

Science fiction is not only inspiring real-world science—scientific knowledge is shaping new science fiction as well. One of my favorite examples comes from the filming of Christopher Nolan's "Interstellar." Nolan met with astrophysicist Kip Thorne to ensure the story would align with current knowledge on black holes. As they worked with others to develop a black hole simulation to feature onscreen, they ended up making a scientific breakthrough in the understanding and modeling of black holes![5] What originally started as a hope for accuracy in scientific portrayal led to actual scientific discoveries—demonstrating how science and science fiction can mutually benefit each other.

I am the first to say that not all people appreciate science fiction—on some days, even I find it difficult to enjoy the Culture series, which are some of my favorite books. It takes curiosity and patience to pull yourself away from the day to day and immerse yourself into a universe so far from our own. However, I was heavily reminded about the excitement of science while recently watching Villeneuve's "Dune" remake. While completely—and literally—out of this world, adventures such as this one are a key reminder for why we do what we do as researchers and as scientists.

When researching a small section of science, it is often easy to forget the bigger picture. Next time you feel overwhelmed, grant yourself a couple of hours to watch or read some science fiction. It can give you the hope that you are working for something much bigger than the furnace breaking or your particles falling out of suspension. Even though some sci-fi is simply fiction, a lot of it is closer to reality than we realize.

Credit: Erin Valenzuela

Me as a baby, probably imagining that the balloon is a rocket. Carrying our childhood wonder into adulthood can greatly benefit our approach to research.

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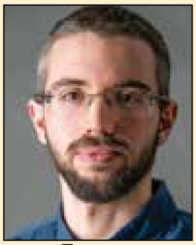
Erin Valenzuela is a Ph.D. student at the University of Birmingham, currently writing her thesis on multifunctional, high-temperature oxide-based ceramic matrix composites. In her spare time, she loves playing Scrabble and cooking food with her family. ■

Toward where no earthling has gone before

By Elia Zancan



Zancan

"Space: the final frontier!" I've never been a Star Trek fan, but I admit those words struck me when I first heard them. While final frontiers do exist within the confines of our atmosphere—more than 80% of the ocean remains unexplored, after all—the thought of exploring among the stars is a tantalizing prospect.

Of course, active exploration of the cosmos currently remains out of reach. But we are slowly increasing our capacity to peek into deep space, with the newly launched James Webb Space Telescope being a star among stars. But these advances are, for the most part, unmanned explorations. Sixty-six years passed between the Wright brothers' first flight and the moon landing, and almost the same time has now passed without any significant steps toward manned space flight, an indication of how great is the technological leap required for space exploration.

Leaving aside—at least for now—the science fiction required for long-distance space travel, one of the most critical improvements we can implement regards the propulsion system. Considering how insignificant our lifespan is related to the incredibly vast ranges of space, faster ships are needed to shorten travel time. To go faster, though, ships require more powerful engines operating at much higher temperatures.

Here is where my research on ultrahigh-temperature ceramics (UHTCs) plays a role. These materials can withstand incredibly demanding thermal and/or mechanical stresses with the help of fibrous reinforcement. Still, their remarkable properties make manufacturing them difficult, especially if more complex shapes are desired. For this reason, I am developing a new production route for UHTCs that overcomes some of the challenges experienced with traditional manufacturing techniques, such as extremely long processing times or very high temperatures.

Credit: NASA

European Space Agency astronaut Luca Parmitano carries the new thermal pump system that was installed on the Alpha Magnetic Spectrometer during the third spacewalk to upgrade the machine. One day, an unknown planet will be in the background of these pictures.

The latter is a crucial point, as it requires adequate materials for the construction of furnaces and other processing equipment capable of resisting high temperatures, plus a considerable energy consumption to run them. As both fixed and operating costs scale superlinearly with component size and progressive harshening of operating conditions, working on alternative manufacturing routes is a must to enable a larger scale deployment of this class of materials.

Of course, we do not have to reach far into the galaxy for a reason to fund UHTC research—commercial aircraft will also benefit from easier access to these materials. The implementation of thermal protection systems, similar to those employed by atmospheric reentry vehicles, will enable hypersonic flight, which will dramatically reduce the duration of intercontinental flights.[1] Traveling from Europe to either the west coast of the Americas or to East Asia will take just a couple of hours rather than a whole day—the dream of every passenger seated next to a whiny baby!

Although the aerospace industry has used UHTCs for some time, much research is still required to cut production costs and to improve their performance. As such, I do not expect my research to produce an immediate breakthrough. But even if it is just a bolt in the framework on a future build, I will deem myself happy. And what is humanity without dreams and hope, after all?

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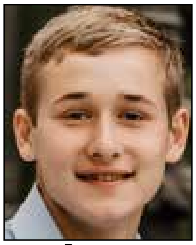
Elia Zancan is a second-year Ph.D. student in the metallurgy and materials department at the University of Birmingham, U.K. He is working on ultrahigh-temperature ceramic matrix composites for aerospace applications, focusing on the polymer-derived manufacturing route. His interests span from board and card games to martial arts and orchestral cinematic music.

Vitrification of nuclear waste offers hope for a cleaner future

By John Bussey



Bussey

In my home state of Washington, the disposition of legacy nuclear waste is a complex pursuit that has evolved since the Hanford site in eastern Washington was converted from a production mission to an environmental cleanup mission in 1989 (Figure 1).

About 56 million gallons of radioactive tank waste are currently stored at Hanford, generated between 1944 and 1989 from five different chemical processes performed on 96,000 tonnes of irradiated nuclear fuel.[1] Some of these tanks are confirmed to be leaking while others are suspected, leading (unsurprisingly) to societal and environmental concerns; releases from these tanks pose a potential health risk to people and organisms that rely on the Columbia River.

The planned approach for safe disposal of the nuclear waste is vitrification, that is, turning the waste into glass.[2] After nuclear waste is vitrified, it will go into long-term storage for thousands of years, either on-site in controlled shallow burial (for low radioactivity waste) or in a yet-to-be-commissioned deep geological repository (for high radioactivity waste).

Nuclear sites throughout the world use vitrification, but each collection of nuclear waste has its own "fingerprint," requiring a unique solution. The waste at the Hanford site is particularly tricky. It includes some of the first nuclear waste ever generated, before standard extraction methods were established. As such, scientists have identified more than 70% of elements (up to curium) on the periodic table in this waste. These many components cause diverse potential technical issues during immobilization, requiring extensive risk reduction research.[1]

Research devoted to solving the technical challenges associated with vitrification has taken place for many years, including at my institution, Washington State University. This devotion has led to large strides in a wide range of basic and applied glass science topics, including composition, characterization, durability, solubility/retention, corrosion, glass-ceramics, and refractory materials used in glass melting furnaces.

All this research—and ongoing work probing outstanding scientific issues to provide further risk reduction—is being used to develop the Hanford Waste Treatment and Immobilization Plant (WTP). The WTP will be the most complex vitrification effort to date, helping to remediate one of the largest environmental clean-up sites of all time.[1] According to Bechtel National, Inc., the Department of Energy contractor obligated to start up the vitrification plant, this facility is currently in the commissioning phase. This phase is the last one before full scale plant operations begin (tank waste vitrification is planned to start at the end of 2023).[3]

Figure 1. 1943 construction of nuclear waste tanks at the Hanford site. These tanks were designed with a 20-year lifetime, although some waste (including the waste stored in the above tanks) was later relocated to tanks with a 50-year lifetime.[1]

I am hopeful and excited to see all the vitrification research being used to develop real-world solutions for nuclear waste storage. As ceramists and glass scientists, we often work on wide-ranging projects that take a long time to come to fruition. This project is a great example of how many years of research, from a broad and diverse community, can eventually be applied. In this case, decades of ceramics and glass research will help to protect human health and the environment for years to come.

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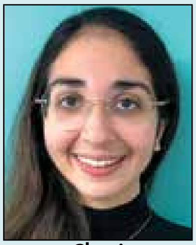
John Bussey is a second-year undergraduate student studying materials science and engineering at Washington State University. John's research focuses on characterizing nuclear waste forms, and broadly exploring glass and ceramic materials to improve environmental sustainability. When not doing research, John can be found outside—hiking, skiing, running, climbing, or playing ultimate frisbee.

With a touch of magic: Lessons learned from alchemists and historic ceramics

By Celia S. Chari



Chari

In April 2020, amid the start of the COVID-19 pandemic, I spent my time reading through the literature and researching production methods of 18th century overglaze enamels from the Meissen porcelain manufactory, which was located near Dresden in present-day Germany.

Founded by Augustus II the Strong, Elector of Saxony, the Meissen manufactory housed renowned alchemists like Johann Friedrich Böttger and Ehrenfried Walther von Tschirnhaus, who helped develop the first European hard paste porcelain. Prior to their breakthrough, porcelain was procured solely from the Far East, primarily China, where its production secret was closely guarded for centuries, including the high firing temperature requirements from specialized kilns. However, through clever control of materials chemistry and a high inclusion of lime, these alchemists produced the desired vitreous consistency of porcelain at a much lower temperature than required in the original formula.

Reading through the recipes and stories of Meissen, I could not help but become captivated and inspired by the resiliency of these ceramists; despite their high-pressure work environments, they still flourished in their production of "white gold" and other admired ceramic objects.

As the months passed by, my research slowly transitioned back to the laboratory, where the pressure to make up for lost time was very real (though admittedly it originated mostly from my own ambitions). With limited access to instruments and facilities, my research pace was infuriating at times. But I remained hopeful as I kept reading about the intricate discoveries from alchemists at Meissen, born under self-pressure and immense creativity.

I was particularly mesmerized by the complex nanotechnology that appeared to be featured in their purple overglaze enamels, predominantly two called *Böttger luster* and *Purple of Cassius*.[1] How did alchemists from 1710–1735 know to work with gold nanoparticles to produce purple glazes? How did they synthesize nanoparticles with their limited technology and understanding of materials science? Were they truly magical beings, or just obsessive experimentalists? Based on the numerous technological advancements that have taken place since the 18th century, it is unlikely the original alchemists from Meissen had any understanding of the fundamental chemistry and physics dominating the optical properties of their glazes. Yet they successfully carried out experiments and produced artworks through repeated trial and error, imagination, and an abundance of pressure from the impatient Augustus II the Strong, who was funding their research. So, I eventually concluded: if they could develop an impressive palette of enamels and porcelains under their work conditions, I could carry out my doctorate during the pandemic.

Hope and resilience. Despite their unfortunate circumstances and timing, alchemists from Meissen made an impact

Example of a tureen created at the Meissen porcelain manufactory (c. 1730–1735).[2] You can see the *Purple of Cassius* overglaze in the people's clothing, while *Böttger luster* is the purple-brown glaze found in the frame-like cartouche around the different images.

in the history of the world, fabricating lustrous glazes that are still talked about today. Studying their historic purple glazes, I felt like I was tackling a mystery that had puzzled conservators and scientists for centuries—what makes *Böttger luster* purple and iridescent? I felt incredibly lucky that I could work on this project using modern microscopy and materials characterization tools, more technologically advanced than ever before.

Yet as I get further into my research, it is sobering to realize that some research questions cannot be answered even with our advanced techniques. That does not mean, however, they cannot be answered in the future when the right analytical equipment and literature is available to aid in investigation. I am filled with hope thinking about the continuity of research from that perspective, and it inspires me to think about how far mankind's knowledge will grow with the right facilities and continued curiosity for discovering why materials behave the way they do.

As modern-day ceramists, please remember the spirit of our alchemist past when studying the advanced materials of the future. With patience, resilience, and hope, what seems magical today will likely be explainable in the future.

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Celia Chari is a Ph.D. candidate in materials science at the California Institute of Technology. Her research focuses on ceramic coatings and glazes, related to both cultural heritage science and aerospace applications, the latter being in collaboration with NASA's Jet Propulsion Laboratory. She is passionate about the intersection between art and science, and in her spare time enjoys making watercolor paints from mineral and organic pigments that she finds on hikes. ■

Hope in collaborations: A driving force for research

By Kartik Nemani and Brian C. Wyatt

Nemani

Wyatt

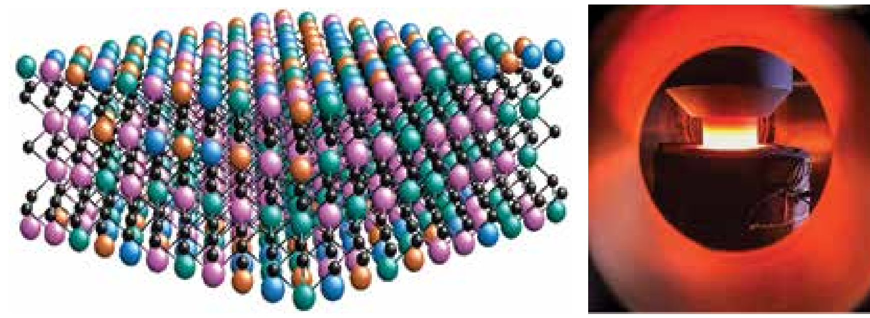
Throughout history, civilizations have gone through periods of highs and lows. Yet even in the hardest times, hope has driven people to come together to beat the odds and emerge triumphant, sometimes with breakthroughs and many times with reinforced will and courage.

The COVID-19 pandemic is again reinforcing the importance of collaborations, something we have personally experienced as Ph.D. students who started a semester before the pandemic hit.

Our research is on the synthesis and high-temperature stability of MXenes, which are a family of 2D transition metal carbides, nitrides, and carbonitrides. First discovered by two groups of Drexel University researchers in 2011, MXenes are quickly finding application in a wide variety of fields, from environmental remediation to electronics to ultrahigh-temperature ceramics.

Though MXenes are a relatively new research field, they have attracted much attention from the 2D materials community, and studies on these materials are being published at a high rate, even during the pandemic. As new Ph.D. students trying to keep up with this ever-growing body of research, the inability to meet with professors and other students in person left feelings of disorientation and worry that we would not grasp the topic well enough to contribute something new.

However, in 2021, our perseverance through these challenging times started bearing fruit when collaborative efforts between us and three other teams, across two continents, led to the discovery of high-entropy MXenes[1] as well as advancements in understanding MXene high-temperature behavior.[2]



Credit: Wyatt and Nemani

Left, schematic representation of high-entropy MXenes $TiVNbMoC_3$ or $TiVCrMoC_3$ discovered by our group in 2021. Right, MXenes being brought to ultrahigh temperatures (> 2,000°C) in a graphite die placed in a spark-plasma sintering equipment.

The vital experiments were conducted at our Indianapolis lab, with the data generated being channeled to a supercomputer at Argonne National Laboratory. Simultaneously, we shipped a batch of our samples to collaborators at Argonne for atomic scale imaging, while our collaborators in Norway verified results and measured other vital parameters through simulations.

Consistent communication helped us develop strong synergy with our collaborators, and this teamwork was the source of much needed hope during tough times, both inside and outside the lab. When we both fell ill and needed to take a break from experiments, our collaborators supported and motivated us to continue our work once we returned. While discovering high-entropy MXenes was exciting scientifically, being able to share the discovery with our collaborators, now friends, helped lessen worries about our individual capabilities and appreciate what we can accomplish when working together.

As Ph.D. students who have conducted well over 70% of our doctoral studies during a life-changing pandemic, we have come to realize that passion in research does not necessarily come from chasing inspirational breakthroughs, published manuscripts, or raucous applause. It comes from the opportunity to express ourselves through something that brings joy and hope to our lives while strengthening relationships with others in the field.

As the Rig Veda, a book of hymns from 10000 BCE, states: "May noble thoughts come to us, may there be advancement in all aspects." (1.89.1) Perhaps hope, in its true essence, is finding our humanity in the pursuit of a solution while steering through the ocean of challenges.

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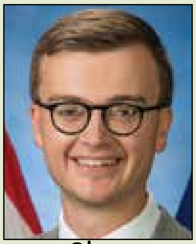
[1]Nemani et al., "High-entropy 2D carbide MXenes: $TiVNbMoC_3$ and $TiVCrMoC_3$," *ACS Nano* **15**(8), 2021:12815–12825.

[2]Wyatt et al., "High-temperature stability and phase transformations of titanium carbide ($Ti_3C_2T_x$) MXene," *J. Phys. Condens. Matter* **33**, 2021:224002.

Kartik Nemani and Brian C. Wyatt are Ph.D. candidates in the Layered Materials and Structures Lab at Indiana University–Purdue University. Their research focuses on synthesis and high-temperature stability studies of MXenes. When not working, Kartik can be found either painting, hunting for subjects to capture with his camera, or behind a moth-eaten book of ancient Sanskrit. Similarly, when not on campus or behind his computer, Brian can be found enjoying the company of his wife and two dogs, trying new coffee shops in the city, or hiking on a trail across the state of Indiana. ■

The far-reaching impact of the Mini Materials Kit

By Nathaniel Olson and Nathaniel S. McIlwaine



Olson

McIlwaine

STEM outreach is more than an activity to inspire and educate the next generation. Outreach also serves as a source of hope for the scientists, engineers, and educators who conduct it—hope that the next generation will continue to advance research and development in support of the planet and its inhabitants.

Recent times have left many of us feeling isolated, with access to in-person education severely limited. Nonetheless, many inventive and passionate individuals overcame these limitations by leveraging new tools and infrastructure for remote education. Here, we highlight outreach efforts by members of ACerS President's Council of Student Advisors, the student-led committee of ACerS, using the Ceramic and Glass Industry Foundation (CGIF) Mini Materials Kits.[1]

CGIF was established by ACerS in 2014 to attract, inspire, and train the next generation of ceramic and glass professionals. CGIF developed the Mini Materials Kit in 2020 as a more accessible follow-up to the larger Materials Science Classroom Kit. The kit is a collection of seven simple experiments accompanied by video demonstrations and written instructions that can be done independently by teachers, parents, and students.

Isabella Costa has led efforts to distribute the kits in Brazil by providing kits she brought back from the U.S. to 7^{th}–9^{th} grade teachers at public schools who do not have laboratory facilities (Figure 1). Speaking to the impact of the kits, Costa relates, "Through the kits I was able to introduce contents that were never discussed in the classroom, such as the periodic table and atomic bonds, in an interactive way. The kids were not only excited about the experiment but were also interested in understanding the science behind it."

Credit: Isabella Costa

Figure 1. Isabella Costa (center, white shirt) with teacher Eduardo Siríaco Trezza (center, blue shirt) and students from Antônio Ferreira Martins Municipal School after a lesson demonstrating the Mini Materials Kits.

Like Costa, Matthew Julian became aware of the significant costs of shipping the kits internationally after accepting a Ph.D. position in France. So, he put together a bill of materials using suppliers in Europe and established a partnership with a French company to assemble and distribute the kits to students and teachers in Europe. Julian says, "This [work] is all in hopes of planting the seeds to cultivate the next generation of scientists who will develop the technology of tomorrow."

Shannon Rogers expanded the kit's reach beyond the classroom and into afterschool programs by helping to establish the ACerS Colorado Section's Denver kit distribution program. This program, in collaboration with the Denver Scholarship Foundation's Future Centers,[2] enabled the distribution of 14 kits to underserved high schools in the Denver area. A key motivation behind Rogers' passion for outreach is her own journey in materials science. She relates, "I didn't know what [materials science] was until I was looking at Alfred University for a degree in ceramic art and design, and saw ceramic engineering listed as a major. … I think [the kits] could really open the minds of young engineers and get them excited about materials."

There are many other past and present PCSA members who helped make these achievements possible, including project leadership from Andy Ericks, Spencer Dahl, Michael Thuis, and Nathan McIlwaine, and hard work from Ruth Adam, Megan Owen, and Anna Schmidt-Verma. This work provides hope that access to STEM education and outreach can be expanded even in the most difficult of times, helping to foster a materials science community that spans the globe.

References

[1] Mini Materials Kit, https://foundation.ceramics.org/mini-kits

[2] "Find Your Future Center," Denver Scholarship foundation, https://denverscholarship.org/students/future-center

Nathaniel Olson is a fourth-year Ph.D. candidate and NASA Space Technology Research Fellow in materials science and engineering at the University of Illinois Urbana-Champaign. His work focuses on the development of highly porous ceramic materials (aerogels) for use as insulation in aerospace applications. In addition to his graduate work, Nate is a member of the Illini Motorsports FSAE team and a Pathways Intern at NASA Johnson Space Center.

Nathaniel McIlwaine is a second-year Ph.D. candidate and National Defense Science and Engineering Graduate Fellow in materials science and engineering at The Pennsylvania State University. His work focuses on the investigation of spinodal-hardened high-entropy ceramics to achieve ultrahigh hardness. In addition to his graduate work, Nathan is a third-year PCSA delegate and is currently serving as Outreach Committee chair. ■

Structural clay experts unite in Charlotte for networking, tours, and more after a two-year pause

Credit: All images from ACerS

More than 100 attendees converged in downtown Charlotte, N.C., from May 9–11, 2022, to take part in the combined meeting of the ACerS Structural Clay Products Division (SCPD), ACerS Southwest (SW) Section, and Clemson University's National Brick Research Center (NBRC).

The meeting was greeted with much enthusiasm by attendees because this annual meeting was canceled the past two years due to the COVID-19 pandemic. The success of this year's meeting is thanks to the combined efforts and teamwork between members of the ACerS SCPD and SW Section and the NBRC.

The meeting kicked off with the NBRC Spring Executive Committee Meeting on Tuesday, May 10. NBRC director John Sanders, testing services manager Mike Walker, and research associate Nate Huygen provided members with updates on the Center. Sanders reminded the committee of the upcoming Clemson Brick Forum, Sept. 25–27, 2022.

On Tuesday afternoon, attendees heard from industry experts on a wide range of topics, including raw materials, firing issues, lessons learned during the pandemic, testing, machine operation, and more.


Attendees tour the Taylor Clay Products plant in Salisbury, N.C.


David Ziegler, right, presents Mat Tamel with ACerS SW Section Past Chair Award.

On Wednesday, May 11, attendees toured four plants—Statesville Brick (Statesville), J.C. Steele (Statesville), Old Carolina Brick Company (Salisbury), and Taylor Clay Products, Inc. (Salisbury).

Meeting attendees reconnected with old friends and built new relationships each evening in the hospitality suite, at the Suppliers Mixer reception on Tuesday, and at the awards banquet on Wednesday. Danser, Inc. once again took on the role of host for the hospitality suite.

During the banquet, ACerS SCPD chair Jed Lee thanked everyone for attending and recognized the presenters, plant hosts, ACerS staff, and sponsors for helping make the meeting a success. Lee then presented Mike Walker (Clemson University) a certificate of appreciation for his service as past SCPD chair.

Neil Kline (Acme Brick) received the 2019 SCPD Best Paper award for his presentation titled "Acme's new scrubbers."Harland Dixson (Acme Brick) accepted the award on Kline's behalf. Mat Tamel (Acme Brick) received the SW Section Past Chair Award from current SW Section Chair, David Ziegler (Prince).

View more pictures from the meeting on ACerS Flickr page at https://bit.ly/SCPD2022. Next year's meeting is scheduled for June 5–8, 2023, in Austin, Texas. ■


Jed Lee, right, presents Mike Walker with the ACerS SCPD Past Chair certificate during the banquet.

ACerS meeting highlights

GOMD CONFERENCE in Baltimore reunites, rejuvenates, and celebrates

Credit: All images from ACerS

After the banquet, left to right: Arun Varshneya, Kathleen Richardson, L. David Pye, and Kathy Jordan. Jordan presented her stained glass restoration artwork at the banquet.

Peter Swanson (right) demonstrates his interactive presentation of the stained glass windows at the National Cathedral.

ACerS president Beth Dickey (right) presents a certificate of appreciation to GOMD co-organizer Charmayne Lonergan. Unfortunately, Lonergan's co-organizer, Ashutosh Goel, spent GOMD week in COVID-19 quarantine.

ACerS Glass & Optical Materials Division held its annual meeting and conference in Baltimore, Md., May 22–26, 2022.

GOMD was among the first of ACerS Division meetings to be cancelled in 2020 due to the COVID-19 pandemic. The conference's return to in person this year gained added luster from the United Nations declaring 2022 the International Year of Glass (IYOG). About 215 people attended the conference in person, and 59 provided prerecorded presentations. Student participation was strong with 53 in attendance, and 22 countries were represented.

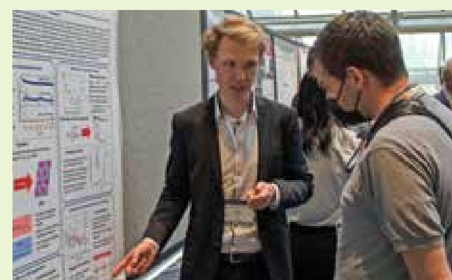
BG Potter (left) and Liping Huang (right) present the Journal of Noncrystalline Solids N.F. Mott Award to Minoro Tomozawa, FACerS and Distinguished Life Member.

Anthony Corradetti (center) works with an apprentice glassworker to demonstrate glassworking principles to Baltimore public high school students as part of GOMD's International Year of Glass outreach.

Program coorganizer Charmayne Lonergan says, "People seemed to enjoy the program and are excited to be back in person. It's like the coming together of family members. Even though the science has evolved, it feels like coming home, regardless of the city."

The banquet on Tuesday evening gave the community an opportunity to recognize its luminaries and rising stars.

This year, inspired by the IYOG, organizers invited two after-dinner speakers from outside the glass science realm. Kathy Jordan, president of the American Glass Guild and glass painter, presented examples of her work restoring damaged or destroyed stained glass windows. Peter Swanson, a documentary producer and director, talked about his documentary on the life and work of Rowan LeCompte, who designed 45 of the stained-glass windows installed at the National Cathedral in Washington, D.C. Swanson brought an interactive cabinet showcasing Rowan's work to the conference for attendees to view during breaks.



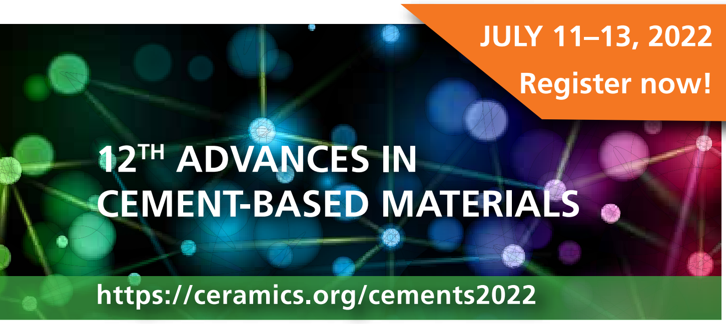
Soren Sorensen of Aalborg University describes his work during the student poster session.

An extracurricular field trip on Wednesday evening to Coppin State University in Baltimore gave attendees the opportunity to view the glass art exhibit, Fired Up!, featuring glass artworks. Though small, the exhibit covered a wide range of artforms, and the presence of artists provided an excellent point of intersection.

Although the conference ended on Thursday, GOMD organizers arranged an IYOG-themed outreach event with local schools on Friday, May 27, that took place at a local glass blowing studio. Students from three local high schools participated and learned about glass compositions and properties in the context of watching artisan Anthony Corradetti create beautiful glass objects.

View more pictures from the meeting on ACerS Flickr page at https://bit.ly/GOMD2022. Next year's meeting is scheduled for June 4–9, 2023, in New Orleans, La. ■

UPCOMING DATES



UNIVERSITY OF CALIFORNIA, IRVINE, CALIF.

Cement is the key ingredient in concrete—the most-used building material in the world—so every advance in understanding how it behaves presents an opportunity to reduce greenhouse gases, advance construction engineering, and improve quality of life around the globe.

HYATT REGENCY BALTIMORE, BALTIMORE, MD.

Energy harvesting has become the key to the future of wireless sensor and actuator networks for variety of applications including monitoring of temperature, strain, humidity, light, and location of persons within buildings, chemical/gas sensor, structural health monitoring, and IoT.

DOUBLETREE BY HILTON ORLANDO, ORLANDO, FLA.

EMA 2023 is an international conference focused on electroceramic materials and their applications in electronic, electrochemical, electromechanical, magnetic, dielectric, and optical components, devices, and systems. Jointly programmed by the Electronics Division and Basic Science Division of The American Ceramic Society.

HILTON PANAMA, PANAMA CITY, PANAMA

The Pan American Ceramics Congress brings together a wide variety of experts from academia, industries, research institutes, and laboratories to discuss current state-of-the-art and various technical challenges in research, development, engineering, manufacturing, and application of ceramic and glass materials. The Congress will provide a collegial forum for information exchange on current status and emerging trends in various technologies in the American continent (South and Central America, Canada, and the United States).

DAVID L. LAWRENCE CONVENTION CENTER, PITTSBURGH, PA.

NEW this year—The Materials Science and Technology Partnership has engaged the commercial exhibition firm Event Partners to sell and manage the full exhibition at MS&T22. In addition, Event Partners will co-locate two commercial exhibitions run by the company within MS&T22: The Advanced Materials Show and the first-ever Nanotechnology Show.

The Materials Science & Technology technical meeting and exhibition series is a long-standing, recognized forum for fostering technical innovation at the intersection of materials science, engineering, and application. At MS&T, you can learn from those who are on the cutting edge of their disciplines, share your work with the leading minds in your field, and build the valuable cross-disciplinary collaborations unique to this conference series.

JUNE/JULY 2022 • VOLUME 3 • ISSUE 2

Ceramic & Glass MANUFACTURING

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GLOBALIZATION: STAYING AGILE IN THE FACE OF WORLDWIDE MANUFACTURING CHALLENGES

AODD PUMPS FOR IMPROVED CERAMICS PRODUCTION

JAPAN FINE CERAMICS ASSOCIATION ROADMAP 2050

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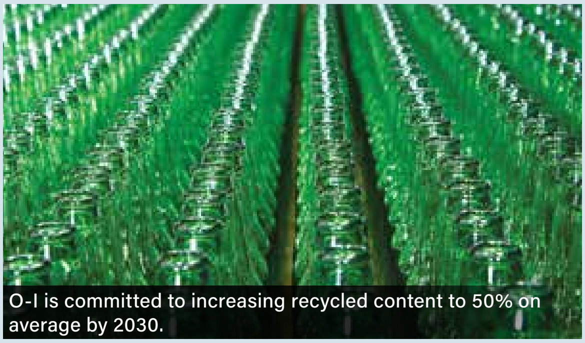


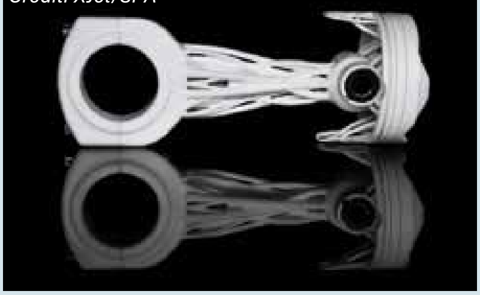
O-I is committed to increasing recycled content to 50% on average by 2030.

LARGE BOTTLER COLLABORATES WITH O-I ON RECYCLING

Coca-Cola Bottling Co. United is partnering with O-I Glass to capture more recycled glass to manufacture into new bottles. Coca-Cola United expects to recycle more than 700,000 out-of-date and damaged bottles annually. The Birmingham, Ala.-based bottling company previously sent its glass bottles to a local recycler that used the material in fiberglass. Now, the center's recycled glass will be taken to O-I's plant in Danville, Va., and remade into new glass bottles.

HYPERCAR WILL USE XJET 3D PRINTING TECHNOLOGY

Spyros Panopoulos Automotive (SPA) is using XJet's ceramic 3D printing technology to produce an engine piston for its Chaos Ultracar. About 78% of the body of the Ultracar is set to be 3D printed, while elements such as the engine block, camshaft, and intake valves will also involve additive manufacturing. The Greece-based company is pursuing speeds of over 500 kph and acceleration from 0 to 100 kph in 1.55 seconds with the vehicle, which is currently under development. SPA says it requires parts that are strong and temperature-resistant, yet lightweight, to deal with such demands.



The additively manufactured piston. *Credit: XJet/SPA*

Borosil Renewables produces low-iron-textured solar glass for photovoltaic panels, flat-plate collectors, and greenhouses.

BOROSIL EXPANDS WITH ACQUISITION IN EUROPE

Borosil Renewables Ltd., a solar glass manufacturer based in Mumbai, India, acquired Interfloat Group, one of the largest solar glass manufacturers in Europe. The Group consists of GMB Glasmanufaktur Brandenburg GmbH, located in Tschernitz, Germany, and Interfloat Corp., based in Ruggell, Liechtenstein. With the acquisition, BRL says its solar glass output will grow to 750 tons per day, an increase of 66%. Borosil says expansions underway in India, as well those planned in Europe, will grow its solar glass output to 2,100 tons per day by the end of 2024–25.

SAINT-GOBAIN ACQUIRES REFRACTORIES MAKER

Saint-Gobain acquired Falconer, N.Y.-based Monofrax LLC from Callista Private Equity GmbH. Monofrax manufactures a range of fused cast refractories. Munich-based Callista acquired the company in June 2016 from RHI AG, and says it shifted the company from a commodity provider to a specialty niche manufacturer. Paris-based Saint-Gobain manufactures fused and sintered refractories for the glass industry and for other markets such as steel, copper, and aluminum.

Monofrax supplies its products to the glass industry worldwide.

The investment in the three-digit million euro range includes an R&D center as well as a logistics and an integrated administrative area. *Credit: IE Group*

SCHOTT INVESTS IN READY-TO-USE DRUG CONTAINERS

SCHOTT plans to significantly expand its production capacity of ready-to-use cartridges. The drug containment and delivery solution is used to store and administer drugs with the help of pen injectors or wearable devices. The company, based in Mainz, Germany, says it would increase the production capacity of ready-to-use cartridges at its facility in St. Gallen, Switzerland, and would build a production facility in Hungary for prefillable glass syringes. The company also says it invested "three-digit million euro" in a new plant in Müllheim, Germany, providing more than 100 jobs.

ARDAGH ACQUISITION OPENS MARKETS IN AFRICA

Ardagh Group completed the acquisition of Consol Holdings Proprietary Ltd., a producer of glass packaging based in Johannesburg, South Africa. Consol operates four glass production facilities in South Africa, and smaller production facilities in Kenya, Nigeria, and Ethiopia. The acquisition was $1 billion, including net debt assumed in Consol. Ardagh says it will also invest $200 million in two new furnaces. With the acquisition, Ardagh operates 65 production facilities in 16 countries, on four continents, and has annual sales approaching $10 billion.

Ardagh employs about 20,000 people worldwide.

GE says the investment will enable it to make wind turbine towers more efficient and sustainable.

GE ACQUIRES STAKE IN 3D CONSTRUCTION PRINTING FIRM

GE Renewable Energy announced a minority investment in COBOD International, a Denmark-based company that manufactures 3D printers for the construction industry. COBOD is experiencing double-digit growth and is a market leader in 3D construction printing, with more than 50 sold worldwide. Financial details were not disclosed. The companies opened a research and development facility in Bergen, N.Y., that will study how to 3D print the concrete base of towers used in wind turbines.

VISY PLANS INVESTMENTS IN AUSTRALIA

Visy says it will invest $500 million to build a new glass container manufacturing facility in Yatala, Australia, as part of executive chairman Anthony Pratt's pledge to invest $2 billion in the country over the next decade. The facility will produce about one billion glass containers annually for clients in the beverage industry. Visy became a dominant player in the beer bottle manufacturing industry in Australia after a $1 billion deal to acquire the local glass bottle manufacturing business of O-I Glass in 2020. Pratt owns Visy with sisters Heloise Pratt and Fiona Geminder, and has sole ownership of Pratt Industries in the U.S.

Visy plans to spend $2 billion over the next decade on recycling and clean energy infrastructure.

GLOBALIZATION: STAYING AGILE IN THE FACE OF WORLDWIDE MANUFACTURING CHALLENGES

By David Holthaus

Many companies have been challenged to find skilled, specialized employees in their industries. *Credit: Schott*

Whether expanding into new, growing markets or sourcing raw materials from faraway countries, businesses are increasingly operating in a global environment that can be rewarding but at the same time risky. Nimble businesses that are prepared to adapt to the challenges of doing business in an unpredictable world can succeed, say several we spoke to.

Despite supply chain challenges, cultural barriers, and a worldwide pandemic now in its third year, Lithoz GmbH, the Vienna, Austria-based maker of ceramic 3D printers, announced in April an installation at a technical university in South Africa. The company, only 11 years old, now does business on every continent except Antarctica, says CEO Johannes Homa.

"We were born a global company," he says. "From the very first day, we were looking into the world."

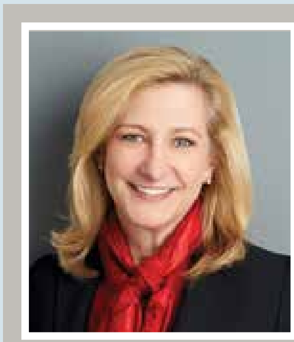
That's an essential vision in the interconnected economy of the 21st century, but the hurdles to achieving it can be high.

PRESSURES ON GLOBAL MANUFACTURING

The most recent Global Manufacturing Purchasing Managers Index from J.P. Morgan cites the pressures affecting production and trade around the world. The Index is an overview of the manufacturing sector based on monthly surveys of more than 10,000 purchasing executives from 32 of the world's leading economies, including the U.S., Japan, Germany, France, and China.

Its May report highlighted what might be called the trifecta of global manufacturing pressures: COVID-19, supply chain problems, and inflation. "COVID restrictions in major cities in China hit production amid global supply chain constraints and high prices," it says.

The three stressors are interrelated, creating a global perfect storm. Average purchase prices for materials and supplies rose to one of the highest levels of the past 11 years, the May report says. "Stretched global supply chains contributed to the price inflationary pressure, with vendor lead times again lengthening to a near-record degree," it adds.



Carol Jackson

In its global outlook for manufacturing in 2022, consulting firm Deloitte found solid reasons for optimism: Industrial production and capacity utilization surpassed pre-pandemic levels in midyear 2021. The year ended with strong increases in new orders for all major manufacturing sectors, it adds, signaling continued growth in 2022.

But these positive economic indicators come with what the firm says are "historic labor and supply chain challenges." The most pressing among these are workforce shortages and supply chain instability, both of which can reduce operating efficiency and profits. This turbulent marketplace will demand "business agility" to succeed, Deloitte says.

AGILITY BRINGS STABILITY AND OPPORTUNITY

Pittsburgh-based HarbisonWalker International is the largest producer of refractory materials and services in North America. Although it is primarily based on this continent, is has longstanding operations in Europe and Asia. For HWI, agility means both stability and opportunity.*

"We tend to go where our customers need us," says Carol Jackson, HWI's president, CEO, and chairwoman. "Sales opportunities are global."

The company also sources raw materials for its products from China, South America, and other parts of the world.

Elected CEO in 2017, Jackson has a long career working internationally in the chemicals, glass, ceramic materials, and specialty steel industries, having been director of global raw materials purchasing at PPG Industries, as well as other roles. She is also the immediate past president of the World Refractories Association.

She emphasized HWI's agility, even in the current environment. "We have the ability to be that first and only call for our customers," she says. "We're there at a moment's notice."

The company serves industrial customers in the steel, glass, petrochemical, energy, cement, and many other sectors, where quality, consistency, and reliability are demanded. Although the global supply chain is stressed, HWI's longstanding relationships with its suppliers helps.

"We have a very stable supply chain that we've worked long and hard to develop," she says. "We're a good customer to our supply base. As a result, we tend to get earned, preferential treatment."

Supply chain instability was one of the five global manufacturing trends to watch this year, according to the Deloitte experts. "There's no mistaking that manufacturers face near-continuous disruptions globally," the report says.

High demand, rising costs of materials, and now, with a war in Europe contributing to a rapid rise in fuel costs, "The entire supply chain for every commodity from beginning to end is stressed," Jackson says. "That means inflation."

MAKING DECISIONS DESPITE UNCERTAINTY

Rising costs are just one of the challenges Schott AG is encountering as it expands globally. Mainz, Germany-based Schott, a multinational company specializing in manufacturing glass and glass-ceramics, has long had a global footprint. It is currently represented in 34 countries, with around 17,300 employees working at 56 locations around the world.

"We are constantly monitoring markets, and we invest in areas where we see potential for sustainable growth," says Schott spokesperson Neda Jaafari.

The main challenge to its global expansion is the nature of the VUCA world, Jaafari says. VUCA is shorthand for managing in a business world that has become Volatile, Uncertain, Complex, and Ambiguous.

In South Africa, Lithoz installed what it says is the first 3D printer on the African continent. *Credit: Lithoz*

**This archival version of the June/July 2022 C&GM contains a correction from the print edition.*

"We have to face new challenges such as geopolitical developments, which means that we have to make decisions despite a degree of uncertainty," Jaafari says.

In this VUCA environment, Schott is moving forward with its expansion plans.

In March, the company announced an investment of 76 million euro at its production site in Lukácsháza, Hungary. The company is planning to build new production capacity for its prefillable glass syringes. Typically, new drugs enter the market in vials, and single-use syringes are used to extract and administer them. But looking ahead, these drugs may be stored in syringes that are prefilled with the medication, simplifying the injection process for health care workers and increasing the dosing accuracy for patients, Schott says.

The expansion in Hungary "will greatly benefit the global market and strengthen supply security for major pharmaceutical companies and contract manufacturing organizations," says Andreas Reisse, executive vice president of Schott's pharmaceutical business unit.

In May, the company announced a similar "double-digit euro" expansion at its plant in St. Gallen, Switzerland, to increase the production of its ready-to-use glass cartridges to administer pharmaceuticals.

In fiscal 2021, Schott invested 350 million euro in expansions. This year, it says it's planning an investment of 450 million euro, which would be a new high mark for the company. "We are laying the foundation for further profitable growth in the coming years," Jaafari says.

Schott is also moving ahead with strategic mergers and acquisitions. In September 2021, it announced the acquisition of Arizona-based diagnostics company AMI, building its expertise in the booming diagnostics market and strengthening its presence in one of its chief growth markets, the U.S.

Schott says it developed a growth culture internally, as its management has defined principles to succeed in the VUCA world. By applying them, "we were able to create a very resilient organization to overcome these challenges," Jaafari says.

Along with geopolitical risks, the VUCA world is filled with currency exchange rate fluctuations, rising energy, raw material, logistics costs, strained supply chains, and chip shortages. In just one example of the world's unpredictability, China experienced power shortages and resorted to rolling blackouts in 2021, further slowing an already disrupted supply chain.

HarbisonWalker International sources raw materials from around the world. *Credit: HWI*

Schott is planning to invest 450 million euro in global expansions in 2022. *Credit: Schott*

To try minimizing these challenges, Schott management created risk-mitigation plans that are in place. They also continually conduct market analyses and seek customer commitments before investing, Jaafari says.

HWI was also able to operate successfully in the volatile global environment by working to ensure its stability, Jackson says.

"We approach everything from a risk-mitigation standpoint," she says. "We attempt to identify the areas of volatility, and we have contingency plans, or risk-mitigation plans, in place to address those things. You can only control the things that are in your control."

NAVIGATING THE WORLDWIDE PANDEMIC

A global pandemic that continues to disrupt business around the world was not something most companies would have anticipated before 2020. Now, its impact needs to be included in any business plan.

Johannes Homa

The pandemic made travel impossible or inadvisable for months. For Lithoz that meant being nimble enough to find ways to install new 3D printer systems in other countries through remote means.

"We had a very good partnerships and well-trained people so we could overcome this," CEO Homa says.

In August 2021, with COVID-19 travel restrictions in place, Lithoz remotely installed a 3D printer at the University of Wollongong in Australia.

Working with the university and Australian 3D printing provider Objective 3D, the remote installation of the high-resolution ceramic printer was successful. It will be used by the Australian National Fabrication Facility Materials Node, which is based at the university, in a range of applications in the development of bioprinting hardware.

"It has become clear to us just how critical flexibility in the manufacturing world is," Homa says.

One of the main challenges of doing business in other countries, according to Homa, is understanding different cultures, and different ways of doing business. To do that, "We get local people in local places," Homa says.

In early 2021, Lithoz set up Lithoz China in Shanghai, a key strategic market in the manufacturing world, and currently the Lithoz base in Asia. To establish a presence in China to work with its customer and distributors there, Lithoz turned to EOS China, a 3D-printing technology firm that has operated in the Chinese market since 2013. With the collaboration, Lithoz was able to leverage the operations, service resources, and experience of EOS, a provider of 3D-printing technology to manufacturers around the world.

The first international expansion of Lithoz was to the United States. In 2016, the company began looking for someone to run its business in the U.S. and found Shawn Allan in New York. Allan is now vice president of Lithoz America, which not only handles sales and service but also develops specialty applications and materials for its customers, Homa says.

WORKFORCE AND CULTURE CHALLENGES

For bigger companies, workforce challenges were an issue for some time. Those challenges can be magnified when looking to grow into other countries. The key is having a strong company culture at the home base, says HWI's Jackson.

"It's been my experience if a company is looking to build operations in other parts of the world, the most successful ones are ones that ensure they have strong and consistent work practices and processes and good governance that they can embed and transfer that knowledge into the region they are attempting to grow into," she says. "The real challenge is how to export a company culture."

Ensuring that work practices are the same all over the world is important, Jackson says. "That's one of the biggest challenges in governance and building operations overseas," she adds.

The scarcity of talent is an ongoing problem both at home and abroad, and it is not expected to improve soon, the Deloitte report says.

Record numbers of unfilled jobs are expected to continue to limit higher productivity and growth, the report continues. Deloitte estimated a shortfall of 2.1 million skilled jobs by 2030 in the U.S. alone. To attract and keep talent, it recommended that manufacturers pair strategies such as reskilling with improving their brand and working with trade groups and others to improve the perception of manufacturing employment.

Lithoz partnered with EOS to establish operations in China. *Credit: Lithoz*

"It is challenging to find qualified, skilled, technical workers for our specialized industry," says Schott's Jaafari. Her company is addressing that by focusing on building up and driving its employer branding, and by collaborating with universities and trade schools on joint programs to attract future talent.

As manufacturers continue to rebound from the shock of the pandemic's emergence in 2020, they'll continue to confront new headwinds as they look to expand globally and work with suppliers around the world. Addressing them in an agile way could build resilience for today's challenges and for whatever obstacles tomorrow may bring.

Why manufacturers are eyeing growth

The following are excerpts from Deloitte's 2022 Manufacturing Industry Outlook, which was led by Paul Wellener, vice chairman and U.S. industrial products & construction leader at Deloitte LLP. Reprinted with permission. The full report can be found at https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/manufacturing-industry-outlook.html.

REMAKING SUPPLY CHAINS FOR ADVANTAGE BEYOND THE NEXT DISRUPTION

Supply chain resilience has been a thread through our recent outlooks, and the challenges are acute and still unfolding.

There is no mistaking that manufacturers face near-continuous disruptions globally that add costs and test abilities to adapt. Purchasing manager reports continue to reveal systemwide complications from high demand, rising costs of raw materials and freight, and slow deliveries in the United States. Transportation challenges are likely to continue in 2022, including driver shortages in trucking and congestion at U.S. container ports.

As demand outpaces supply, higher costs are more likely to be passed on to customers. Root causes for extended U.S. supply chain instability may include overreliance on low inventories, rationalization of suppliers, and hollowing out of domestic capability.

Supply chain strategies in 2022 are expected to be multipronged, according to our survey, including 41% of executives who report their companies will further add or diversify suppliers in existing markets.

Fifty-three percent of surveyed organizations plan to enhance data integration for supply-and-demand visibility and planning. Manufacturers are likely to continue to seek an upper hand by integrating operational data for more transparency and insight in operations. For example, centralizing a manufacturing control tower can bring together data from different facilities, production lines, and equipment and visualize dependencies on suppliers and effects on logistics.

Digital supply networks and data analytics can be powerful enablers for more flexible, multitiered responses to disruptions. The risks from not "connecting the dots" through available data can be significant: A lack of supply chain integration could stall smart factory initiatives for 3 in 5 manufacturers by 2025.

Beyond the data, reshoring of components or even final assemblies are likely to pick up steam as global sourcing and low-inventory models continue to diverge. Rising wages and transportation costs globally make nearshoring or onshoring more competitive at the same time that organizations look to avoid a repeat of 2020–21.

Twenty-four percent of manufacturing executives surveyed are considering moving operations closer to end customers in different regions in 2022. Some manufacturers already in the process of localizing supplier networks in response to tariffs may redouble efforts.

The United States–Mexico–Canada Agreement is likely to continue to drive nearshoring from China to Mexico. Along with trade, policymakers may further support domestic supply chains. The White House's 100-day supply chain review in 2021 recommended initiatives and investments to strengthen resiliency in supply chains for semiconductors, large-capacity batteries, critical minerals, and pharmaceuticals.

ACCELERATION IN DIGITAL TECHNOLOGY ADOPTION COULD BRING OPERATIONAL EFFICIENCIES TO SCALE

Manufacturers looking to capture growth and protect long-term profitability should embrace digital capabilities from corporate functions to the factory floor.

Smart factories, including greenfield and brownfield investments for many manufacturers, are viewed as one of the keys to driving competitiveness. More organizations are making progress and seeing results from more connected, reliable, efficient, and predictive processes at the plant. In 2022, 45% of manufacturing executives surveyed expect further increases in operational efficiency from investments in industrial Internet of Things (IIoT) that connect machines and automate processes.

Emerging and evolving use cases can continue to scale up from isolated in-house technology projects to full production lines or factories, given the right mix of vision and execution. For example, one heavy equipment manufacturer has been accelerating convergence of "man, machine, and method" by optimizing performance using sensors to track assets and connecting its machinery to the cloud to enable real-time insights on maintenance. Others have been transforming brownfield facilities with IIoT, robotics, automation platforms, and AI-enabled tools to support production.

U.S. manufacturers have room to run with advanced manufacturing compared to many competitors globally. The number of industrial robots as a share of manufacturing workers in the United States is below countries like Korea, Singapore, and Germany.

Half of executives we surveyed expect to increase operational efficiency in 2022 through their investments in robots and cobots [collaborative robots]. Investment in artificial intelligence technologies is also expected to see a compound annual growth rate (CAGR) above 20% through 2025.

Discrete manufacturing is among the top-three industries expected to invest most heavily in AI, primarily in quality management and automated preventive maintenance use cases. Advanced global "lighthouse" factories showcase the art of the possible in bringing smart manufacturing to scale. Foundational technologies such as cloud computing enable computational power, visibility, scale, and speed.

Industrial 5G deployment may also expand in 2022 with advances in technology and use cases. One global equipment manufacturer invested in multiple private 5G networks to enable automation and intelligence on factory floors as well as to support connected products. Use cases for mobility, such as communication with automated guided vehicles and mobile robots, are likely to complement other edge-computing applications, such as quality monitoring, to increase factory efficiency.

AODD PUMPS FOR IMPROVED CERAMICS PRODUCTION

In a critical worldwide market that is central to the manufacture of many everyday products, AODD pumps offer efficiency, reliability, and versatility that can result in optimized operations.

By Agostinho Rosa Neto

As we approach the bicentennial of the ceramics industry—large-scale ceramics production originated in Europe around 1830—many countries beyond the industry's traditional base in Europe and the United States are now involved with the manufacturing of these materials. Emerging markets in BRIC countries (Brazil, India, and China) came to lead the advancement of tile manufacturing in the past few decades, while Mexico and Turkey are setting the pace, along with China, in the production of sanitaryware.

The basic definition of ceramics—articles made from clay hardened by heat—no longer adequately expresses the slew of advances in ceramic manufacturing technology that helped transform the industry. Giant silos and ovens, printers that can emboss any type of image on a tile, and robots for the automated enameling of sanitaryware are some examples of this great transformation.

To store all these technologies, huge ceramics plants of more than 100,000 m^2 are required. Regardless of location or product produced, the ceramic manufacturing process relies on pumps to transfer very abrasive materials, solid-laden slurries, and corrosives. Finding a way to identify best efficiencies for the process—the highest flow rate with volumetric consistency and with the lowest air consumption, with a greater mean time between failure (MTBF)—is often the greatest challenge for ceramic plant operators.

In tile production, the engobe and glaze application process is key, where a pump's ability to provide the greatest MTBF makes the difference. In sanitaryware production, the molds must be filled as quickly and smoothly as possible, without the generation of air bubbles that can create craters in the pieces. In both cases, most of the pumps that are used have 2-inch and 3-inch (51-mm and 76-mm) inlets and outlets because they must deliver high flow rates with low air consumption.

Traditionally, manufacturers used two pump technologies in ceramic production. The first is the progressive cavity pump, which has several operational shortcomings in these applications, including an inability to consistently handle liquids with high levels of abrasives, which leads to increased maintenance cost; wear on expensive stators, rotors, and mechanical seals, which will eventually need to be replaced; and overall higher purchase, operating, and repair/replacement costs.

The second common pumping technology used is the peristaltic (hose) pump, which can deliver liquids with a high amount of abrasive particles. To do that, however, it may be necessary to oversize the pump because it needs run at low speed. There is also the issue of hoses wearing out rather quickly and needing replacement, meaning higher costs for maintenance and repair/replacement. Plus, there is the ever-present chance that a hose will burst during a production run. To safeguard against this event, the hose is outfitted with an alarm to warn of leakage, after which the pump will need to be shut down immediately or a catastrophic failure may result.

Nowadays, air-operated double-diaphragm (AODD) pumps are often used instead of these traditional pump technologies to transfer barbotine, the base material in tile and sanitaryware manufacturing. In general, it is the design and method of operation of AODD pumps that enable them to reliably outperform their progressive cavity and/or peristaltic (hose) pump cousins in ceramics production.

AODD DESIGN

The simple design of AODD pumps features few moving parts, which simplifies maintenance, while the seal-less construction results in fewer leaks, a critical consideration when handling very abrasive and solid-laden liquids that are prevalent in the manufacture of ceramics. AODD pumps are available in a choice of metal and plastic housing constructions, while a wide array of elastomers can be used in the diaphragms, some of which eliminate abrasion concerns. AODD pumps also possess the capability to move liquids with low air pressure. These features make for a powerful combination that offers many benefits to ceramics manufacturers.

Below are some examples of the operational capabilities of common sizes of AODD pumps and how they can be used in two key stages of the ceramic production process, which can require pumping pressures of up to 125 psi (8.6 bar).

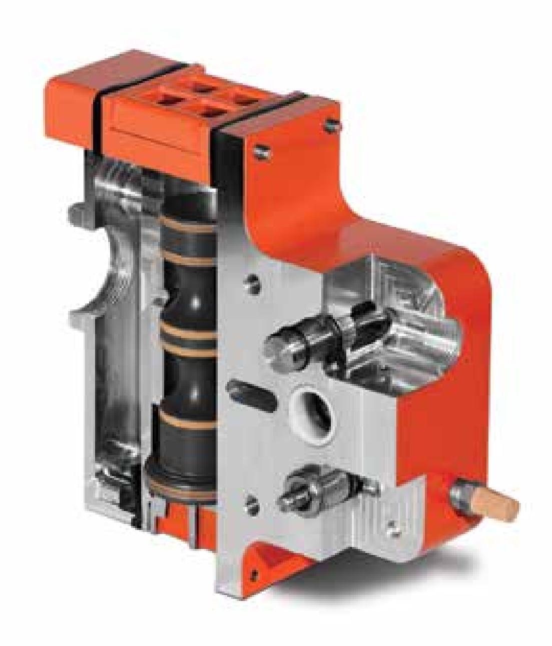
Painting and enameling booth

- 1 inch (26 mm): A bolted metal configuration allows this pump to achieve flow rates up to 56 gpm (212 L/min), depending on the diaphragm type, with the ability to handle solids as large as ¼ inch (6.4 mm)
- 1½ inch (38 mm): This larger bolted metal AODD pump can reach flow rates up to 135 gpm (510 L/min), again depending on the diaphragm type, with the ability to handle solids as large as ¼ inch (6.4 mm). An advanced liquid-chamber design allows the creation of these higher flow rates.

Barbotine transfer

- 2 inch (51 mm): This bolted metal configuration enables the pump to achieve flow rates up to 181 gpm (685 L/min), depending on the diaphragm type, with the ability to handle solids as large as ¼ inch (6.4 mm)
- 3 inch (76 mm): The larger inlet/outlet size of this bolted metal pump can achieve flow rates up to 271 gpm (1,026 L/min), depending on the diaphragm type, with the ability to handle solids as large as ½ inch (12.7 mm)

The versatility of these AODD pumps also means they can be used in many other applications within a ceramic plant, such as to wash/clean sanitaryware molds with corrosive chemicals, water treatment, and filter press.



The Wilden Pro-Flo SHIFT Air Distribution System revolutionizes AODD pump operation through a design that reduces air consumption by up to 60% when compared to competitive models. *Credit: Wilden*

AODD OPERATIONAL CAPABILITIES

A closer look at the built-in operational capabilities of AODD pumps indicates three main advantages for use in ceramic applications.

Optimized internal flow paths. An AODD pump with an optimized internal flow path will minimize the change of direction of the liquid that is being transferred, which reduces its velocity and the abrasive effect of any suspended solid. This optimization also helps the flow stay laminar, which keeps solids in the current line, reducing the abrasive effect. This new design allows the flow rate to be increased while still running the pump at lower strokes per minute, which allows a smooth, laminar flow that reduces the abrasive effect even more. The liquid path is also designed for longer diaphragm life, minimizing the contact between the diaphragm and the liquid chamber. These pumps are also easier to maintain through the elimination of unnecessary fasteners that can be hard to reach. The manifolds are also interchangeable, allowing modifications to be made quickly and easily.

The latest additions to Wilden's family of diaphragm models are the Chem-Fuse Integral Piston Diaphragm and EZ-Install Diaphragm, both of which deliver improved performance through higher levels of reliability, service life, and efficiency. *Credit: Wilden*

High-efficiency air distribution systems (ADSs). Next-generation ADSs optimize air usage through a breakthrough design that reduces air consumption by as much as 60% through the elimination of the wasteful loss of air to the atmosphere at the end of each pump stroke. Many ceramic plants use a huge number of 3-inch (76-mm) pumps that consume a large amount of air. Therefore, reducing air consumption by 60% is a tremendous benefit.

State-of-the-art diaphragm designs. There are also some recent advances in the materials and designs used for AODD pump diaphragms, all of which can improve performance and reliability in any severe liquid-handling application. Two of the most recent advancements in this area are

- Integral piston diaphragms (IPD): These diaphragms are designed to deliver an elevated level of performance, which makes them ideal for use in high-volume ceramics manufacturing applications. Most significantly, the IPD design eliminates potential leak points at the outer piston, along with outer-piston abrasion that can compromise diaphragm life, especially when pumping abrasive fluids. IPDs are also easier to clean than traditional diaphragm models, which makes for faster changeovers within product runs.
- Quick-install diaphragms: These diaphragm models feature a unique convolute shape that do not require inversion of the diaphragm during installation. This feature allows for quick, easy installation with minimized risk of injury, making them a convenient like-for-like replacement for traditional diaphragms with corresponding reductions in pump downtime.

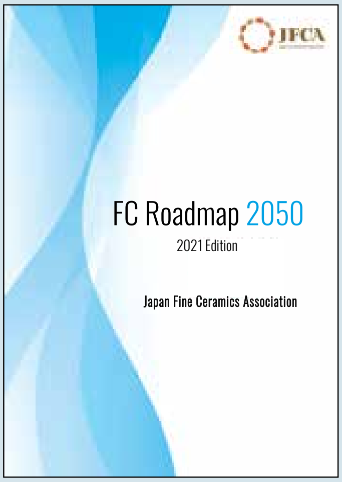
CONCLUSION

To meet the diverse, demanding, and critical needs of the ceramics industry, a complete roster of AODD pump designs, many of which feature cutting-edge advanced technology, can provide improved efficiency, reliability, and safety, all of which help maximize performance in the various stages of the ceramics manufacturing process.

ABOUT THE AUTHOR

Agostinho Rosa Neto is regional manager of South Latin America for Wilden, a leading manufacturer of air-operated double-diaphragm pumps. Contact Neto at agostinho.rosaneto@psgdover.com.

FC ROADMAP 2050



The Japan Fine Ceramics Association (JFCA), an organization comprising more than 100 corporate members with a mission to promote development of the fine (advanced) ceramics industry, recently published an English-language version of its 2021 "FC Roadmap 2050."

The first edition of this roadmap published in 2016. The purpose is to investigate advanced ceramic technologies and products that will meet increasingly diverse needs of society, market, and industry by the year 2050, and to identify technological developments needed over the coming three decades to realize these needs.

"Facing globally grand challenges, such as climate change, energy, sustainability, communications, and health care, we need new ceramic technologies to provide new solutions to them. JFCA developed this roadmap to anticipate the coming gap in advanced ceramic materials available and advanced ceramics that will be needed," says Tomosaburo Yano, executive director of JFCA.

The roadmap consists of the core report and a supplement. The core part comprises roadmaps on key technologies for advanced ceramics to reach 2050 goals, based on results of interviews with numerous researchers, engineers, technologists, industrialists, and other specialists from industry, universities, and research institutions in fields related to ceramic technologies.

Table I. Six primary and three crosscutting fields with one to five themes each. *Credit: JFCA*

	Fields	Themes		
Primary Fields	Transportation	Motive Power	Power Supply & Vehicle	Aircraft, e-VTOL, Space plane
	Telecoms	Telecom Infrastructure	Communication Terminals 1	Communication Terminals 2
	Medical	Advanced Medicine	Implant	Prevention, Remote & Home Healthcare
	Energy	Clean Fuel	Solar, Thermoelectric, Energy Harvesting	Wind, Ocean, Geothermal, Hydro
		Biomass & Thermal Power	Nuclear Energy	
	Infrastructure	Electricity, Gas & Water	Information & Communication	
	Environment	CCUS & Purification	Resource Recycling (exc CCUS)	Energy Saving
		Smart Agriculture, Forestry & Fisheries		
Cross-cutting Fields	Sensor	Pressure, Acceleration, Sonic Wave	Light, Electromagnetic Wave & Magnetism	Gas, Biological Element & Electrical Potential
	Battery	Automotive	Storage Batteries	Fuel Cells
	Semiconductor	Materials & Devices		

Table II. Major innovations in advanced ceramics over the next three decades. *Credit: JFCA*

Category	Major innovations
Application	H_2 energy cycle, CO_2 separation, Water purification, Electronic, Communication, Transportation, Medical, *etc.*
New materials	Materials search via. MI/AI, Polymer-integrated ceramics, Self-crack-healed ceramics, *etc.*
Properties improvement	Multi-functionality, Harsh environment resistance, New properties of ceramic/non-ceramic composites, *etc.*
Structure control	Atomic-level control, Precise surface/interface control, Integrating dissimilar phases, Critical defect control, *etc.*
Processing	Sensor/monitor-controlled manufacturing, Zero-waste production, Recycling/reusing, MI/AI-incorporated, Advanced 3D printing, *etc.*
Analysis/ Evaluation	Advanced modeling/simulation, Better prediction via. MI/AI, Visualization/monitoring of process, *etc.*

CORE ROADMAP FEATURES

- Covers six primary fields (transportation, telecommunications, medical care and welfare, energy, infrastructure, and environment) as well as three device technologies for crosscutting fields (sensors, batteries, and semiconductive materials and devices).
- Addresses one to five relevant themes in each field, adding up to 27 themes, or roadmaps, in the nine fields, as shown Table I.
- Organized into three levels: market, product, and technology. "Market" describes overall trends, market size, technology needs, etc., in each of the primary themes over the next three decades. "Product" addresses performance, functionality, quality, etc., that the markets will demand. "Technology" discusses potential approaches to realize the products.
- Demonstrates a variety of products and technologies in which ceramics play key roles, so that readers can identify the significance of ceramics.

ROADMAP SUPPLEMENT

The supplement presents a survey of opinions of researchers and engineers from around the world concerning the future visions identified in the core roadmap. The questions asked of experts include

- Major issues that will affect society over the next three decades.
- Major application fields that will be influential to the advanced ceramics industry over the next three decades.
- Key technologies that will be necessary for development of ceramics over the next three decades.
- Major innovations in advanced ceramics over the past four decades.
- Major innovations in advanced ceramics over the next three decades (Table II).
- Driving force necessary for the future development of advanced ceramics industry, e.g., society/research system, human resource development, and research/technical issues.

The full report is 64 pages long and on sale now for $3,000. For further information or to purchase, contact Keiko Koyanagi at koyanagi@jfca-net.or.jp.

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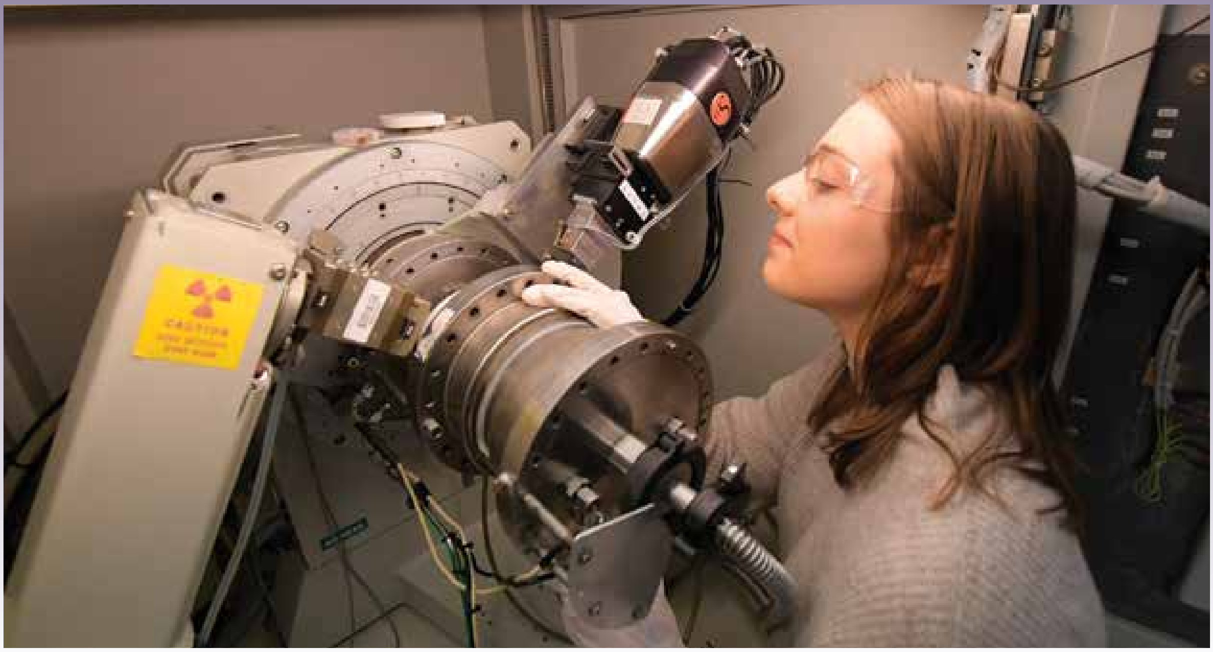

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Calendar of events

June 2022

21–22 ceramitec 2022 – Munich, Germany; https://www.ceramitec.com/en/trade-fair/information/exhibition-sectors

28–30 2022 FIRE-ECerS Summer School: Eco-Design of Refractories – RWTH Aachen University, Germany; https://ecers.org/fire-ecers-summer-school

28–Jul 2 ICG Workshop for new researchers in glass science and applications – Berlin, Germany; https://icglass.org

July 2022

3–8 ➨ ICG Annual Meeting 2022 – Berlin, Germany; https://ceramics.org/event/icg-annual-meeting-2022

10–14 International Congress on Ceramics (ICC9) – Krakow, Poland; https://ceramics.org/event/international-congress-on-ceramics-icc9

24–28 Pan American Ceramics Congress and Ferroelectrics Meeting of Americas (PACC-FMAs 2022) – Hilton Panama, Panama City, Panama; https://ceramics.org/PACCFMAs

August 2022

28–Sept 1 ➨ 11th International Conference on High Temperature Ceramic Matrix Composites – Ramada Plaza Jeju Hotel, Jeju, Korea; https://www.ht-cmc11.org

29–31 ➨ 7th Ceramics Expo co-located with Thermal Technologies Expo – Huntington Convention Center, Cleveland, Ohio; https://ceramics.org/event/7th-ceramics-expo

September 2022

7–9 5th Energy Harvesting Society Meeting – Hyatt Regency Baltimore, Baltimore, Md.; https://ceramics.org/event/5th-energy-harvesting-society-meeting

October 2022

9–12 ACerS 124th Annual Meeting with Materials Science & Technology 2022 – David L. Lawrence Convention Center, Pittsburgh, Pa.; https://ceramics.org/MS&T22

12–13 AM Ceramics 2022 – Fraunhofer IKTS, Winterbergstraße, Dresden, Germany; http://www.am-ceramics.dkg.de

30–Nov 3 7th International Conference on Electrophoretic Deposition – LaFonda on the Plaza, Santa Fe, N.M.; http://engconf.us/conferences/materials-science-including-nanotechnology/electrophoretic-deposition-vii-fundamentals-and-applications

November 2022

6–8 Total Solutions Plus (TPS) – Hyatt Regency, Indian Wells, Calif.; https://www.ctdahome.org/tsp/2022/index.shtml

30–Dec 2 ASEAN Ceramics – IMPACT Forum Hall 4, Bangkok, Thailand; https://aseanceramics.com/thailand/#thai-about

December 2022

7–9 ➨ 7th Highly-functional Ceramic Expo Tokyo – Makuhari Messe, Chiba, Japan; https://www.ceramics-japan.jp/en-gb.html

January 2023

17–20 Electronic Materials and Applications 2023 (EMA 2023) – DoubleTree by Hilton Orlando at Sea World Conference Hotel, Orlando, Fla; https://ceramics.org/EMA23

May 2023

17–19 ➨ 8th Highly-functional Ceramic Expo Osaka – INTEX Osaka, Osaka, Japan; https://www.ceramics-japan.jp/en-gb.html

22–27 47th International Conference and Expo on Advanced Ceramics and Composites (ICACC 2023) – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla; https://ceramics.org/ICACC23

27–31 The International Conference on Sintering 2023 (Sintering 2023) – Nagaragawa Convention Center, Gifu, Japan; https://www.sintering2021.org

September 2023

26–29 ➨ Unified International Technical Conference on Refractories (UNITECR) with 18th Biennial Worldwide Congress on Refractories – Kap Europa, Frankfurt am Main, Germany; https://unitecr2023.org

July 2024

14–19 International Congress on Ceramics – Hotel Bonaventure, Montreal, Canada; www.ceramics.org

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- Glass science
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- Phase equilibria

Candidates with expertise in one or more of the above areas plus experience with bioactive ceramics or materials informatics are also encouraged to apply.

Further information can be found at https://wp.me/aar57d-GEs.

The editor is a remote part-time position. Candidates should email a cover letter detailing your interest and your strongest areas of expertise for editorial decision making, along with your brief CV, by **June 25, 2022**, to Jonathon Foreman at jforeman@ceramics.org.

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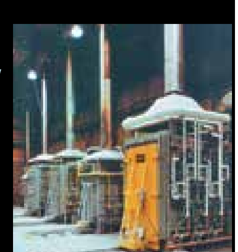

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