

AMERICAN CERAMIC SOCIETY

bulletin

emerging ceramics & glass technology

JUNE/JULY 2026

Supporting ceramic industries through training and collaborations

Also inside...

EMERGING PROFESSIONALS



Turning to the future.

What are your firing needs, and are you getting the custom kiln design you require?

For more than a century Harrop has worked hard to design, build, and service custom kilns that fit your specific requirements.

We don't stop there. If you aren't sure what you need, we can help. Our laboratory can run tests to help identify your process boundaries. Through our toll firing facility, we can help to further define the equipment/processing combination that works best for your material. And if you are not ready for a new kiln, we can toll fire your material to meet your production needs.

How can we help you?



www.harropusa.com

1.614.231.3621

contents

June/July 2026 • Vol. 105 No. 5

feature articles



From Missouri clay to global impact: A century of ceramic engineering at Missouri S&T
by David Lipke and Charmayne Lonergan



Multimaterial research as the key to innovation in ceramic additive manufacturing
by Raul Bermejo, Josef Schlacher, Serkan Nohut, Martin Schwentenwein, and Johannes Homa



From campus to commerce: Four things every academic inventor needs to know
by Randy B. Hecht



Preparing a data-aware workforce: Applied data science at Case Western Reserve University
by Hein Htet Aung



Tackling SiC manufacturing challenges for a sustainable future
by Joshua Robinson, Tekin Ozdemir, and David Fecko



Durable and programmable metasurfaces enabled by phase change materials
by Cosmin-Constantin Popescu

departments

News & Trends 3
ACerS Spotlight 10

industry

Business and Market View 7
Hydrogen fuel cell recycling and AI's market impact
by BCC Publishing Staff
Industry Insights 8
How standards can speed the development of ceramic additive manufacturing
by David Holthaus

columns

Journal Highlights 6
Supporting ceramic industries through advances in tile production
by Brittney Hauke

meetings

Upcoming meetings 44

resources

Calendar 45
Classified advertising 46
Ad index 48

Cover image credit

Billion Photos / Shutterstock

36 EMERGING PROFESSIONALS

The "Emerging Professionals" section showcases young ACerS members along every step of their journey, from undergraduates to recent graduates.

INTRODUCTION

Welcome to the 'Emerging Professionals' issue
by Randi Swanson 36

RESEARCH ARTICLES

Experiential learning: Developing the next generation of engineers by Ryan Eaton 37

Vitrification of nuclear waste: The case of chlorine
by Yanis Daoud 38

Empowering emerging researchers: Cements Division Rising Star Webinar Series
by Alessandra Fujii Yamagata 39

SCIENCE FOR SOCIETY

One small tweak to the lens of materials research, one giant leap for mankind
by Rishabh Kundu and Ryan C. Eaton 40

Microwave firing: Inspiring young scientists through rapid ceramic demos
by Grace Dunham 41

Shaping materials science through policy engagement by Hossein Libre 41

FUTURE FOCUS

Hope and resilience: The unbroken thread of science
by Kartik Nemani 42

Glass Strengthening Competition levels up student learning at conferences
by Lisa McDonald 43

Editorial and Production

Lisa McDonald, Editor

lmcDonald@ceramics.org

Michelle Martin, Production Editor

Helen Widman, Content Coordinator

Cyndy Griffith, Graphic Designer

Editorial Advisory Board

Henry Colorado, Universidad de Antioquia

Scott McCormack, University of California, Davis

Daniela Messina, RHI Magnesita

Lavina Backman, Naval Research Laboratory

Somnath Mandal, Vesuvius

Joseph Shi, Micromaterials LLC

Customer Service/Circulation

ph: 866-721-3322 fx: 614-899-6109

customerservice@ceramics.org

Advertising Sales

National Sales

Mona Thiel, National Sales Director

mthiel@ceramics.org

ph: 614-794-5834

Executive Staff

Mark Mecklenborg, Executive Director and Publisher
mmecklenborg@ceramics.org

Amanda Engen, Director of Publications and Strategic Programs
aengen@ceramics.org

Marcus Fish, Director of Development, Ceramic and Glass Industry Foundation
mfish@ceramics.org

Michael Johnson, Director of Finance and Operations
mjohnson@ceramics.org

Andrea Ross, Director of Meetings, Membership, and Marketing
aross@ceramics.org

Erica Zimmerman, Executive Office Manager
ezimmerman@ceramics.org

Officers

Mario Affatigato, President

Shibin Jiang, President-elect

Monica Ferraris, Past President

Mark Peters, Treasurer

Mark Mecklenborg, Secretary

Board of Directors

Alexandra Navrotsky, Director 2023–2026

Dileep Singh, Director 2023–2026

Todd Steyer, Director 2023–2026

Christopher Berndt, Director 2024–2027

Ruyan Guo, Director 2024–2027

Palani Balaya, Director 2025–2028

Yutai Katoh, Director 2025–2028

Yiquan Wu, Director 2025–2028

Rodney Trice, Director 2024–2027

Stephen Freiman, Parliamentarian



<http://bit.ly/acerstwitter>



<http://bit.ly/acerslink>
<https://bit.ly/bulletinlink>



<http://bit.ly/acersfb>

As seen on Ceramic Tech Today...



Credit: LifeCollectionPhotography / Shutterstock

Azulejos: A Portuguese tradition influenced by globalization

The beautiful blue and white tiles known as azulejos are a common sight in Portugal, but these tiles trace their origin and design to cultures around the world.

Read more at <https://ceramics.org/azulejos>

Also see our ACerS journals...

Emerging machine learning strategies for digital processing and additive manufacturing of advanced ceramics

By S.T. Monteiro, I.A.T. Monteiro, J.R. Fernandez-Gamboa, et al.

International Journal of Applied Ceramic Technology

Research on ceramic slurries for near-net-shape large-sized silicon carbide mirrors via vat photopolymerization

By S. Zhou, S. Li, C. Hu, et al.

International Journal of Applied Ceramic Technology

Enhanced aqueous tape casting slurries via coating and modification for silicon nitride ceramic substrates

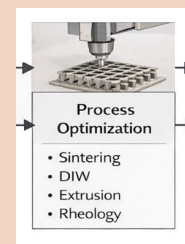
By Y. Lu, Y.L. Song, R.F. Jia, et al.

International Journal of Applied Ceramic Technology

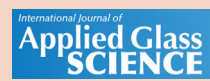
Mechanical and dielectric properties of porous slip cast silicon nitride: Yttrium oxide-aluminum oxide sintering aids

By A.R. Kimery, M.A. Thompson, K.S. Caruso, et al.

International Journal of Applied Ceramic Technology



Credit: Monteiro et al., ACT



Read more at <https://ceramics.org/journals>

American Ceramic Society Bulletin is the membership magazine of The American Ceramic Society. It covers news and activities of the Society and its members and provides the most current information concerning all aspects of ceramic science and technology, including R&D, manufacturing, engineering, and marketing. American Ceramic Society Bulletin is published monthly, except for February, July, and November. Subscription included with The American Ceramic Society membership. Institutional subscription rates can be found online at www.ceramics.org or by contacting customer service at customerservice@ceramics.org.

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 these sections. Publication of articles does not constitute endorsement, acceptance, or approval of the data, opinions, or conclusions of the authors on the part of the Society or its editors.

POSTMASTER: Please send address changes to American Ceramic Society Bulletin, 470 Olde Worthington Road, Suite 200, Westerville, OH 43082-8985. Periodical postage paid at Westerville, Ohio, and additional mailing offices. Allow six weeks for address changes.

American Ceramic Society Bulletin. ISSN (Print): 0002-7812; ISSN (Online): 1945-2705. ©2026. Printed in the United States of America.

ACSBA7, Vol. 105, No. 5, pp. 1–48. All feature articles are covered in Current Contents.

news & trends

New Mizzou Center focuses on the impact of energy infrastructure on rural America

Across the United States, farmland is disappearing as the demand for renewable energy and artificial intelligence increases. But although passions run high on this topic, there is a lack of information on the economic, environmental, health, and cultural consequences of these projects on rural communities. To fill this gap, the University of Missouri announced the Center for Rural Energy Security (CRES) in January 2025.

CRES is a partnership between the university's College of Agriculture, Food and Natural Resources and the College of Arts and Sciences. Formally launched in Q3 of 2025, CRES conducts indepen-

dent, nonpartisan research and analysis to help inform decision makers and policy experts on rural energy security matters.

"There's a large amount of infrastructure that has to be built and most of that ends up crossing rural communities, which impacts farmers, impacts residents, impacts the economies of local communities," says Michael Sykuta, director of CRES and associate professor of applied economics at the University of Missouri, in a news release. "And quite frankly, despite all of the work that is done, there's not a lot of work actually examining systematically what the consequences of these investments are."

A multidisciplinary team of University of Missouri scholars is providing guidance for CRES's research programs.

This team includes economists, legal experts, sociologists, and even a historian. As of September 2025, the Center is conducting three research projects:

- **Economic effects of large-scale wind and solar projects.** These effects are being investigated in terms of county GDP, county employment, median income, and other factors that are segregated by industry sectors, using data from all wind and solar installations in the U.S. at the county level.



TevTech
Materials Processing Solutions

CUSTOM DESIGNED VACUUM FURNACES FOR CHEMICAL VAPOR DEPOSITION

- Unsurpassed thermal and deposition uniformity
- Exceptional Automated control systems providing consistent quality product
- Pilot Scale systems available for rapid product development



Systems installed and operating in Asia, U.S. and Europe



100 Billerica Ave
Billerica, MA 01862
sales@tevtechllc.com
Call (978) 667-4557

www.tevtechllc.com

- **Residential electrification and arrearages.** CRES is using customer data provided by a large investor-owned utility electric company in a northern climate to analyze differences in arrearage patterns. (Arrearage refers to the total amount of debt accumulated when customers fall behind on their electricity payments.)
- **County zoning laws for large-scale renewables.** Data from all 114 counties in Missouri were collected regarding zoning boards and regulations for large-scale renewables, including permitting and ordinances, with the ultimate goal to create an interactive map.

CRES was initially funded by the Missouri Farm Bureau Foundation for Agriculture, whose membership is made up of agriculture producers across the state. Other stakeholders are being invited

to join CRES, including renewable energy companies, investor-owned utilities, and various other industries.

All of CRES' work will be peer-reviewed, and every academic paper will have a policy white paper associated with it to show the relevance to community stakeholders and policy makers. Semiannual research roundtables will be held to provide stakeholders early access to the research and to determine future direction for projects. Stakeholders will also have opportunities to work with graduate and undergraduate students, with the goal of developing a pipeline of experts.

"What's exciting is, for the first time ever, there's going to be a think tank here in the country that's going to be focused on the issues that we face in rural America," Sykuta says in the news release. ■

Boca Bearing founder helps develop the World Power Transmission Association

Florida-based Boca Bearing Company founder Allen Baum has become a founding member of the World Power Transmission Association (WorldPTA). WorldPTA defines itself as "the first and only open global association connecting power transmission industries entire value chain to drive collaboration, innovation, and growth." Read more: <https://www.bearing-news.com>

Hindalco and industry leaders present India–UK/Europe Green Corridor initiative

In early 2026, a group of senior leaders across the metals and mining, energy, clean mobility, circularity, finance, and clean tech sectors met the President of India Smt. Droupadi Murmu to help advance the vision of the India–UK/Europe Green Corridor. This initiative is designed to increase sustainable trade, circular economy solutions, clean mobility, and industrial decarbonization. Read more: <https://www.hindalco.com/media/press-releases>

NETZSCH Group subsidiary awarded EcoVadis Gold

NETZSCH Lohnmahltechnik GmbH ranked in the 95th percentile worldwide in the EcoVadis Sustainability Rating. The rating confirms a solid and verified sustainability performance across all relevant ESG dimensions. Read more: <https://grinding.netzsch.com/en/news>

SINTX Technologies announces first successful implant surgery in a human

SINTX Technologies announced the first successful human implant surgery with its FDA-approved SINAPTIC Foot & Ankle Osteotomy Wedge System. Read more: <https://investors.sintx.com/news-events/news-releases> ■



mo·sci
Your Vision, Our Glass

A partner for your glass manufacturing needs

DENTAL
Materials for toothpaste, dental implants, white-label bone grafts, and fluorosilicate fillers used in glass ionomer cements.

HEALTHCARE
White-label orthobiologic solutions and engineered glass materials for radiation delivery and minimally invasive surgical applications.

INDUSTRIAL
Precision-engineered glass microspheres designed for bond line spacing and sealing, with advanced surface-coated options available.

DEFENSE
Glass solutions for hermetic sealing and thermal protection, from an ITAR-registered partner.

ENERGY
Engineered glass for photovoltaic (PV) technologies and metal oxide varistors (MOVs).

CUSTOM SOLUTIONS
Our Pilot-to-Product roadmap provides a clear, structured pathway from initial idea to successful commercialization of custom glass solutions.

Contact us at sales@mo-sci.com to see how we can help with your next project.



Deltech Furnaces

YOUR INDUSTRY

YOUR FURNACE

OUR EXPERTISE

Hazardous locations certifications
NFPA86, UL1203, C1D2
(Groups A,B,C,D and G)

www.deltechfurnaces.com



An ISO 9001:2015
certified company



ASME NQA-1 2008
Nuclear Quality
Assurance



Control systems are
certified by Intertek
UL508A compliant

Supporting ceramic industries through advances in tile production

Traditional ceramic products such as tiles continue to make up most of the manufactured ceramics market. Yet even though the production of these products is well established, manufacturers still struggle with the challenge of shrinkage during drying and sintering processes due to the colloidal nature of clay. Shrinkage can cause structural integrity issues and lower dimensional accuracy, so minimizing the amount of shrinkage that occurs is a goal in the ceramics industry.

Fluxing agents, such as feldspars, can help combat shrinkage by creating a glassy phase at low temperatures, which provides a rigid and inert skeleton within the clay body to limit shrinkage and enhance the mechanical strength. However, growing concerns about sustainability in the ceramics industry means manufacturers are exploring environmentally friendly alternatives to current common fluxing agents.

Using soda–lime–silica (SLS) glass as a fluxing agent in ceramic tile production is one option being explored. The working point of SLS glass is a few hundred degrees lower than what is needed for traditional feldspars, reducing the energy consumption. SLS can also be recycled multiple times, making it an abundant material that can be used in the ceramics industry.

The article “Upcycling waste glass into ceramic tiles: Eco-design for a circular manufacturing route” by Hamidivadigh and Parval evaluated using SLS as a partial replacement for feldspar flux and investigated how the glass content influences the microstructure and properties of the final ceramic tiles (Figure 1).¹ The authors found that incorporating up to 15 wt.% SLS enhanced densification, reduced open porosity and water absorption, and improved the mechanical performance. However, at higher glass

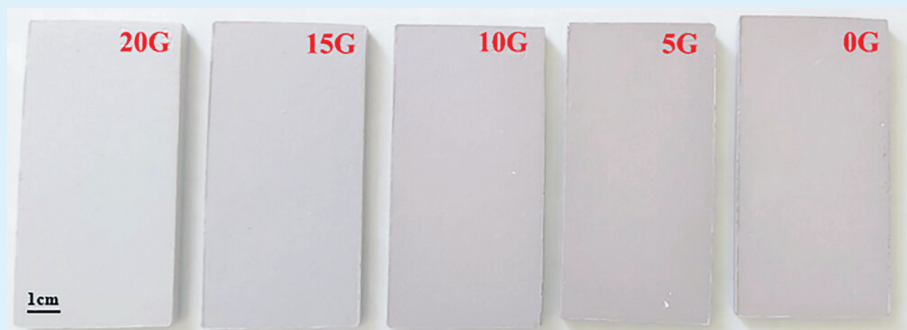


Figure 1. Final tile samples with varying amounts of waste glass.

content, there was gas entrapment, more shrinkage, and a lowering of the structural integrity. The authors also performed thermal and phase analysis and suggested that future work include an investigation of different SLS compositions and fluctuating fire temperatures, which are more realistic in industrial settings.

Another area of research related to ceramic tile processing is the type of sintering method used. There are a variety of field-assisted sintering techniques such as spark plasma sintering, microwave sintering, and flash sintering (FS). FS uses an enhanced electric field applied during heating that enables the rapid densification of a ceramic body within seconds. This densification occurs much faster and at temperatures that are several hundred degrees lower than conventional firing.

With FS, there are many parameters that need to be tuned, such as the applied electric field, furnace temperature, and current density. In the article “Processing–property mapping of flash-sintered wall tile bodies,” Çetinkaya et al. studied the combined effects of those parameters on the sintering behavior of wall tile samples.² Three different electrical fields, two different temperatures, and three current densities were used to study the FS behavior, phase formation, and microstructural evolution of the tiles. The authors also generated a

processing–property map showing the relationship between bulk density and water absorption under different processing conditions.

Their data confirmed that Joule heating plays an important role in sustaining the FS behavior and demonstrated the power density ranges and optimum electrical conditions needed to successfully flash sinter ceramic wall tiles. The authors also linked these parameters to the phase development, microstructure, and physical properties. They suggested that future work could involve scaling the FS approach to full-sized ceramic tiles.

These articles are just two examples of the important research being reported in ACerS journals that supports the ceramics industry. To read more, visit the ACerS journals homepage at <https://ceramics.onlinelibrary.wiley.com>.

References

- ¹F. Hamidivadigh and A. Parval, “Upcycling waste glass into ceramic tiles: Eco-design for a circular manufacturing route,” *Int. J. Appl. Ceram. Technol.* 2026, 23(2): e70163.
- ²Z. Çetinkaya et al., “Processing–property mapping of flash-sintered wall tile bodies,” *Int. J. Appl. Ceram. Technol.* 2026, 23(2): e70178. ■

Hydrogen fuel cell recycling and AI's market impact

The market for hydrogen fuel cells is growing rapidly as hydrogen technology matures and companies look to lower the carbon footprint of operations.

But with the growing demand for fuel cells comes the need to manage the market effectively. Specifically, high-value platinum group metals can account for 40% to 60% of fuel cell stack costs, so recovering these metals after a cell is retired from service helps mitigate material supply risk and overall system cost.

Two recent BCC Research reports investigate the nascent hydrogen fuel cell recycling market and how it will support development of the hydrogen ecosystem.

Market statistics and recycling approaches

The global hydrogen fuel cell recycling market was valued at \$358.7 million in 2024 and is expected to grow at a compound annual growth rate (CAGR) of 14.5% to reach \$762.4 million by the end of 2030.

Both chemical (hydrometallurgy) and thermal (pyrometallurgy) processes are used to recycle hydrogen fuel cells. However, the chemical process segment held the largest market share in 2024 due to its ability to selectively and efficiently recover high-purity, valuable materials (Table 1). Other emerging recycling approaches in the hydrogen fuel cell recycling industry include

- **Ultrasound-based disassembly:**

This method uses sound waves to separate layers of the membrane electrode assembly and recover up to 92% of the platinum from hydrogen fuel cell stacks. It was developed by British sustainable technologies company Johnson Matthey and the University of Leicester in 2025.

Table 1. Global market for hydrogen fuel cell recycling, by recycling process, through 2030 (\$ millions)

Recycling process	2024	2025	2030	CAGR % (2025–2030)
Chemical	203.4	222.5	460.4	15.7
Thermal	126.9	136.2	258.0	13.6
Others	28.4	29.4	44.0	8.4
Total	358.7	388.1	762.4	14.5

- **Electrochemical dissolution and selective metal separation:**

This novel recycling method uses controlled electric potential to dissolve catalyst layers and separate valuable metals from fuel cell materials, thereby achieving high platinum group metals recovery with minimal secondary waste.

- **Biometallurgy:**

This technique, still in its infancy, uses microorganisms to leach metals from spent fuel cell components under mild conditions.

- **Digital traceability and closed-loop recycling platforms:**

Digital tracking systems integrate material traceability with recycling optimization, allowing recycled platinum group metals to be directly returned into the manufacture of new fuel cells.

AI's impact on hydrogen fuel cell recycling

Artificial intelligence is playing an increasingly important role in the development of hydrogen fuel cell recycling from aspects of material recovery efficiency, process optimization, and lifecycle analysis. Two examples of AI-assisted recycling processes include

- **Preprocessing predictions:**

Machine learning models were trained using historical recycling and spectroscopy input together with process conditions to predict the concentration of platinum group metals, suitable leaching conditions, and pathways for separation. These models resulted in lower resource consumption.

- **Clarifying end-of-life protocols:**

AI-driven predictive analytics and digital twin models were used to evaluate solid oxide fuel cell stack degradation, residual material worth, and optimal recycling paths to maximize material recovery while minimizing energy use.

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 ereister@bccresearch.com.

Resources

BCC Publishing Staff, "Global hydrogen fuel cell recycling market," BCC Research Report FCB079A, February 2026. <https://bit.ly/February-2026-fuel-cell-recycling>

BCC Publishing Staff, "AI impact on hydrogen fuel cell recycling market," BCC Research Report AIT109A, March 2026. <https://bit.ly/March-2026-AI-hydrogen> ■

How standards can speed the development of ceramic additive manufacturing

Additive manufacturing (AM) of ceramics is a promising technology that has already demonstrated the ability to speed the prototyping of parts, enable the production of complex geometries, reduce the waste of materials, and save money on tooling costs. Despite this potential, ceramic AM is at a much earlier stage than the technology's application to the manufacturing of polymer and metal products.

The slower development and scale-up of ceramic AM is due to several aspects of the ceramic manufacturing process, including the need for specialized raw materials; the complex sintering process; and the unique properties of ceramics, such as brittleness. These characteristics may also have slowed the creation of international standards for ceramic AM, whose development could encourage the wider use of the technology.

"The issue is that we're lacking standards, and that runs from academia all the way through to industry," says Ollie Osborn in an interview. Osborn is a senior ceramic scientist at Lucideon, an international materials technology consultancy based in Stoke-on-Trent, U.K. He has talked to numerous colleagues in industry and academia about ceramic AM, and he says everyone agreed that the dearth of standards for this technology is holding back its wider application.

International manufacturing standards are critical to the advancement and application of technologies as they bring consensus around consistency, reliability, and scalability. Standards act as a common language for innovations and are considered essential for moving technologies from experimental stages to widespread industrial use.

The importance of standards in commercializing innovations was shown by

three European scientists in their 2024 open-access paper, "Initiation and evolution of systemic innovations: Patterns and interactions in the emergence of additive manufacturing technologies."¹ Their main research question was: How do systemic innovations emerge, through the interaction of system components and multiple technologies? They specifically examined the "particularly lucrative manufacturing technological opportunity" of ceramic AM because it is an innovation that requires the coordination and development of multiple technologies to succeed.

The researchers concluded that while competition among private businesses and research organizations may lead them to avoid cooperation during the early stages of technology development, sharing knowledge is ultimately beneficial.

"The emergence of systemic innovations may be improved through more coordinated inter-technology knowledge transfers between the parallel technology development paths," they write.

International standards are a key platform for sharing because they provide a recognized, trusted forum for collaborating, sharing data, comparing results, validating procedures, and enabling repeatable production techniques.

"When you start to ask why this technology is struggling to find industrial application, you realize that we are starting to hit a bit of a barrier where the lack of standards means that the work being done in the field is not actually building on the foundations of previous work," Osborn says in the interview.

The first standards for additive manufacturing were issued in 2009 by ASTM International. They did not address ceramic AM specifically, but they included descriptions of terms and nomenclature used by AM users and researchers so that



Figure 1. A Lucideon technician works on an additive manufacturing robocaster.

everyone in the field could begin speaking the same language.²

In 2016, ASTM and the International Organization for Standardization (ISO) jointly issued a structure to be used to develop further general standards for AM and for broad categories of materials.³ It was not until 2025 that the first international standards specifically for ceramic AM were published. They specify standards for ceramic slurry as a feedstock in vat photopolymerization AM processes.⁴

Currently, a joint ISO/ASTM committee has drafted design guidelines for ceramic AM that include proposed standards for material properties, design freedoms and constraints, and process limitations.⁵ These guidelines are not finalized.

The development of standards generally moves slowly because they will affect not only a wide range of manufacturers and researchers but also the certification efforts of regulatory bodies such as the Federal Aviation Administration and NASA. The variety and complexity of the ceramics industry is another factor in the slow development.

"The problem in the ceramics world is there is such a large number of potential technologies you can use," Osborn says. "Within each of those technologies, there are specific requirements."

He also believes the development of standards for ceramic AM may have lagged because the technology was first used for prototyping rather than for making functional parts. With the market's interest now turning to printing actual

parts rather than as a prototyping tool for product development, exacting specifications are required.

Despite the lag in formal, global standards, businesses and organizations are moving forward to continue the evolution of the technology (Figure 1). For example, in October 2025, Lucideon announced a partnership with Hydra Manufacturing of Leeds, U.K., to pair Hydra's printer technology with Lucideon's expertise in ceramic ink formulation, materials testing, and validation.

Lithoz, the Vienna-based maker of 3D printers for ceramic AM, announced its Ceramic 3D Factory in 2024. This "factory" is a network of service providers that use the company's lithography-based ceramic manufacturing technology to scale up industrial applications.

The National Institute of Standards and Technology (NIST), based in Gaithersburg, Md., is leading a program to speed commercialization by develop-

ing new measurement approaches for ceramic AM processes, including methods for predictive modeling of an AM workflow from feedstock to printed part.

With the ceramic AM market expected to grow, "There is urgent need for testing methods and standards adapted to ceramic feedstock and AM-built parts and for databases of feedstock characteristics, AM process parameters, and properties of the resulting product," NIST says.⁶

About the author

David Holthaus is an award-winning journalist based in Cincinnati, Ohio, who covers business and technology. Contact Holthaus at dholthaus@ceramics.org.

References

¹T. Luomaranta et al., "Initiation and evolution of systemic innovations: Patterns and interactions in the emergence of additive manufacturing technologies," *Creativity and Innovation Management* 2024, 33(3): 476-495.

²T. Sprinkle, "The 5 most important standards in additive manufacturing," ASTM International. Published 14 March 2019. <https://bit.ly/4cwUekR>

³ASTM International and ISO Unveil Framework for Global 3D Printing Standards," ASTM International. Published November 2016. <https://bit.ly/4sZ9nkT>

⁴"ISO/ASTM 52940:2025 Additive manufacturing of ceramics—Feedstock materials—Characterization of ceramic slurry in vat photopolymerization," International Organization for Standardization. Published November 2025. <https://www.iso.org/standard/83078.html>

⁵"ISO/ASTM DIS 52957 Additive manufacturing of ceramics—Design—Design guidelines," International Organization for Standardization. In development. <https://bit.ly/4ea8AJ6>

⁶"Additive manufacturing of ceramics," National Institute of Standards and Technology. Published 23 July 2021, updated 26 March 2025. <https://bit.ly/3PWqGVe>

*All references verified as of May 12, 2026. ■



ACerS Learning Center



On-Demand Course Feature: Using Phase Diagrams for Industry | Instructed by Carl Frahme, Ph.D.

4 modules | 20 lessons | ~18 hours of instruction | On-Demand

ceramics.org/course/frahme-phase-diagrams

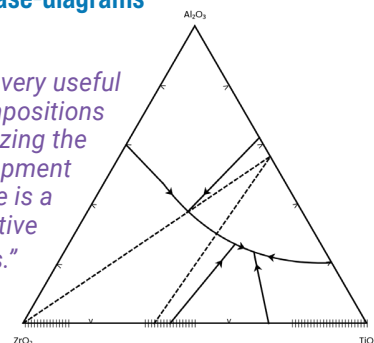
Use code **PHASE20** to get 20% off your registration!

From ~~\$845~~ to \$676!

Offer cannot be combined with other discounts. Valid for one-time use from June 10–Oct. 10, 2026.

"Phase diagrams are very useful in understanding ceramic compositions and processes and in optimizing the direction of R&D and the development of new products. This course is a powerful tool for the productive application of phase diagrams."

– Carl Frahme, Ph.D.



SOCIETY DIVISION SECTION CHAPTER NEWS



Meet the 2026–2027 officers and Board members

President-elect



DILEEP SINGH, FACERS

Thermal and Structural Materials group lead
Argonne National Laboratory
Lemont, Ill.

ACerS has been my home professional society for several decades. I have passionately volunteered at different leadership levels within the Society, starting as the local Chicago Chapter chair to currently serving as a director on the ACerS Board. I have also served on numerous Society-level committees.

These volunteer experiences have provided me many fruitful interactions with peers and mentors from around the world as well as the dedicated ACerS staff. This journey has provided me exposure to the Society's operations as well as its successes and challenges, networking opportunities, and career growth.

I feel it is time for me to give back, perhaps more than what I received, to the society that has shaped my professional career. My goal as president-elect will be to address several current and upcoming challenges the Society faces by proactively working alongside ACerS leadership, staff, and its members. I plan to work diligently to meet the needs of diverse membership and ensure a strong future for the ACerS. It will be an honor and privilege to serve ACerS as president-elect.

Directors



VICTORIA BLAIR, FACERS

Research materials engineer
DEVCOM Army Research Laboratory
Aberdeen Proving Ground, Md.

My ACerS journey began in high school. Curious about the science behind the ceramic art I enjoyed, my web search for "Ceramics + Science" led me here. I joined immediately, and this society opened the door to a career I had never imagined, becoming my professional home ever since.

For more than a decade, I have demonstrated my commitment to ACerS. I was a committee chair of the inaugural President's Council of Student Advisors (PCSA) and also served on several Society committees, including the Education and Professional Development, Strategic Planning, and Member Services Committees. I brought my focus back to students in 2018 when I served as the Mentor-at-Large for the PCSA until 2024. I was most recently recognized as an ACerS Fellow in 2024.

As a Board member, I will work to strengthen our community's role in nurturing the next generation, just as it nurtured me. I will focus on creating robust pipelines for talent by expanding mentorship programs that connect students and young professionals with leaders across industry, academia, and government. I will also champion initiatives that enhance career development at all stages, ensuring ACerS remains an essential community for every ceramist.

FOR MORE
INFORMATION:

ceramics.org/spotlight



WILLIARD CUTLER, FACERS

Division vice president and commercial technology director
Corning Inc.
Corning, N.Y.

The ACerS Board consists of many talented people. I can perhaps add an additional perspective to the group as an experienced advocate of ceramics on the industrial scale, where it serves as a solution to novel problems.

I spend a lot of time in front of customers all over the world, with diverse sets of problems (e.g., pollution, energy storage, climate change). They often do not care what materials are used to solve the problem; they just want economical solutions. Fortunately, glass- and ceramic-based solutions can often solve their problems, but most people have little or no experience with glass and ceramics. So, they must be educated as to the potential and limits of glass and ceramic materials.

Glass and ceramic materials have a bright future, and they will be integral to technological developments over the next century. I am delighted to help these materials progress.



LISA RUESCHHOFF

Senior materials research engineer
Air Force Research Laboratory
Dayton, Ohio

It is a great honor to be appointed to the ACerS Board of Directors. Currently, I am a senior materials research engineer at the Air Force Research Laboratory, where I have spent the last eight years leading research on ceramics and composites for extreme environments. Since joining ACerS as a student 15 years ago, I have found the Society to be my technical home, building my professional career and a global network through its vibrant community. I am eager to leverage this dual perspective, as both a researcher and a long-term member and volunteer, to ensure ACerS remains the premier hub for ceramics innovation and professional growth for all members.

My commitment to the Society began as a graduate student in the President's Council of Student Advisors, where I served first as Communications Committee chair and then as Council chair, leading programming to engage student leaders worldwide. I have continued this service by serving as chair of the Membership Services Committee, where I led initiatives to enhance member engagement. I have remained committed to technical programming within the Society as well, including serving as program co-chair for the 10th International Congress on Ceramics, symposia co-organizer for five ACerS symposia, and as an associate editor for the *International Journal of Applied Ceramic Technology*.

As a Board member, I will be a dedicated voice for the membership, ensuring we engage all career levels across industry, academia, and government labs worldwide. I am committed to the Board's goal of promoting the Society's long-term health by organizing impactful symposia, mentoring the next generation, and fostering an inclusive, technologically vibrant community. ■

AdValue Technology

Quality Materials to Empower a World of Solutions

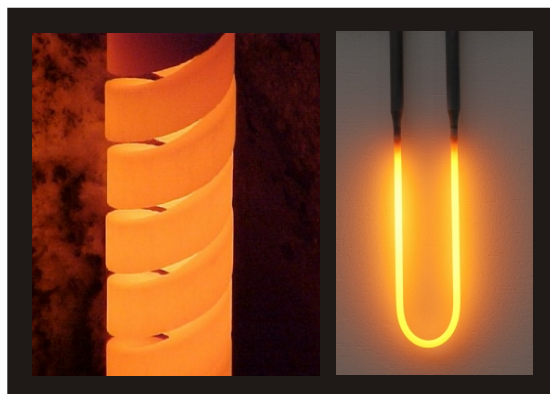
- Alumina
- Quartz
- Sapphire
- Diamond
- Zirconia
- Boron Nitride
- Transparent Ceramics
- Thick Film Pastes
- High Purity Powders
- Refractory Metals



www.advaluetech.com

Tel: 520-514-1100 Fax: 520-747-4024
Sales@advaluetech.com
3158 S. Chrysler Ave., Tucson, AZ 85713

Starbar[®] and Moly-D[®] elements
are made in the U.S.A.
with a focus on providing
the highest quality heating elements
and service to the global market.



60 years of service and reliability



I Squared R Element Co., Inc.
Phone: (716)542-5511

Email: sales@isquaredrelement.com
www.isquaredrelement.com

MORE
SOCIETY
DIVISION
SECTION
CHAPTER
NEWS

ACerS President-elect

*To serve a one-year term from
Oct. 7, 2026, to October 2027*

Dileep Singh

ACerS Board of Directors

*To serve three-year terms from
Oct. 7, 2026, to October 2029*

Victoria Blair

Lisa Rueschhoff

Willard Cutler

Division and Class Officers

*To serve a one-year term from
Oct. 7, 2026, to October 2027,
unless otherwise noted.*

FOR MORE
INFORMATION:

ceramics.org/spotlight

2026–2027 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. 7, 2026, at the conclusion of ACerS 128th Annual Meeting at MS&T26.

Art, Archaeology and Conservation Science Division

Chair: **Christina Bisulca**

Vice chair: **Xiao Ma**

Secretary: **Annette Ortiz-Miranda**

Treasurer: **Annika Blake-Howland**

Trustee: **Darryl Butt**

Basic Science Division

Chair: **Fei Peng**

Chair-elect: **Ming Tang**

Vice chair: **Klaus van Benthem**

Secretary: **Jessica Krogstad**

Secretary-elect: **TBD**

Member Engagement

representative: **Victoria Blair**

Bioceramics Division

Chair: **Ashutosh K. Dubey**

Chair-elect: **Anamika Prasad**

Vice chair: **Artemis Stamboulis**

Secretary: **Candan Tamerler**

Cements Division

Chair: **Kendra Erk**

Chair-elect: **Juan Pablo Gevaudan**

Secretary: **Allie Yamagata**

Trustee: **Matt D’Ambrosia**

Member Engagement representative:

Christopher Shearer

Education and Professional Development Council

Co-chair: **Frank DelRio**

Co-chair: **TBD**

Electronics Division

Chair: **Reeja Jayan**

Chair-elect: **Aiping Chen**

Vice chair: **Christina Rost**

Secretary: **Eric Patterson**

Secretary-elect: **TBD**

Trustee: **Geoff Brennecka**

Member Engagement

representative: **Brady Gibbons**

Energy Materials and Systems Division

Division chair: **Jianhua Tong**

Vice chair: **Sepideh Akhbarifar**

Secretary: **TBD**

Program Committee: **Kai He**

Engineering Ceramics Division

Chair: **Federico Smeacetto**

Chair-elect: **Yuki Nakashima**

Vice chair/Treasurer: **Dong (Lilly) Liu**

Secretary: **Hyun-Sik Kim**

Trustees: **Michael Halbig**

Counselors: **Jie Zhang**

and **Amjad Almansour**

Parliamentarian: **Manabu Fukushima**

Glass & Optical Materials Division

Chair: **Collin Wilkinson**

Chair-elect: **Charmayne Lonergan**

Vice chair: **Xiaonan Lu**

Secretary: **TBD**

Member Engagement

representative: **Kathryn Goetschius**

Manufacturing Division

Chair: **Chao Ma**

Chair-elect: **Rehan Afza**

Vice chair: **Max Modugno**

Secretary: **Jorgen Rufner**

Counselor: **William Carty**

Member Engagement

representative: **Manoj K Mahapatra**

**Refractory Ceramics Division
(term begins March 2026)**

Chair: **Rebecka Annunziata**

Chair-elect: **Brady Gould**

Vice chair: **Dan Gower**

Secretary: **TBD**

Trustee: **Dana Goski**

Member Engagement

representative: **Bill Hedrick**

Structural Clay Products Division

Chair: **Marian Clark**

Chair-elect: **Clarke Burns**

Vice-chair: **Jim Zwick**

Secretary: **TBD**

Trustee: **Bryce Switzer**

Welcome new ACerS Corporate Partners

ACerS is pleased to welcome its newest Corporate Partners: Expert Lab Service, Keramischer OFENBAU, Synova USA Inc.



To learn about the benefits of ACerS Corporate Partnership, contact Yolanda Natividad, associate director of membership and industry relations, at (614) 794-5827 or ynatividad@ceramics.org.

Ceramics are the hot ticket in the Washington DC/ Maryland/Virginia Section area

The Washington, D.C./Maryland/Virginia (DC/MD/VA) Section hosted its largest-ever in-person networking event on March 13, 2026, drawing more than 40 attendees from academic institutions, federal laboratories, and industry. The turnout sent a clear signal: The ceramics community in the greater Washington, D.C. region is ready to connect.

This region is home to a dense concentration of ceramics-relevant activity. Dozens of advanced ceramics companies, world-class university research programs, and multiple federal laboratories all operate within a short drive of one another. Despite that concentration of expertise, the region has historically lacked regular opportunities for face-to-face professional engagement. This event was a step toward changing that.

The program opened with the presentation of the DC/MD/VA Section Student Research and Travel Awards. Two invited speakers then offered perspectives on the future of ceramic science. Carol A. Handwerker, professor of materials engineering at Purdue University, presented "Grain boundaries and the forces that mold them: Inspiring pathways in science and life." Shenqiang Ren, professor of materials science and engineering at the University of Maryland, College Park, presented "Materials beyond limit: Synthesis and processing of preceramic precursors."

Beyond the formal program, attendees made new connections spanning the University of Maryland; Johns Hopkins University; the University of Virginia; Virginia Polytechnic Institute and State

Call the Experts
for all your solids processing

Size Reduction
Wet & Dry Size Reduction
Steel & Ceramic Lined Mills
Jars & Jar Rolling Mills

Vacuum Drying
Dryers & Complete Systems

Solids & High Viscosity Mixing
Ribbon & Cone Blenders
Fluidizing Mixers
Sigma Blade Mixers

Applications:
Ceramics · Al₂O₃
Glass Frit · SiC
Tungsten Carbide
Quartz Refractory
Organometallics
Catalysts · Minerals
Pigments · Polymers
Powdered Metals
Graphite · Resins

Quality & Innovation Since 1911

PAULO ABBE
www.pauloabbe.com 630-350-3012 sales@pauloabbe.com



Members of the DC/MD/VA Section at the March 2026 event.

University; the University of Maryland, Baltimore County; The Catholic University of America; TA Instruments; Ion Storage Systems; Tethon; NASA; NIST; the Naval Research Laboratory; and the Smithsonian Institution. These connections open the door to future research collaborations and workforce development across the region.

The DC/MD/VA Section will be planning its next event soon. If you work in ceramics in this region and want to get involved, reach out to the board of the DC/VA/MD Section through the ACerS online membership directory.

MORE
SOCIETY
DIVISION
SECTION
CHAPTER
NEWS

**Eastern Tennessee Section members
tour local facility**

On March 20, 2026, members of the Eastern Tennessee Section visited Howmet Aerospace, in Morristown, Tenn. The host, Austin Bleacher, gave a tour of the ceramics processing capabilities at Howmet Aerospace. ■



Eastern Tennessee Section members on the Howmet Aerospace tour.

ACerS International Japan Chapter completes International Session at Annual Meeting 2026 of the Ceramic Society of Japan

The ACerS International Japan Chapter and the International Committee of the Ceramic Society of Japan completed the International Session at the Annual Meeting 2026 of the Ceramic Society of Japan in Yokohama, Japan, on March 4, 2026.

The session's opening remarks were given by Japan Chapter Chair-elect Yoshihiko Imanaka. Later, ACerS Past President Monica Ferraris from Politecnico di Torino, Italy, and ACerS Fellow Susan Trolier-McKinstry from The Pennsylvania State University presented invited talks.

Four 2025 Richard M. Fulrath Award winners also presented invited talks: Lane W. Martin from Rice University, Texas; Takashi Teranishi from Okayama University, Japan; Mori Satoshi from Niterra Co., Ltd., Japan; and Daiki Shota from Tokuyama Corp., Japan. ■



Members of the ACerS International Japan Chapter and the International Committee of the Ceramic Society of Japan at the Annual Meeting 2026 of the Ceramic Society of Japan.

The American Ceramic Society
ceramics.org



WEBINAR
LIBRARY



CHECK OUT THESE RECENT ADDITIONS TO THE ACERS WEBINAR ARCHIVE:

ENGINEERED PEROVSKITE OXIDES FOR VERSATILE APPLICATIONS IN SOFCS, SOECS, AND RSOCS

ELECTROCALORIC CERAMICS FOR SOLID-STATE COOLING WITH EMPHASIS ON BATIO_3 -BASED LEAD-FREE MATERIALS EXHIBITING HIGH AND TUNABLE CURIE TEMPERATURES

Original air date: Feb. 16, 2026

Hosted by: ACerS International Italy Chapter and ACerS International Türkiye Chapter

Featured speakers: Leonardo Duranti and Umut Adem

EXAMINING FEATHERWORKS WITH USAXS SYNCHROTRON TECHNIQUES

Original air date: Feb. 20, 2026

Hosted by: ACerS Art, Archaeology & Conservation Science Division

Featured speaker: Madeline Meier

ACerS members can view these webinars and other past recordings by visiting the ACerS Webinar Library at <https://ceramics.org/education/webinars>.

MEMBER HIGHLIGHTS



IN MEMORIAM

John B. Pickett

FOR MORE INFORMATION:

ceramics.org/membership

Volunteer Spotlight: José Marcial

ACerS Volunteer Spotlight profiles members who demonstrate outstanding service to the Society.



José Marcial is a materials scientist at Pacific Northwest National Laboratory (PNNL) and embedded staff at the Waste Treatment and Immobilization Plant on the Hanford site in south-eastern Washington. He received both his B.S. and Ph.D. in materials science and engineering from Washington State University. Before joining PNNL, he worked as a postdoctoral researcher at the University of Chemistry and Technology, Prague, conducting research with collaborators at the Institut de Physique du Globe in Paris.

Marcial actually began his work at PNNL as a high school intern in 2008 and continued conducting research there during his undergraduate studies. Now through his current joint appointment, Marcial focuses primarily on vitrification of Hanford nuclear waste. This work is at a historic stage, as the plant just started operations to transform radioactive and hazardous tank waste into glass at the end of 2025. During this time, Marcial also served as team lead for the Materials Testing and Development Team at PNNL.

Marcial is a first-generation migrant student and the first in his family to graduate from university. Outside of work, he performs community outreach through career fairs and classroom visits to promote science, technology, engineering, arts, and mathematics education. He also mentors students, early-career staff, and research interns.

Marcial is the current chair of the Glass & Optical Materials Division and associate editor for the *International Journal of Applied Glass Science*. His first exposure to the Society was as an undergraduate presenter at the 2011 GOMD meeting in Savannah, Ga. Since then, he has served as a delegate for the President's Council of Student Advisors and as a student delegate for the then Nuclear Energy & Technology Division (now part of the Energy Materials and Systems Division). While at Washington State University, he served as president of both the Materials Advantage Chapter and the Materials Research Society Chapter.

We extend our deep appreciation to Marcial for his service to our Society! ■

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.



Kathleen Richardson, DLM, FACerS, UCF Trustee Chair Professor of Optics and Materials Science and Engineering at the University of Central Florida, and **Steve Martin**, FACerS, Distinguished Professor of materials science and engineering at Iowa State University, received the 2026 Otto Schott Research Award for their pioneering work on glasses, including structure and optical properties. Richardson and Martin are shown center left and center right receiving the award. ■

AWARDS AND DEADLINES



Nomination deadlines for Society awards: Sept. 1, 2026

Contact: Erica Zimmerman | ezimmerman@ceramics.org

Society award	Deadline	Description
Darshana and Arun Varshneya Frontiers of Glass Lectures	September 1	Lectures encourage scientific and technical dialogue 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.
Samuel Geijsbeek PACRIM International Award	September 1	Recognizes individuals who are members of the Pacific Rim Conference societies for their contributions to ceramic and glass technology that have resulted in significant industrial and/or academic impact, international advocacy, and visibility of the field. ■

Nomination deadlines for Division awards: July 1, Aug. 1, or Aug. 31, 2026

Contact: Vicki Evans | vevans@ceramics.org

Division	Award	Deadline	Contacts	Description
ECD	Mrityunjay Singh Bridge Building	July 1	Federico Smeacetto federico.smeacetto@polito.it	Recognizes individuals outside of the United States who have made outstanding contributions to engineering ceramics, international collaboration, and outreach.
ECD	Global Young Investigator	July 1	Yuki Nakashima nakashima-yuki@aist.go.jp	Recognizes the outstanding young ceramic engineer or scientist whose achievements have been significant to the profession and to the general welfare of the community around the globe. Nominations are open to candidates from industry, academia, or government-funded laboratories around the world.
ECD	James I. Mueller Lecture	July 1	Amjad Almansour amjad.s.almansour@nasa.gov	Recognizes the accomplishments of individuals who made similar contributions as James I. Mueller to the Engineering Ceramics Division and to the field of engineering ceramics.
ECD	Jubilee Global Excellence	July 1	Michael Halbig michael.c.halbig@nasa.gov	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.
EMSD	Outstanding Student Researcher	August 1	Sepideh Akhbarifar sepideha@vsl.cua.edu	Recognizes exemplary student research related to the mission of ACerS Energy Materials and Systems Division.
BSD	Graduate Excellence in Materials Science (GEMS)	August 31	Eve Mozur evemozur@mines.edu	Recognizes the outstanding achievements of graduate students in materials science and engineering. The award is open to all graduate students who are giving an oral presentation in any symposium or session at the 2026 Materials Science & Technology meeting. ■

Materials science students advocate for federal R&D on Capitol Hill

Each spring while Congress is in session, Material Advantage brings students studying materials science and engineering to Washington, D.C., for Congressional Visits Day (CVD), an opportunity to step out of the lab and classroom and into the offices of the people who shape federal science policy. The 2026 event brought together 38 undergraduate and graduate students for two days of advocacy, professional development, and peer engagement, with Ceramic and Glass Industry Foundation Program Manager Nathan McIlwaine organizing everything on site.

The evening of March 25 began with a reception and training session that set the tone for the visits ahead. Three faculty advisors from the Material Advantage community volunteered their expertise to prepare students for the experience. Megan Malara, director of the Innovation Hub at the National Center for Defense Manufacturing and Machining, brought a dual perspective to the program as a former AAAS Congressional Science and Technology Policy Fellow. Patrick Johnson of Iowa State University and Michael Titus of Purdue University contributed their depth of experience in materials research as well as helped with the months of preparation to ensure students arrived ready to participate in the event.

Alessandra Zimmerman, senior manager of research and development policy at AAAS, delivered a presentation on the federal budget process, giving students a clear overview of how funding decisions are made, where science and engineering fit within federal R&D priorities, and how advocates can engage effectively with policymakers. A panel of three AAAS Congressional Fellows—Rachael Lau, Rubi Gonzales, and Swati Narasimhan—moderated by Malara added practical grounding to that foundation. Each had completed advanced degrees in scientific fields before transitioning into roles supporting members of Congress, and their accounts offered students a grounded perspective on what science advocacy looks like in practice.

On March 26, students carried those conversations onto Capitol Hill, where they coordinated with peers from the same state or congressional district to meet with legislative offices throughout the day to make the case for federal investment in materials science and engineering. Their visits came at a meaningful moment, with congressional offices in the early stages of the fiscal year 2027 budget process.

The conversations that the students held with the legislative staffers were substantive. Eric Lin, undergraduate student at Carnegie Mellon University, described one discussion where students successfully connected fundamental limits in semiconductor technology with the need for sustained U.S. investment in research and manufacturing, reinforcing the role of federal support in maintaining global competitiveness. He says, “It was a great experience walking into the Senate and House buildings and talking directly to the staffers to advocate for materials science.”

The experience extended well beyond the policy discussions themselves. As Hossein Libre, an undergraduate student at Missouri University of Science and Technology, shared, “Congressional Visits Day opened up a whole new world for me. It changed how I think about the broader impact of technical work and how researchers can engage



Students and faculty advisor Patrick Johnson (second row, farthest left) gather outside the U.S. Capitol during Congressional Visits Day on March 26, 2026.



Eric Lin, left, meets with staff from Senator David H. McCormick's (R-Pa.) office following their discussion on materials science and federal research and development.



AAAS Congressional Fellows served as panelists during the Congressional Visits Day welcome reception, sharing insights into the role of congressional staff and science policy engagement ahead of Capitol Hill visits.



Undergraduate students from North Carolina State University meet with staff (second from right) from Senator Ted Budd's (R-N.C.) office. Left to right: Adriana Lara, Ariel Diem Nguyen, Cordelia McKelvey, and Aaron Thomas.

with policy. Seeing people with backgrounds similar to mine working on the Hill made me realize this path could be for me, too.”

The Ceramic and Glass Industry Foundation extends its sincere thanks to the students who represented their institutions and the broader materials community with enthusiasm and distinction.

Material Advantage is a collaborative program of four professional societies: ACerS, AIST, ASM International, and TMS. Events such as Congressional Visits Day represent a shared investment in the future of the field and in ensuring the materials community has a voice in decisions that shape scientific research in this country. Those interested in supporting this work through the CGIF are encouraged to visit www.foundation.ceramics.org or to reach out at foundation@ceramics.org. ■

From Missouri clay to global impact:

A century of ceramic engineering at Missouri S&T



Current faculty and students in the Missouri S&T ceramic engineering program as of spring 2026.

By David Lipke and Charmayne Lonergan

Ceramics occupy a uniquely demanding and versatile space within the materials landscape.

These inorganic, nonmetallic substances bridge the extremes of structure and performance—from ultrahigh-temperature stability in hypersonic environments to precise optical transmission in infrared systems, from bioactive implants to chemically durable waste forms.

Unlike metals or polymers, ceramic behavior is governed by complex bonding, defect chemistry, and processing–structure–property relationships that are highly sensitive to composition and thermal history. As a result, advancing ceramic materials requires more than general materials knowledge; it depends on scientists and engineers specifically trained to understand and control these nuances across synthesis, processing, and characterization.

The discipline of ceramic engineering has long provided this specialized expertise, enabling innovations that underpin critical technologies in energy, defense, healthcare, and infrastructure. Yet despite their continued importance, formal ceramic engineering degree programs are now far less common than they once were.

In the early to mid-20th century, such programs were widely established across the United States to meet industrial and

technological demands. Over time, many were consolidated into broader materials science departments or phased out altogether, leading to a narrowing pipeline of engineers with deep, ceramics-focused training. This shift makes it even more important to recognize and sustain the institutions that continue to educate specialists in this field.

In 1926, the Missouri School of Mines and Metallurgy (MSM), now Missouri University of Science and Technology (Missouri S&T), located in Rolla, Mo., officially established its Department of Ceramic Engineering. As we approach the centennial of this milestone, we reflect on the university's century of contributions to the field, contributions that have maintained a focus on solving complex engineering problems through the fundamental study of ceramics and glass.

Founding a department of ceramic engineering

The path to establishing a ceramic engineering program in Rolla was marked by significant institutional and political challenges. Although the discipline was gaining traction at institutions such as The Ohio State University and Alfred University, the initial effort in Missouri was met with resistance.

The push for a dedicated curriculum began as early as 1907, led by then MSM Director Lewis Young, who recognized the untapped potential of Missouri's extensive clay and shale



Credit: Missouri S&T University Archives

Figure 1. First class of ceramic engineering students (1926–1927).

deposits. However, these early efforts were delayed by a prolonged period of institutional friction within the University of Missouri system, where the very scope of engineering education at the Rolla campus was a subject of intense debate.

A. Ross Hill, then president of the University of Missouri, along with his predecessor Richard Jesse, viewed the very existence of the Rolla campus as an “educational mistake” and a historical error that split the university’s resources. For years, Hill blocked the expansion of engineering at MSM, arguing that ceramics was a “vocational matter” unfit for a college curriculum. The conflict grew so heated that by 1915, Hill even proposed moving MSM to Columbia entirely, a move that would have effectively ended Rolla’s engineering legacy.

The survival of the campus and the eventual birth of the ceramics department were secured through legislative and legal battles. The passage of the Buford Act in 1915 explicitly granted MSM the right to offer degrees in chemical, civil, electrical, and mechanical engineering. When the Board of Curators refused to comply, a lawsuit led by student Harry Heimberger reached the Missouri Supreme Court, which ruled in favor of MSM, permanently securing its right to expand its curriculum.

The final catalyst for the department’s founding was the arrival of MSM Director Charles Fulton in 1920. Fulton recognized that the only way to overcome institutional resistance was to form an unbreakable alliance with industry. At the time, Missouri’s clay industries ranked third in the state’s mineral production, and the state led the nation in tonnage. Yet Missouri companies were forced to recruit out-of-state engineers because there was no local training program.

In 1925, the Missouri Clay Association and the Missouri Refractories Association met with Fulton and made a compelling case: The industry would finance the department’s immediate needs and lobby the legislature for funding if MSM would

commit to the program. Allen Percival Green, founder of the A.P. Green Fire Brick Company and an MSM alumnus, was the most influential figure in this movement, recognizing that scientific research into high alumina-content minerals such as diaspore, of which Missouri was the world’s leading producer at the time, was essential for high-heat industrial furnaces.

In 1926, the Board of Curators finally relented. Major Edward Holmes was named the founding head of the department, which opened on the second floor of the U.S. Bureau of Mines Mississippi Valley Experiment Station (later named Fulton Hall). The initial cohort had 15 students (Figure 1), many of whom were employees of A.P. Green sent to MSM at company expense.

The foundational ties between the Rolla program and the refractories industry have been sustained for decades through a unique professional bridge: the annual Refractories Symposium. Hosted by the Greater Missouri Section (formerly the St. Louis Section) of The American Ceramic Society, in partnership with the ACerS Refractory Ceramics Division, this symposium has served for more than 60 years as a premier global forum for the exchange of technical knowledge between academia and the refractories industry. This enduring partnership reflects the department’s original mandate to provide scientific rigor to the study of heat-resistant materials.

The synergy between the campus and the Section is perhaps most visible through the Theodore J. Planje St. Louis Refractories Award. Presented annually at the Refractories Symposium, this prestigious honor commemorates Theodore J. Planje, an MSM alumnus and dean who was a titan of the refractories field, ensuring that the spirit of industrial collaboration that founded the department remains a cornerstone of its second century.

From Missouri clay to global impact: A century of ceramic engineering at . . .

Evolution of the institution and department

MSM operated under its original name until 1964, when it became the University of Missouri at Rolla (and shortly thereafter, the University of Missouri–Rolla, or UMR). In 2008, the institution adopted its current name, Missouri University of Science and Technology (Missouri S&T), to more clearly communicate its mission as a leading technological research university.

Today, Missouri S&T is classified as a Carnegie R1 institution, a designation reserved for universities with the highest level of research activity. This status, achieved in 2025, places Missouri S&T among the top tier of research universities in the U.S. Missouri S&T graduates approximately 1,000 engineers annually from its more than 15 ABET-accredited programs, consistently ranking in the top 30 to 50 of institutions nationwide. Figure 2 highlights some of the university's many graduates since the founding of the ceramics program.

In the United States, ceramic engineering as a specialized academic discipline peaked around the 1980s, when there were as many as 14 ABET-accredited ceramic engineering programs. However, the late 20th century saw a massive wave of consolidation, as many universities merged their ceramic and metallurgical departments into broader materials science and engineering programs.

Missouri S&T was not immune from these pressures, as the Departments of Metallurgical Engineering (founded 1870) and Ceramic Engineering (founded 1926) were merged into a Department of Materials Science and Engineering in 2004. However, the identities of each degree program have been maintained in distinct curricula featuring hands-on laboratory sequences and specialized coursework each semester from sophomore year through graduation.

By 2025, the number of accredited ceramic engineering programs in the U.S. had dwindled to just two: Missouri S&T and the New York State College of Ceramics at Alfred University. A third accredited program at Colorado School of Mines is forthcoming, reflecting a renewed interest in the field.

Notably, there are now fewer ceramic engineers produced in the U.S. as of 2025 (about 50) than in 1925 (about 125). This rarity makes the graduates of accredited ceramic engineering programs highly sought after by industries that require practical, hands-on expertise in the design and manufacture of inorganic, nonmetallic materials.

Ceramic engineering at Missouri S&T: Present and future

As the ceramic engineering program at Missouri S&T begins its second century, the faculty has developed a strategic vision that ensures the program remains relevant to the evolving needs of industry, government, and society.

The program maintains extensive hands-on laboratories in traditional clay-based ceramics; powder processing; sintering and microstructure development; and mechanical, thermal, and electrical properties of ceramics. Starting in the 2026–2027 academic year, the Bachelor of Science in Ceramic Engineering will offer six new emphasis areas to better define the relevance of the degree to prospective students and hiring managers.

These areas reflect strategic research priorities and provide students with specialized expertise in high-impact fields.

- 1. Materials for Extreme Environments:** This emphasis explores the physics and chemistry of materials subjected to extreme heat, radiation, and corrosive environments. This focus area builds on long-standing department strengths in refractories and high-temperature materials. Research into ultrahigh-temperature ceramics grew significantly over the last 20 years as the U.S. government invested in structural materials and thermal protection systems for reusable hypersonic aerospace vehicles. Recent years have seen further growth to include research for materials for concentrated solar power, nuclear fission/fusion energy systems, and in-situ sensors for steelmaking.
- 2. Biomaterials:** This emphasis prepares students to develop materials that interact with biological systems. Research in this field includes resorbable implants, drug delivery vehicles, and ceramic scaffolds for tissue engineering. Researchers at Missouri S&T are internationally recognized for pioneering bioactive glass and ceramic materials, including radioactive glass microspheres used clinically to deliver localized radiation therapy for liver cancer. Current efforts focus on ion-doped and borate-based bioactive glasses that release therapeutic ions (such as copper and zinc) to combat infection, disrupt biofilms, and accelerate healing in chronic and traumatic wounds.
- 3. Energy Materials:** This emphasis focuses on materials used in energy conversion and storage, including solid-state batteries, fuel cells, capacitors, and photovoltaics. Development of solid oxide fuel cells, a technology that holds promise as a high-efficiency electrochemical energy conversion and power generation technology for use in aircraft and electrical power, has been one of the key research areas.
- 4. Functional Materials:** This emphasis examines ceramics and glasses engineered to perform active physical functions rather than structural roles. Focus is placed on materials exhibiting controlled electrical and ionic transport, dielectric and ferroelectric responses, magnetic ordering, and optical functionality, with attention given to processing–structure–property relationships relevant to electronic, sensing, and information technologies. These efforts align closely with and benefit from the university's new semiconductor engineering degree program, which provides strong synergy through shared interests in electronic materials, thin-film processing, and next-generation micro- and nanoscale technologies.
- 5. Computational Materials Science and Engineering:** This emphasis addresses the modeling and simulation of materials using physics-based and data-driven approaches. Core themes include multiscale modeling, high-performance computing, and machine learning methods for predicting materials properties and informing materials design. These efforts are further strengthened by Missouri S&T's new AI+X Master of Science degree program, which integrates artificial intelligence with disciplinary research.

6. Materials Characterization and Analysis:

This emphasis focuses on advanced microscopy, spectroscopy, diffraction, and other techniques used to analyze materials from the atomic to the macroscopic level. A strong priority is placed on hands-on training, with students gaining direct experience in state-of-the-art instrumentation through research and coursework. Planned developments include an expanded undergraduate materials characterization laboratory designed to integrate modern analytical tools into the curriculum and strengthen experimental competencies for both research and industry pathways.

Centennial celebration and invitation

The upcoming centennial of ceramic engineering at Missouri S&T is more than a departmental milestone; it is a celebration of a century of industrial partnership and scientific progress. From the early 20th-century advocacy of A.P. Green to the modern collaborations with federal funding agencies, national labs, and industry, the program's success has always been rooted in its ability to address real-world engineering challenges.

We invite all alumni, industry partners, and members of the broader materials community to participate in our centennial activities throughout the 2026–2027 academic year. Planned events include technical seminars, laboratory showcases, and community gatherings that honor our history while looking forward to the next century of innovation. Furthermore, we are pleased to announce that a hardcover history of the department is currently under preparation and will be available for purchase in 2027.

For updates on the centennial schedule and information on the forthcoming historical volume, please contact matlsci@mst.edu.

Acknowledgments

The authors gratefully acknowledge the ceramic engineering faculty at Missouri University of Science and Technology for their support and encouragement during the writing of this perspective article. Special thanks are extended to campus historian Larry Gragg for contributing historical context featured in this article, which will be further elaborated in his forthcoming book.

About the authors

David Lipke is associate professor of ceramic engineering and associate chair for academic affairs and Charmayne Lonergan is the Richard K. Brow Endowed Chair in glass science and assistant professor of ceramic engineering at Missouri University of Science and Technology. Contact Lipke at lipke@mst.edu and Lonergan at clonergan@mst.edu. ■

Selection of notable alumni — Missouri S&T Ceramic Engineering

A LEGACY OF LEADERSHIP AND DISCOVERY

<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'40</div> <p>Theodore Planje B.S. 1940 • Ph.D. 1950 <i>Dean, UMR • ACerS President • Planje Award namesake</i></p>	<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'40</div> <p>William Smothers† B.S. 1940 • M.S. 1942 • Ph.D. 1944 <i>Refractories section head, Bethlehem Steel • ACerS President • T.J. Planje Award Winner</i></p>	<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'49</div> <p>James Mueller† Ph.D. 1949 <i>Professor, U. of Washington • Helped develop the first Space Shuttle tiles • ACerS President</i></p>
<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'52</div> <p>George MacZura*† B.S. 1952 <i>Refractory expert at Alcoa • First president of UNITECR • ACerS President • T.J. Planje Award Winner</i></p>	<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'54</div> <p>Gene Haertling*† B.S. 1954 <i>Grandfather of PLZT • NAE Member • NASA Public Service Medal</i></p>	<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'56</div> <p>Robert Moore B.S. 1956 • Ph.D. 1962 <i>Longest serving department head of ceramic engineering, MSM • T.J. Planje Award Winner</i></p>
<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'58</div> <p>Delbert Day*† B.S. 1958 <i>Founded Mo-Sci • NAE & NAI Member • ACerS President</i></p>	<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'60</div> <p>Kent Weisenstein*† B.S. 1960 <i>One of five founders of Missouri Refractories Company (MORCO) • T.J. Planje Award Winner</i></p>	<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'65</div> <p>James Shelby* B.S. 1965 • M.S. 1967 • Ph.D. 1968 <i>Professor, Alfred University • Glass science textbook author</i></p>
<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'78</div> <p>Mary Reidmeyer* B.S. 1978 • M.S. 1984 • Ph.D. 1989 <i>Professor, Missouri S&T • ACerS Greaves-Walker Lifetime Service Award Winner</i></p>	<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'82</div> <p>Wayne Huebner* B.S. 1982 • Ph.D. 1987 <i>Professor, Missouri S&T • ACerS Outstanding Educator Award Winner</i></p>	<div style="background-color: #2e7d32; color: white; border-radius: 50%; width: 40px; height: 40px; margin: 0 auto; display: flex; align-items: center; justify-content: center; margin-bottom: 5px;">'05</div> <p>Steve Jung* B.S. 2005 • M.S. 2007 • Ph.D. 2010 <i>Chief Commercial Officer, Mo-Sci LLC</i></p>

Also among our distinguished alumni

Laura Agee	Justin Crider	Glenn Hollenberg*	Rebecca Murray	Robert Stone
John Bartel*	Kevin Edwards	Orville Hunter Jr.*	Darrell Ownby	Natalie Vanderspiegel
Michel Barsoum*	Erik Erbe	Walter Keller	Ralph Padfield*	Dwight Viehland*
Mark Biznek	Robert Farris*	Rasit Koc	Jerry Plunkett	Jeremy Watts
Edward Boulos*	Qiang Fu	Dan Krueger	Sarah Reeves	Tom Wetteroth
Geoff Brennecke*	Lauren Garten	Rod Larson	Sam Schneider*	Jack Williams*
Jeff Bullard*	Brian Gorman	Daniel Marincel	Evan Schwind	Kelley Wilkerson
Vernon Burdick*	Rachel Grodsky	Ronald McCauley	Bill Scott*	Taylor Woehl
Jack Burst	Helio Guimaraes	William McKee	Scott Sehlin	Ki Hyun Yoon*
Bill Carty*	John Halloran*†	Mike Millard	Jeff Smith*	Weiming Zhang
Sam Conzone	James Hemrick*	Edward Mueller*	Charles Sorrell*	Xiao-Dong Zhou
Rachel Cook	James Hill	Steven Muir	Jim Steibel	Frank Zvanut

*Denotes ACerS Fellow · †Denotes ACerS Distinguished Life Member

Missouri School of Mines and Metallurgy ♦ University of Missouri–Rolla ♦ Missouri S&T

Figure 2. The Missouri S&T ceramic engineering program has been defined by faculty and alumni who have made enduring contributions to the field. The individuals mentioned in this figure represent a selection of the leaders who have shaped the program's legacy.

Preparing a data-aware workforce: Applied data science at Case Western Reserve University



Credit: Hein Htet Aung

Picture of researchers in Case Western Reserve University's Center for Materials Data Science for Stockpile Stewardship (MDS³ Center of Excellence) at the 2026 National Nuclear Security Administration Symposium. From left to right: Jonah Bachman (Ph.D. student), Roger French (Distinguished University Professor and Kyocera Professor of Ceramics), Laura Bruckman (Climo Associate Professor), Hein Htet Aung (Ph.D. student), and Tariq Shabazz (program manager of the MDS³ Center of Excellence).

By Hein Htet Aung

Modern scientific research produces data at an unprecedented rate.

The Large Hadron Collider at CERN is an extreme example, producing roughly 1 petabyte (10^{15} bytes) of raw data per second from particle collisions. But even more standard facilities produce copious amounts of data, such as the beamlines at different synchrotron facilities. For example, the Advanced Photon Source at Argonne National Laboratory can generate data up to 20 gigabytes (10^{10} bytes) per second.¹ Advances in sensor technology have made even conventional manufacturing processes increasingly data rich,² in sharp contrast to the early computers that considered 5 megabytes (10^6 bytes) of total storage large in the 1950s.

Conventional analysis approaches cannot keep pace with the amount of data generated. As such, various artificial intelligence techniques are increasingly used to sort through and evaluate the large amount of data. However, these approaches often function as black boxes, meaning it is hard to interpret the system's internal workings or logic. Because their performance depends directly on the quality of input data and how that data is represented in the model architecture, cultivating data awareness becomes critical to curating quality AI-ready datasets and designing how data should be structured for these models.

Data science skills are an essential component of data awareness. Data science is an interdisciplinary field that draws on computer science, mathematics, statistics, and domain-specific expertise.³ A researcher with a strong domain background, complemented by these skills, is better equipped to curate high-quality datasets and develop effective models for their field.

Case Western Reserve University (CWRU) is helping address this need for data-aware researchers through its applied data science (ADS) program, offered through the Case School of Engineering.⁴ Launched in fall 2014, the ADS program began as a minor for students across all eight schools at CWRU; it has since expanded to be offered as a major or certificate as well.^{5,6}

The introductory courses are taught in the R programming language and cover essential data science concepts, such as exploratory data analysis, data management, and Git workflows. More advanced courses build on these foundational concepts with predictive statistical and deep learning models. State-of-the-art models, such as transformers and graph neural networks, are introduced in these advanced modeling courses.

Students can pursue personal projects or extend ongoing research through project-based courses (see sidebar "Leveraging data science at the MDS³ Center of Excellence"). Courses focused on specialized topics, such as geospatial data science,

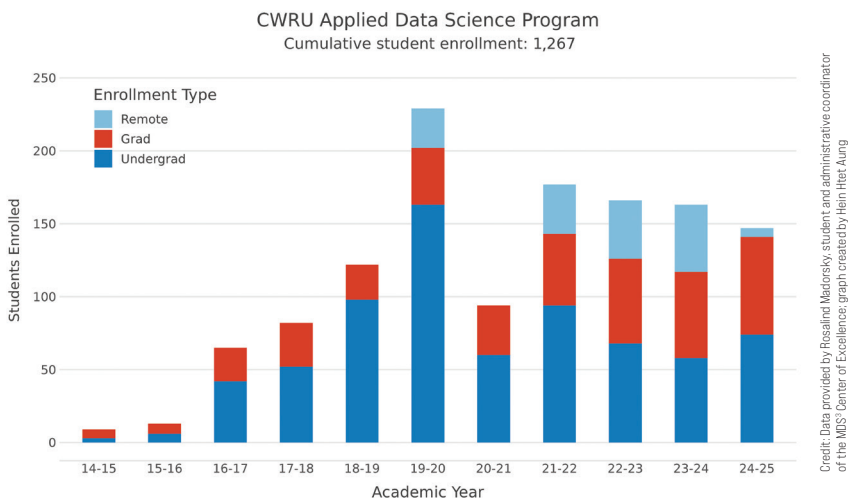


Figure 1. Enrollment in the CWRU applied data science program from 2014 to 2025.

data visualization, and tooling for robust workflows, are available as electives. The program also emphasizes data literacy, including ethics, privacy, and security.

Since the program’s launch, about 1,270 students across all eight CWRU schools have enrolled (Figure 1). These students gain data science skills and research experiences that align with national laboratory interests, thus opening opportunities for internships, co-ops, and full-time employment at these facilities.

As a former student and teaching assistant in the ADS program and now Ph.D. candidate in materials science and engineering at CWRU, I have experienced firsthand how data science and domain expertise reinforce each other. The co-development of these skills is even more critical today with the upcoming Genesis mission, a national effort that aims to steward a new age of AI-accelerated innovation and discovery.⁷ Through the ADS program, students are equipped with the data science skills to support their domain-specific research—preparing them to meet future scientific challenges head on.

About the author

Hein Htet Aung is a Ph.D. candidate in the Department of Materials Science and Engineering at Case Western Reserve University (Cleveland, Ohio). Contact Aung at hxh483@case.edu.

References

- ¹J. V. Wray, “Steve Henke is building data pipelines for beamline science at scale,” Argonne National Laboratory. Published 24 Nov. 2025. <https://bit.ly/3QoQtpt>
- ²D. Mourtzis, E. Vlachou, and N. Milas, “Industrial big data as a result of IoT adoption in manufacturing,” *Procedia CIRP* 2016, **55**: 290–295.
- ³K. Mike and O. Hazzan, “What is data science?” *Communications of the ACM* 2023, **66**(2): 12–13.
- ⁴J. Hanc, “With innovation, colleges fill the skills gap,” *The New York Times*. Published 7 June 2017. <https://bit.ly/4mLiLpX>
- ⁵Business-Higher Education Forum, “Creating a minor in applied data science: Case Western Reserve University engages business leaders to produce T-shaped professionals. A BHEF case study,” Institute of Education Sciences. Published 2016. <https://eric.ed.gov/?id=ED569350>
- ⁶R. H. French and L. S. Bruckman, “Learnings from developing an applied data science curricula for undergraduate and graduate students,” *MRS Advances* 2020, **5**(7): 347–353.
- ⁷“Launching the Genesis Mission,” The White House. Published 24 Nov. 2025. <https://bit.ly/4e4hurU>

*All references verified as of April 23, 2026. ■

Leveraging data science at the MDS³ Center of Excellence

The Center for Materials Data Science for Stockpile Stewardship (MDS³ Center of Excellence) at CWRU aims to leverage data science tools to advance the understanding of materials and their behaviors. For materials science students in the ADS program, working with faculty members in the MDS³ Center of Excellence provides them an opportunity to apply their new skills directly through research.

I personally conducted research on direct ink writing (DIW) under Professor Laura Bruckman and Professor Roger French at the MDS³ Center of Excellence. DIW is a 3D printing technique that deposits ink layer by layer through a nozzle using pressure or mechanical force to create complex structures.

Drawing on domain knowledge from materials science and mechanical engineering, my research seeks to connect the different stages of DIW, from ink formulation to deposition and post-processing, to minimize print errors. By leveraging data science principles in the process, we can develop a knowledge base that links printable ink formulations to fabricated parts that meet application-specific requirements and refine our analysis as more data becomes available.

In addition to my specific area of research in DIW, we also developed a semantic data management framework at the MDS³ Center of Excellence. Leveraging ontologies and the semantic web technology stack, our framework connects materials and data science concepts and constructs knowledge graphs that are semantically enriched with (meta) data and historical data. More details can be found in our article, “Semantic data management: A data-centric approach to advanced manufacturing in the ceramics and glass industry,” in the April 2026 issue of the *ACerS Bulletin*.

Learn more about the MDS³ Center of Excellence at <https://mds3-coe.com>. ■



Photo of team members involved in the ongoing collaboration between Austria-based Lithoz GmbH and Technical University of Leoben.

Credit: Lithoz GmbH

Multimaterial research as the key to innovation in ceramic additive manufacturing

By Raul Bermejo, Josef Schlacher, Serkan Nohut, Martin Schwentenwein, and Johannes Homa

The current rapid advances in the field of ceramic additive manufacturing (AM)—driven by the industrial sector’s emphasis on scalability, cost efficiency, and reliable production of high-performance components—can sometimes obscure the long path scientists have forged over decades to set the fundamentals of ceramic science and engineering,¹ which are widely employed in manufacturing processes today.

Understanding processing physics, sintering mechanisms, and the microstructural evolution and corresponding complex material behavior under distinct in-service conditions is key to developing additively manufactured components. But as both industry and academia push toward more complex geometries, multifunctional materials, and sustainable production routes, the ability to accurately model and predict these coupled phenomena becomes even more essential.

Aligning scientific understanding with industrial application will be key to unlocking the full potential of ceramic AM. Fortunately, academia–industry partnerships, such as the one between Austria-based Technical University of Leoben (Montanuniversität Leoben, or MUL) and Lithoz GmbH, provide a pathway to successfully realizing this potential.

Ceramic AM in academia and industry

Advanced ceramics exhibit exceptional thermal, chemical, and mechanical properties, making them indispensable in sectors such as aerospace, biomedical engineering, and electronics. However, their inherent brittleness and processing challenges have historically limited design freedom. Ceramic AM overcomes these constraints by enabling layer-by-layer fabrication without tooling, reducing lead times and enabling unprecedented geometrical complexity.

In academia, ceramic AM has been a vibrant research field focused on improving and optimizing material quality, densification processes, structural properties, and functional integration. Universities and research institutes continue to investigate novel materials and processing routes, pushing the boundaries of microstructural control and mechanical performance.

For industrial applications, ceramic AM has historically been limited to prototyping and small-series production. However, recent technological advances are enabling a transition toward industrial-scale manufacturing.² Increasing demand from sectors such as aerospace, semiconductors, and medical technology is driving the adoption of ceramic AM for serial production of high-performance components. Industrial players are particularly interested in reproducibility, scalability, and integration into digital manufacturing ecosystems.

In both sectors, the exploration of additively manufactured multimaterial architectures for enhanced functionalities is becoming more common. Although this topic is a recent addition to the AM field, knowledge of traditionally layered multimaterial architectures can help support the efforts of academic and industrial scientists pursuing multimaterial ceramic AM.

Lessons learned from ‘flatland’: Designing with ceramic layers

Inspired by the damage tolerance of natural materials such as nacre and wood, researchers have sought to replicate—and even improve—their hierarchical architectures by combining inorganic components with metallic or polymer phases to enhance toughness and durability.³ Technical ceramics have been engineered via compositional control (e.g., particle templates) and sintering strategies (e.g., templated grain growth) to yield “nacre-like” microstructures whose crystallographic and/or morphological texture can improve their mechanical response.

Another strategy to increase strength and improve reliability has been to engineer layered ceramics that develop in-plane compressive residual stresses. Surface-compressive layers have been shown to raise strength and suppress environmentally assisted cracking, while embedded compressive interlayers are highly effective at arresting or deflecting the propagation of surface-initiated cracks.

The magnitude of the residual stress depends on the strain mismatch between layers, such as those arising from differences in thermal expansion upon cooling, as well as on the elastic properties and relative layer thicknesses of the constituent materials. Based on elasticity theory and linear elastic fracture mechanics, optimal designs often use nonperiodic (or graded) distributions of distinct layers to maximize crack shielding.⁴

A known shortcoming of residual-stress designs is the development of out-of-plane stresses, especially near or at free edges, which can promote tunneling or edge cracks. Recent academic work has established models that rationalize crack formation in layered ceramics and provide guidelines for the design of crack-free components with enhanced damage tolerance.⁵

Avoiding material junctions at free edges is key to mitigating surface cracking in multilayer ceramics. However, conventional processing routes such as tape casting of planar structures generally yield high stress locations around material interfaces at the free surfaces, with the possible crack formation in the ceramic part. The use of multimaterial 3D printing to “embed” protective regions in the ceramic part and thereby avoid material junctions at free surfaces can change this situation.

Leaving ‘flatland’: Toward complex geometries through 3D printing

Among the AM techniques being investigated for multimaterial fabrication, lithography-based methods are a strong contender. These methods belong to the family of vat photopolymerization techniques, which involve selectively curing a photosensitive resin loaded with particles layer by layer. The resulting green part undergoes debinding and sintering to achieve a dense component with high resolution and excellent material properties.

Lithography-based methods have enabled the production of components with micrometer-scale resolution, including complex multimaterial architectures and graded porosity using a two-vat system—capabilities that move bulk ceramics from simple 2D stacks to intricate 3D parts. This transition broadens the design space for structural ceramics and their applications and may enable “function-by-design” at the component level.

The long-term collaboration between MUL and Lithoz, which started in 2014, has been pivotal in integrating advanced printing process knowledge with materials design strategies. This partnership established multimaterial printing as a central approach for improving the structural integrity of ceramic components compared with single-material analogues, thereby delivering performance and reliability gains that add value to the technology.

Multimaterial successes at Lithoz and MUL

For many years, material design concepts investigated at MUL mainly focused on planar multimaterial architectures. These concepts can be now realized and exploited in complex geometries thanks to the multimaterial AM technology developed at Lithoz.

Lithoz is an Austrian company founded as a spin-off from Technical University of Vienna. Lithoz has played a pivotal role in translating academic research into industrial solutions for many years, particularly through its proprietary lithography-based ceramic manufacturing (LCM) technology.

Lithoz’s LCM technology is based on a digital light processing approach, which offers a significant speed advantage over laser-based methods in batch production. An entire layer is cured simultaneously using a digital projector, rather than tracing each layer point by point with a laser.

Multimaterial research as the key to innovation in ceramic additive manufacturing

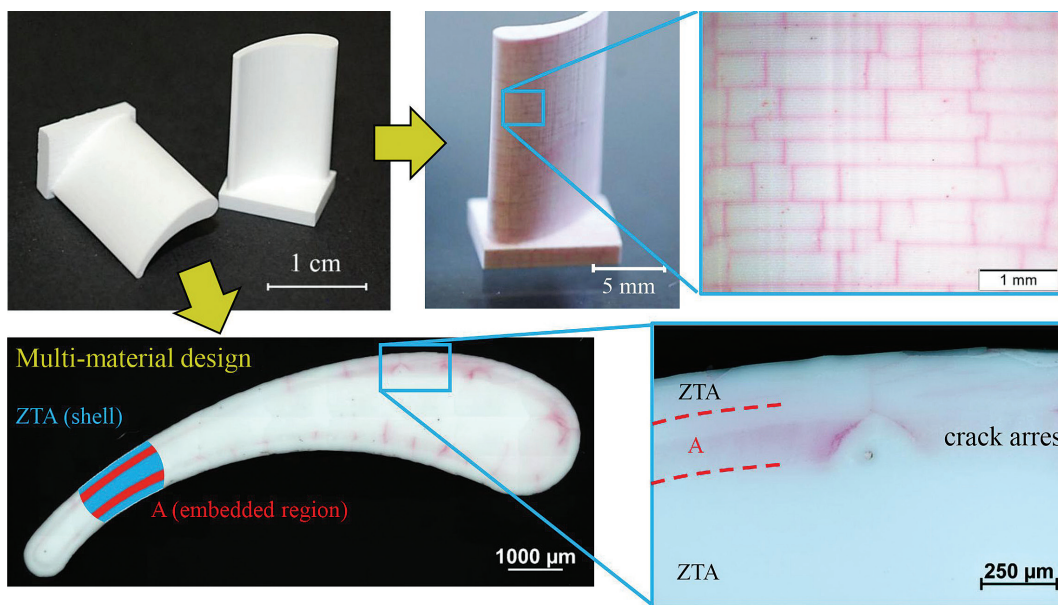


Figure 1. Top left: 3D-printed multimaterial turbine blades. Top right: Crack pattern on the alumina-zirconia (ZTA) surface region of a 3D-printed multimaterial turbine blade, induced through water quenching from about 400°C. Bottom: Cross-section of the multimaterial blade. The close-up depicts the crack arrest in the compressive embedded alumina (A) region. Adapted from Reference 7 under the CC BY 4.0 license.

Lithoz's expertise in multimaterial ceramic AM is exemplified by the CeraFab Multi 2M30 system. This printer enables the simultaneous processing of two materials, such as ceramic-ceramic, ceramic-metal, or ceramic-polymer combinations, within a single build. Using dual vats, the system facilitates the fabrication of functionally graded structures with spatially varying properties. Such capabilities open new possibilities for multifunctional components, eliminating the need for assembly and enabling entirely new design paradigms.

In cooperation with MUL researchers, Lithoz used the CeraFab Multi 2M30 system to demonstrate a proof of concept with 3D-printed alumina parts, where internal alumina-zirconia regions generate compressive stresses at the surface, raising the biaxial strength to values exceeding 1 GPa.⁶ Likewise, embedding alumina regions in 3D-printed ceramic blades has been shown to enhance damage tolerance by arresting the propagation of surface cracks initiated due to thermal-shock stresses (Figure 1).⁷ By embedding the second material within the part, free edges are avoided, thereby mitigating the formation of edge cracks driven by high in-plane stresses, which are seen in planar systems.

Another possibility with multimaterial printing is the deliberate combination of dense and porous regions within a single ceramic part. In general, two pore-generation strategies can be distinguished. In the first, the printed geometry incorporates a scaffold or lattice with macropores (i.e., designed voids), whose size and topology are defined in a computer-aided design system. In the second, porosity is introduced into the material intrinsically by adding pore formers or by adjusting printing and/or thermal post-processing parameters.

By employing the latter approach, researchers at MUL and Lithoz created dense alumina containing polymeric spheres that burn out during debinding/sintering to create controlled porosity. The embedded porous regions were proven effective at mitigating the propagation of thermal-shock-induced cracks compared with bulk alumina (Figure 2).⁸ This approach also enabled local tailoring of compliance without compromising

overall strength, which is primarily governed by the dense surface region of the 3D-printed component.

Up next: Tailoring microstructures by combining printing and sintering strategies

In 3D-printed ceramic parts, debinding and conventional sintering are pivotal for producing a homogeneous microstructure, which underpins both structural integrity and targeted functional performance. Increasing interest in nonconventional sintering routes—such as rapid sintering and ultrafast firing—has accelerated research efforts in ceramic AM to more precisely control densification kinetics, grain growth, and, ultimately, the microstructure and properties of the finished component.

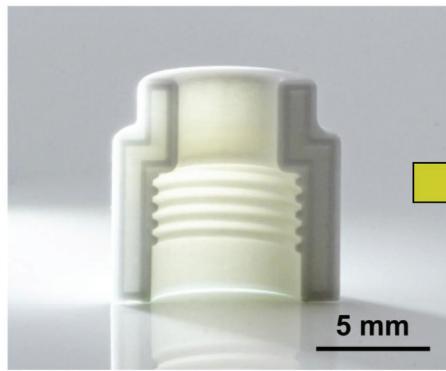
Employing rapid sintering protocols (~30 min total sintering time) using a spark plasma sintering (SPS) system, MUL researchers successfully processed 3D-printed alumina samples with dense microstructures (>97% relative density) and submicron grains ($\approx 0.5 \mu\text{m}$). These samples achieved higher specific strength than conventionally sintered alumina.⁹ The higher strength is associated with a relatively higher fracture toughness and the smaller critical defect sizes in the 3D-printed and rapid sintered alumina. In another recent work, researchers also successfully rapid sintered a bioinspired design of fine-grained alumina with embedded textured layer regions meant to enhance the damage tolerance.¹⁰

Ongoing work aims to rapidly sinter 3D-printed multimaterial parts, combining the benefits of tailored compressive residual stresses through architectural design with fine-grained, dense microstructures.

Education and research in ceramic AM

The ceramic AM advancements described above are built on the interplay of education and research, a central role in strengthening ceramic AM as a whole. Universities and research institutions play a crucial role in developing the fundamental understanding of materials, processes, and design principles required to successfully print high-performance ceramics.

3D-printed nozzle



Thermal shocked parts

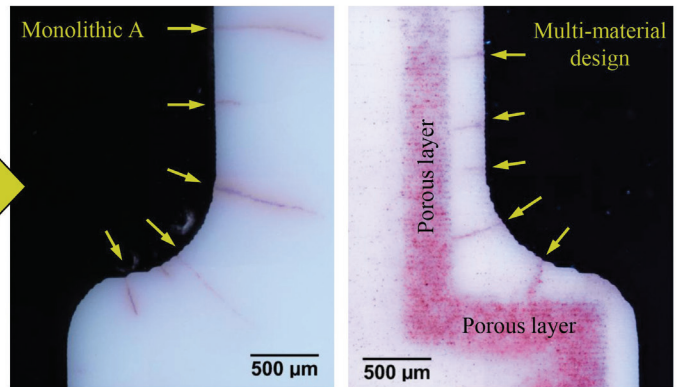


Figure 2. Left: 3D-printed nozzle component. Right: Cross-sections of monolithic alumina and the multimaterial design with embedded porous layers. These samples were water quenched from about 300°C to evaluate thermal shock resistance. The thermal shock cracks (arrows) were arrested by the weak internal layers of the multimaterial design. Adapted from Reference 8 under the CC BY 4.0 license.

From an academic perspective, research in multimaterial ceramic AM focuses on material formulation and compatibility, interface engineering, and process optimization. Combining multiple materials within a single build introduces significant challenges, including differences in shrinkage behavior, thermal expansion, and sintering kinetics. These aspects are critical to achieving consistent quality and reliability, two key requirements for industrial applications.

Academic programs are evolving to reflect the increasing complexity of the field, integrating materials science, chemistry, and digital design to train highly specialized engineers, while industrial partners contribute their specialized know-how, application-driven requirements, and the infrastructure needed to scale production, ensuring that research outcomes are aligned with real-world needs.

The importance of this collaboration is particularly evident in the development of multimaterial AM technologies. Industrial stakeholders provide insights into application areas such as electronics, medical devices, and energy systems, where multifunctional ceramic components can offer substantial advantages. Meanwhile, academic researchers contribute fundamental knowledge and innovative approaches, enabling the exploration of new material combinations and architectures.

Ultimately, the future of additively manufactured multimaterial ceramics depends on a continuous feedback loop between research, education, and industrial practice. As this technology matures, educational efforts will need to expand further, incorporating standardized curricula and hands-on training with industrial systems to close the gap between academic innovation and industrial implementation.

In conclusion, education and research are not just supporting elements but foundational pillars of ceramic AM. Their integration with industrial development ensures that this technology can evolve from a specialized research topic into a robust and widely adopted manufacturing solution. The long-term cooperation between MUL and Lithoz is an example of scientific effort transferred into innovative technology at industrial scale.

About the authors

Raul Bermejo is full professor and head of the Institute of Structural and Functional Ceramics at Montanuniversität Leoben. Josef Schlacher is senior scientist at the same institute. Serkan Nohut is senior researcher, Martin Schwentenwein is chief scientific officer, and Johannes Homa is CEO at Lithoz GmbH (Vienna, Austria). Contact Bermejo at raul.bermejo@unileoben.ac.at.

References

- ¹M. N. Rahaman, *Ceramic Processing and Sintering*. CRC Press, 2017.
- ²D. Sher, “How the collaboration between KLS Martin and Lithoz led to hundreds of patient-specific ceramic implants,” *VoxelMatters*. Published 6 April 2026. <https://bit.ly/4vZzfii>
- ³R. O. Ritchie, “The conflicts between strength and toughness,” *Nat. Mater.* 2011, 10:817–22.
- ⁴R. Bermejo, “‘Toward seashells under stress’: Bioinspired concepts to design tough layered ceramic composites,” *J. Eur. Ceram. Soc.* 2017, 37(13): 3823–3839.
- ⁵R. Pašik et al., “Prediction of edge and tunnelling crack formation in layered ceramics using a stress-energy fracture criterion,” *J. Eur. Ceram. Soc.* 2023, 43(7): 2928–2934.
- ⁶J. Schlacher et al., “Additive manufacturing of high-strength alumina through a multi-material approach,” *Open Ceramics* 2021, 5: 100082.
- ⁷J. Schlacher et al., “Towards 3D-printed alumina-based multi-material components with enhanced thermal shock resistance,” *J. Eur. Ceram. Soc.* 2024, 44(4): 2294–2303.
- ⁸J. Schlacher et al., “Thermal shock resistant 3D-printed ceramic components through spatially tailored porosity,” *Addit. Manuf.* 2024, 96: 104582.
- ⁹A.-K. Hofer et al., “High-strength lithography-based additive manufacturing of ceramic components with rapid sintering,” *Addit. Manuf.* 2022, 59: 103141.
- ¹⁰T. Prötsch et al., “Bio-inspired damage-tolerant alumina-based layered ceramics through rapid sintering,” *J. Am. Ceram. Soc.* 2025, 108(11): e20706.

*All references verified as of April 30, 2026. ■



Tackling SiC manufacturing challenges for a sustainable future



Credit: Seana Wood, Materials Research Institute, Penn State

Members of the recently formed Silicon Carbide Innovation Alliance during the group's kick-off meeting in March 2025.

By Joshua Robinson, Tekin Ozdemir, and David Fecko

Silicon carbide (SiC) has evolved from a niche ceramic material into a foundational platform for power electronics, extreme-environment components, and high-efficiency energy systems.

Its wide bandgap, high thermal conductivity, and superior breakdown field make SiC the material of choice for next-generation power devices—enabling lighter, smaller, and more efficient converters for electric vehicles, renewable energy systems, rail transportation, military and aerospace technologies, and advanced data centers through device integration. Beyond electronics, SiC's exceptional hardness, wear resistance, and high-temperature stability continue to drive its adoption in structural ceramics, protective coatings, and advanced composites.

Though the unique properties of SiC position it as a cornerstone material for industries seeking performance, reliability, and sustainability under the most demanding conditions, transforming raw materials into dependable, cost-effective, and scalable SiC components remains a complex and challenging process (Figure 1). The industry faces persistent manufactur-

The manufacturing challenge: Purity and defect control

Producing large-diameter, low-defect SiC boules for high-yield wafering remains one of the industry's most significant hurdles. Physical vapor transport crystal growth requires precise control of thermodynamics, mass transport, and thermal gradients within ultrahigh-temperature furnace conditions that can easily introduce defects such as dislocations, basal plane stacking faults, and the lingering issue of micropipes. Although micropipe densities have been greatly reduced, the focus has now shifted to managing extended defects and ensuring epilayer quality at scales relevant to device performance. ■

ing obstacles, ranging from crystal defects and stringent purity requirements for electronic-grade wafers to densification challenges and advanced joining techniques for ceramics. (Learn more about these challenges in the sidebar “The manufacturing challenge: Purity and defect control.”) These hurdles directly impact yield, cost, and consistency across the supply chain.

Fortunately, the new Silicon Carbide Innovation Alliance (SCIA), based at The Pennsylvania State University, offers

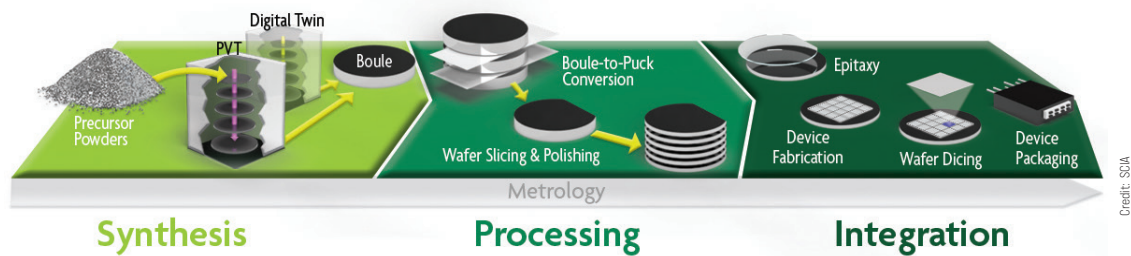


Figure 1. Illustration showing the steps to SiC synthesis, processing, and device integration. Manufacturers face various challenges at each step of the process.

industry partners a unique opportunity to codevelop strategies aimed at improving usable wafer yield and reducing overall energy requirements.

Mission and scope of SCIA

SCIA was established in July 2025 to accelerate innovation and deployment of SiC wafers through shared infrastructure, global collaborative research, and workforce development (see sidebar “SCIA objectives”). Because SCIA’s research priorities were co-designed with industry members, it addresses real manufacturing pain points across the SiC value chain—improving crystal quality and yield while reducing cost and material waste.

SCIA is committed to advancing a deep understanding of SiC and related manufacturing materials to enable breakthroughs in SiC-based semiconductor technologies. A cornerstone of this effort is the onsemi Silicon Carbide Crystal Center (SiC3) at The Pennsylvania State University, established through close partnership with Hudson, N.H.-based semiconductor manufacturing company onsemi to tackle shared challenges in crystal quality, scalability, and manufacturing efficiency.

The onsemi SiC3, pictured in Figure 2, is the only open-access SiC materials research laboratory in the United States, representing a major leap forward in SiC crystal growth and processing R&D. By working side-by-side with industry scientists and engineers, SCIA ensures that advances made at the onsemi SiC3 at Penn State translate directly into improved industrial processes with reduced scrap and energy intensity.

Beyond growth and processing, SCIA leverages the world-renowned capabilities of the Penn State Materials Research Institute (www.mri.psu.edu) and collaborates with centers, such as the Center for Quantitative Imaging within Penn State’s Institute of Energy and Environment, to access high-end microscopy, diffraction, spectroscopy, and computerized tomographic imaging of grown boules and wafers.

Enabling the future of SiC manufacturing

By fostering global partnerships and leveraging advanced facilities, SCIA ensures that innovation in SiC manufacturing translates into real-world impact across industries worldwide. SCIA invites industry and academic institutions to join the alliance and strengthen the nation’s leadership in SiC research and production by visiting <https://scia.psu.edu/welcome-silicon-carbide-innovation-alliance>.



Figure 2. The onsemi Silicon Carbide Crystal Center (SiC3). It is equipped with three 150 mm and one 200 mm physical vapor transport growth furnaces, a Boule Pro 200AX CNC grinder, an ENGIS surface grinder, an Accretech edge grinder, a SOMOS IWT diamond wire cutter, a SOMOS double-side polisher, and an AXUS scrubber—enabling full industry-grade wafer production.

SCIA objectives

SCIA focuses on four key objectives to strengthen U.S. leadership in SiC research and production:

- **Be the nation’s SiC research center:** Utilize the onsemi SiC3’s growth, processing, and metrology capability to serve as the national resource for advancing SiC crystal science.
- **Strengthen the academic-industry ecosystem:** Partner with member companies to jointly define research priorities, accelerate manufacturing-relevant discoveries, and translate advances into more efficient production pathways.
- **Enhance the semiconductor workforce pipeline:** Implement comprehensive training programs for SiC crystal growth, processing, and metrology across all academic levels—from associate degrees to Ph.D.s—while building a robust workforce development pipeline.
- **Create specialized curriculum:** Design curriculum ensembles that enable students to earn certificates or academic minors focused on SiC and wide-bandgap semiconductor theory and experimentation. ■

About the authors

Joshua Robinson is director, Tekin Ozdemir is operations director, and David Fecko is industry liaison officer of the Silicon Carbide Innovation Alliance (State College, Pa.). Contact Fecko at dlf5023@psu.edu. ■



Credit: Precious / Shutterstock

From campus to commerce: Four things every academic inventor needs to know

By Randy B. Hecht

Knowledge can be its own reward—
or the gateway to a discovery with
commercial potential.

Creating something that may have market value introduces academics to unfamiliar territory in the business world. How they navigate that territory depends in part on the role they are prepared to play in a fledgling enterprise.

“In academics, our end goal is generally publications, and those are important. It lets us build up the basic science knowledge base,” says Brian Gorman, professor and Faculty Startup Fellow at Colorado School of Mines. He founded the low-carbon building materials company Minima Scientific PBC in 2021 and serves as its chief technology officer. “The gap to commercialization is not easily bridged, mostly because, as academics, we don’t think that way. Changing the mindset is the first big challenge.” Once that mindset hurdle is cleared, the paperwork—and networking—begins.

STEP 1: ESTABLISHING AND FORMALIZING OWNERSHIP

The United States Patent and Trademark Office recognizes six types of intellectual property (<https://ipidentifier.uspto.gov>). These types include design patents, which protect “a new,

original, and ornamental design for an article of manufacture,” and utility patents, which protect “an invention that is a new and useful process, product (machine, article of manufacture, or composition of matter), or any new and useful improvement thereof.”

University employees may own their inventions outright or may have to share ownership (including patents, licensing fees, and profits from a business) with the university and any corporate joint venture partners or underwriters of their research.

“If you use their tech transfer office, the university owns a more significant portion,” Gorman says. “They are paying for the lawyers, for their own staff to help you interface with the lawyers, and to help you write your first disclosures.” On the upside, that means a professor who is new to all this will not have to learn every part of the process from the ground up.

STEP 2: SPEAKING ‘INVESTOR,’ TEAMING WITH EXPERTS

Inventors who are immersed in the science and technology universe may need support explaining their breakthroughs in a way that is meaningful to investors.

“The audience at a scientific conference is going to be interested in how you got this amazing performance by doing this to the material. Investors couldn’t care less,” Gorman

says. “They want to know things like, ‘What’s the market for this invention?’ ‘Is there a market for it?’ ‘How much can you charge if you bring this new material to market?’ and ‘How long would it take you to get it to market?’”

Telling the right story may require support in shifting the narrative from information about the properties of a new material or the process that created it to straight talk about the benefits the invention delivers and its commercial potential.

STEP 3: FINDING FINANCING, NEGOTIATING TERMS

Investors may be drawn to an invention’s scientific value or potential to benefit people or the planet—but they are still going to seek a return on their investment, and they may want a role in operations.

Angel investors are typically individuals who provide capital to early-stage startups in return for an ownership stake in the venture. Depending on their interests, sectors of focus, and expertise, angel investors may provide input on product development, business model and strategy, networking, developing a customer base, and other commercial concerns. They can be valuable advisors and partners in the business venture, but it is important to clarify the terms of the relationship up front.

Investment can also come in the form of an agreement with an established business that can take on manufacturing and distribution costs within its existing operations.

“I made this awesome product in my kiln in my garage, and that was great, but I didn’t know the next piece. I didn’t know how to make a billion bricks a year. So, I knocked on the door at a brick factory, and now they’re my manufacturing partners,” Gorman says.

“When you calculate how much capital you need to build a brick factory, to build a powder processing facility, to build a glass plant, whatever it is, you’ll realize quickly that you need manufacturing help. You need partners,” he adds. Having that partnership in place also made his pitch for capital investment more credible.

STEP 4: CHOOSING YOUR ROLE IN THE ENTERPRISE

Some inventors uncover their inner entrepreneur. Others want to go back to the lab and leave the business administration and project management to people born for those roles. Gorman took the latter path. Serving as Minima’s CTO instead of running the company frees him to continue pursuing additional projects, one of which he estimates is “halfway to commercialization.”

He sees an analogy between spotting different kinds of talent in the classroom and finding the right professionals to manage the business aspects of the start-up.

“I’ve been doing my faculty job for 22 years. I know who will be a great grad student and who should probably go into industry instead,” he says. “You need to shift that skill from the lab to a production mindset. Put together the same great team you put together in your academics. You’re great at science. Get out of the way and let the business people do their thing.”

RESOURCES FOR ENTREPRENEURIAL ACADEMICS

If you are a faculty member or laboratory researcher thinking about launching a start-up, it is best to begin by reviewing the protocols your university already has in place for commercializing products or solutions invented on campus. The resources below provide additional support for those pursuing start-up ventures.

The United States Patent and Trademark Office Inventor and Entrepreneur Resources page provides an overview of types of intellectual property and how to protect ideas and inventions. There is also a guide to the patent process, information about reduced patent filing fees, and a searchable map of Patent and Trademark Resource Centers, “which offer free public access to products and services, patent and trademark training, and reference assistance.” Another web page offers drop-down menus about “federal funding to support your innovation” and “commercialization resources for small and minority-owned businesses.” Learn more: <https://www.uspto.gov/learning-and-resources/inventors-entrepreneurs-resources>

The U.S. Small Business Administration operates a nationwide network of Small Business Development Centers that provide free counseling and training in support of start-ups as well as established small businesses that are planning to expand. Search for SBDCs by zip code: <https://www.sba.gov/local-assistance/resource-partners/small-business-development-centers-sbdc>

SCORE is a volunteer organization that provides executives as mentors to start-ups and existing businesses. Its Business Planning & Financial Statements Template Gallery covers “business planning, finance, sales, marketing, and management, designed to assist you in developing strategies for either launching a new business venture or expanding an existing one.” Learn more: <https://www.score.org>

In the article “What to look for in an angel investor,” J.P. Morgan explains the difference between generalists and specialists and provides guidance on conducting due diligence on prospective investors. Learn more: <https://bit.ly/3OZ4ERw>

Early-stage entrepreneurs also have the option of entering into an agreement with a start-up accelerator that takes an equity stake in the enterprise in return for mentoring and funding. Silicon Valley Bank provides an overview of how they work, how they differ from start-up incubators, and how to evaluate accelerators as prospective business partners. Learn more: <https://bit.ly/4wcqKkb>

ABOUT THE AUTHOR

Randy B. Hecht is founder and owner of Aphra Communications (Brooklyn, N.Y.). She works extensively with clients in Europe, Asia, and the Americas on materials science content produced for global audiences. She has written The American Ceramic Society’s annual report on international ceramics and glass markets since 2009. Contact Hecht at rbhecht@aphra.com. ■

Durable and programmable metasurfaces enabled by phase change materials

By Cosmin-Constantin Popescu

Credit: DesignPoint69 / Shutterstock

Controlling light with high spatial precision enables technologies ranging from imaging and sensing to communications.

Traditionally, optical components such as lenses and filters rely on bulk materials and fixed geometries, which limit their ability to adapt dynamically. Metasurfaces offer a fundamentally different approach. These materials consist of planar arrays of subwavelength structures that locally control the phase, amplitude, or polarization of light. In essence, each “pixel” of a metasurface can be engineered to shape light in a prescribed way, enabling flat and compact optical systems.

A major frontier in this field is the realization of programmable metasurfaces, in which the optical response of each pixel can be dynamically reconfigured. Phase change materials (PCMs), particularly chalcogenide glasses such as $\text{Ge}_2\text{Sb}_2\text{Se}_4\text{Te}$ (GSST),¹ are promising candidates for this purpose. These materials can reversibly switch between amorphous and crystalline states, accompanied by large changes in optical properties, while retaining their state without continuous power input.

Despite these advantages, practical implementation remains challenging. Most demonstrations have been limited to single elements or small arrays, and device lifetimes are often restricted to tens or hundreds of switching cycles.² These limitations arise from coupled materials and device-level issues, including thermal stresses, interfacial instability, and compositional changes during repeated phase transitions. Addressing these challenges requires a detailed understanding of the failure mechanisms and their interaction with device architecture.

Failure mechanisms in chalcogenide PCMs

To study the degradation in optical PCMs systematically, we developed an experimental platform that combines automated electrical cycling with in-situ optical monitoring.³ This approach enables real-time tracking of phase transitions, morphology evolution, and optical response during repeated switching, providing direct insight into degradation pathways.

The observed failure mechanisms can be grouped into three categories: extrinsic, interfacial, and intrinsic, as summarized in Figure 1.⁴ This framework provides a useful materials-centric lens for understanding device degradation.

Materials-informed design of PCM metasurface

The identification of the failure mechanisms informed the design of a more robust metasurface architecture.⁵

From a structural standpoint, we introduced a patterned, fishnet-like geometry in the PCM layer.⁶ While this geometry supports guided-mode optical resonances that enhance light-matter interaction, it also serves a mechanical function. The patterned openings act as anchor points that improve adhesion between layers, reducing the likelihood of delamination.

Materials processing was also modified to improve stability. Instead of conventional plasma-enhanced chemical vapor deposition, silicon nitride capping layers were deposited by reactive sputtering, resulting in denser films with reduced hydrogen content and improved thermal robustness. The thickness of this layer was optimized to balance mechanical protection with optical transparency.

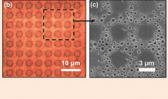
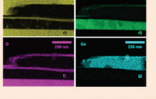
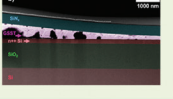
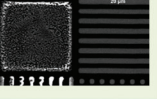
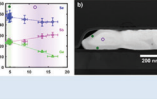
The thermal and electrical designs were co-optimized. Pixel spacing was selected to balance thermal crosstalk, fill factor, and current density constraints. The interconnects were engineered to carry the required current without excessive heating, and transition regions were introduced to shield electrodes from elevated temperatures. More stable electrode materials, such as tungsten, were used to improve reliability. In addition, improving thermal uniformity within each pixel helps suppress compositional segregation, linking device design directly to intrinsic material stability.

Programmable metasurface pixel array example

Using these design principles, we demonstrated a 2D array of independently addressable metasurface pixels operating in the mid-infrared. Representative images of the fabricated devices and their operation are shown in Figure 2.⁵

The metasurface array, shown in Figure 2a, consists of densely packed pixels integrated with heaters and selector elements that enable individual electrical addressing. The packaged chip, shown in Figure 2b, highlights the practical integration of the device onto a measurement platform suitable for optical testing.

The functional capability of the system is illustrated in Figure 2c, where different subsets of pixels are programmed into distinct phase states to produce spatially varying optical transmission patterns. By switching selected pixels between

Extrinsic		Interface		Intrinsic
Capping layer failure	Metal contact failure	Delamination	Dewetting	Elemental segregation
				
Cause <ul style="list-style-type: none"> Fracture of the capping layer likely due to PCM volume change H dissociation Mitigation <ul style="list-style-type: none"> Bi-layer capping with increased thickness H-free capping film 	Cause <ul style="list-style-type: none"> Thermal migration of the contact metal Mitigation <ul style="list-style-type: none"> Multilayer diffusion barrier Heater design with reduced temperature at the contacts 	Cause <ul style="list-style-type: none"> PCM volume change during crystallization Poor adhesion between PCM and the heater Mitigation <ul style="list-style-type: none"> 'Fishnet' structure to provide anchor points Adding a wetting layer 	Cause <ul style="list-style-type: none"> Morphological instability in liquid phase during amorphization Mitigation <ul style="list-style-type: none"> Adding a wetting layer 	Cause <ul style="list-style-type: none"> Incongruent melting Mitigation <ul style="list-style-type: none"> Single-phase PCM up to the liquidus line Liquid-phase homogenization Heater with better thermal uniformity

Credit: C.-C. Popescu et al., Adv. Opt. Mater. (CC BY 4.0)

Figure 1. Summary of failure mechanisms in chalcogenide optical phase change materials and their mitigation strategies. The failure modes are categorized as extrinsic (capping layer failure, metal contact failure), interface (delamination, dewetting), and intrinsic (elemental segregation). Images compiled from Reference 4.

Conclusions

By integrating materials characterization, device design, and scalable fabrication, we developed a durable and programmable metasurface platform based on PCMs. More broadly, this work illustrates how materials-level phenomena directly govern the performance and reliability of functional photonic systems. The classification of degradation pathways provides a general framework for understanding failure in phase-change materials under repeated thermal cycling, while the device demonstration shows how these insights translate into improved system-level performance.

About the author

Cosmin-Constantin Popescu is a senior staff engineer at the startup 2Pi Inc. (Cambridge, Mass.) He graduated from Massachusetts Institute of Technology in May 2025. Contact Popescu at popescu.cosmin@hotmail.com.

Editor's note

Popescu will present the 2026 Kreidl Award Lecture at ACerS Annual Meeting at MS&T in October 2026. Learn more about the conference at <https://www.matscitech.org/MST26>.

References

- Y. Zhang et al., "Broadband transparent optical phase change materials for high-performance nonvolatile photonics," *Nat. Commun.* 2019, 10: 4279.
 - Y. Zhang et al., "Electrically reconfigurable non-volatile metasurface using low-loss optical phase-change material," *Nat. Nanotechnol.* 2021, 16: 661.
 - C.-C. Popescu et al., "An open-source multi-functional testing platform for optical phase change materials," *Small Science* 2023, 3(12): 2300098.
 - C.-C. Popescu et al., "Understanding and circumventing failure mechanisms in chalcogenide optical phase change material Ge₂Sb₂Se₄Te," *Adv. Opt. Mater.* 2025, 13(8): 2402751.
 - C.-C. Popescu et al., "2D addressable mid-infrared metasurface spatial light modulator," *arXiv* 2025, 2511.03583.
 - C.-C. Popescu et al., "Electrically reconfigurable phase-change transmissive metasurface," *Advanced Materials* 2024, 36(36): 2400627.
- *All references verified as of May 12, 2026. ■

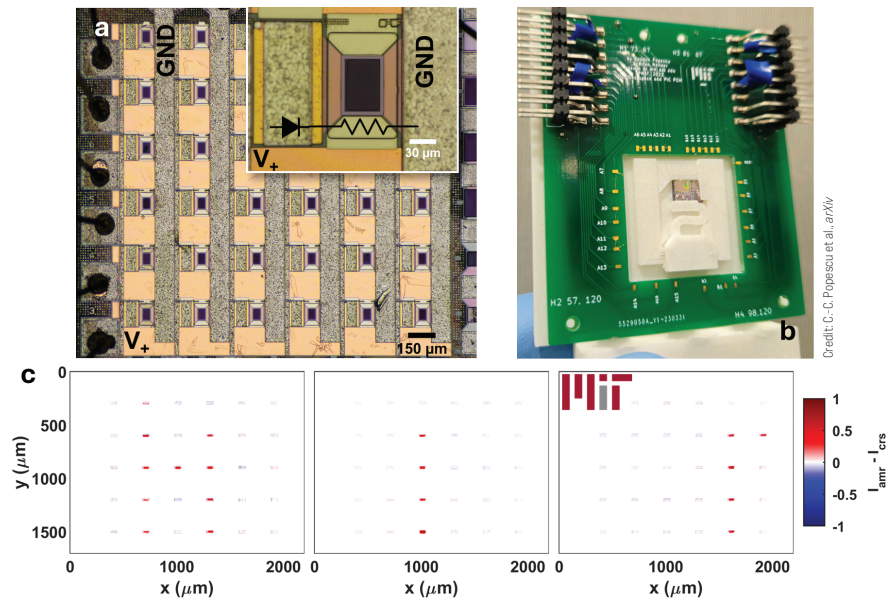


Figure 2. (a) Optical micrograph of the fabricated array, with the inset showing a single pixel consisting of a heater and selector diode. (b) Photograph of the packaged chip wire-bonded onto a custom printed circuit board carrier designed for transmissive optical measurements. (c) Difference between background images, set amorphous/high transmission at 2,585 nm, and images with specific pixels set crystalline/low transmission spelling "M," "I," and "T." Images compiled from Reference 5.

amorphous (high transmission) and crystalline (low transmission) states, arbitrary 2D images can be encoded directly into the metasurface. Optical characterization reveals transmission contrast exceeding 40%. Electrical switching is achieved using longer, lower-voltage pulses for crystallization and shorter, higher-voltage pulses for amorphization. Endurance testing demonstrates stable operation for more than 16,000 switching cycles, representing a substantial improvement over prior PCM metasurface devices.



Alfred University
OUTSIDE of ORDINARY

**Alfred University engineers imagine
the future and make it happen.**

Ideas become the inventions, solutions and
breakthroughs to solving tomorrow's challenges.



Alfred University
NEW YORK STATE COLLEGE OF CERAMICS

CACT Center for
Advanced
Ceramic
Technology

Meet Alfred University Graduate Students



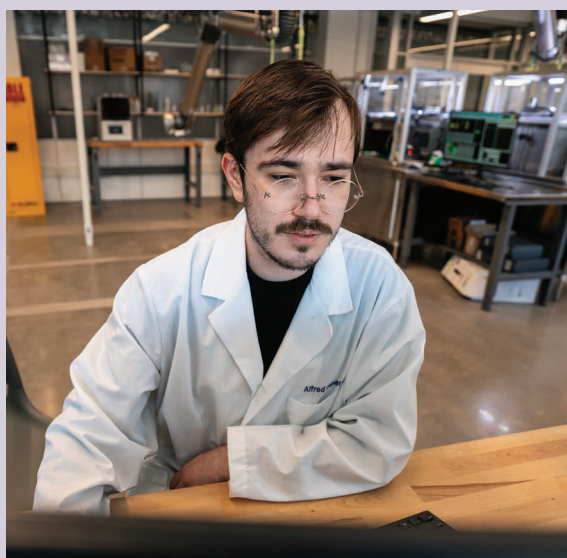
Montana Weidman

Montana Weidman is a master's student in Materials Science and Engineering at Alfred University, continuing from her undergraduate degree in the same field. Mentored by Drs. Scott Misture and Collin Wilkinson, her work centers on additive manufacturing of fully dense silicon carbide ceramics. She focuses on tailoring slurry rheology to optimize sintering and microstructure. Montana is also active in outreach and mentorship, and plans to pursue a PhD in ceramic and glass engineering.



Danielle Perry

Danielle Perry is a PhD candidate in Materials Science and Engineering at Alfred University, where she has also earned bachelor's degrees in Biomaterials Engineering and Biology, and a master's in Biomaterials Engineering. Her research focuses on bioactive glass composites doped with therapeutic ions for tissue repair, particularly ACL injuries. Danielle's work combines bioactive glass with biodegradable polymers for 3D printing, with the goal of advancing healthcare materials and applications.



Cooper Howard

Cooper Howard is a PhD candidate in Ceramic Engineering at Alfred University, holding both bachelor's and master's degrees in the field. Advised by Dr. Scott Misture, his research explores pressureless sintering of ultrahigh temperature ceramics, with a focus on silicon carbide and the role of boron as a sintering aid. He is passionate about advancing ceramic processing methods and plans to pursue a career in teaching and materials research mentorship.



Lauren Meyer

Lauren Meyer is a first-year PhD student in Glass Science at Alfred University, working under Dr. Collin Wilkinson. With a background in Physics, Mathematics, and Computer Science from Coe College, Lauren specializes in computational glass research. Lauren's work uses molecular dynamics simulations and statistical mechanics to predict temperature-dependent viscosities of glasses. This research aims to accelerate the development of novel glass systems by reducing the reliance on time-intensive experimental methods.

WELCOME TO THE 'EMERGING PROFESSIONALS' ISSUE

By Randi Swanson



The ceramics and glass community sits at the center of some of today's most important and rapidly evolving industries. From energy and medicine to infrastructure and aerospace, ceramics enable technologies that shape how we live and work.

As these types of industries continue to evolve, supporting them

requires not only materials innovations but also investing in the people who drive innovation. That is why this year's theme for the June/July *ACerS Bulletin*, "Supporting ceramic industries," is ultimately about people. It is about preparing students and early-career professionals to step into complex, evolving, and often uncertain roles to make meaningful and necessary contributions.

As a student myself, I know firsthand that navigating this path can feel overwhelming. That is where ACerS, and specifically the President's Council of Student Advisors (PCSA), plays such an important role. The PCSA is built around the idea that students should not have to figure the interpersonal aspects of science out alone. Over the past year, our delegates have worked to create opportunities that make the ceramics community more accessible, more engaging, and more supportive for students at every stage.

- **The Conference Programming & Competitions Committee** advanced student engagement through both in-person and online competitions, equipping students with practical insights and skills needed to support ceramic industries. Learn more about this year's new event—the Glass Strengthening Competition—on page 43.
- **The Professional Development Committee** expanded career development through IGNITE MSE, including a Kennedy Space Center visit before ICACC 2026 that highlighted high-temperature reentry materials.
- **The Education Committee** strengthened the future ceramics workforce by engaging K-12 students through new outreach materials, classroom resources, and Scouts of America merit badge development, introducing materials science early to support long-term ceramic industries.
- **The Recruitment and Retention Committee** strengthened PCSA's inclusivity and global accessibility by reducing financial barriers for international delegates and expanding alumni engagement, ensuring a broader and more connected student community that supports the future of ceramic industries.



The 2025–2026 PCSA delegates at the PCSA annual meeting in September 2025.

Credit: ACerS

- **The Communications Committee** brought new energy to how we share these stories through growing social media, video, and outreach initiatives that highlight both the science we do and the people behind it.

The "Emerging Professionals" section of the June/July *Bulletin* is a yearly expansion on the PCSA's commitment to student development. Coordinated by the Communications Committee, this section consists of three parts:

1. **Research articles:** Three full-page articles describing research based on this issue's theme, "Supporting ceramic industries." These articles are contributed by Material Advantage, Graduate and Doctoral Student, and Young Professionals Network members.
2. **Science for Society articles:** This two-page spread features three stories on the IGNITE MSE poster topics of technology for social good; outreach and community engagement; and inclusivity, diversity, and ethics in research.
3. **Future Focus articles:** Two full-page articles contributed by ACerS members and staff exploring the importance of hope and resilience in research and the benefits of hands-on learning.

I hope you enjoy this thought-provoking look at the next generation of young professionals in the field.

Randi Swanson is a Ph.D. candidate at the University of California, Davis, studying in the McCormack research group. As the 2025–2026 PCSA Council Chair, she has worked to identify and sustain high-impact PCSA initiatives, lowering operational barriers so committees have the bandwidth to develop new, creative ideas and programs. ■

The Material Advantage Student Program offers students membership benefits and access to The American Ceramic Society (ACerS), Association for Iron & Steel Technology (AIST), ASM International, and The Minerals, Metals and Materials Society (TMS). Learn more at <https://ceramics.org/material-advantage>.

Experiential learning: Developing the next generation of engineers

By Ryan Eaton



When a measure becomes a target, it ceases to be a good measure. Goodhart's law, coined in reference to monetary policy, is readily applicable to engineering education. When students begin optimizing their study habits to pass an exam rather than understanding and applying the material in the real

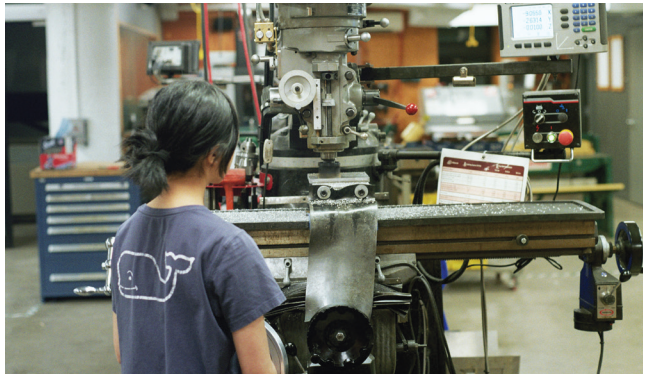
world, we risk producing graduates who are good at being students but do not know what it means to be an engineer.

With the ubiquity of the internet and increasing access to large language models, traditional lecture and exam structures fall short in their ability to instill the traits of hard work, initiative, and creative qualities that differentiate an effective engineer from someone who only knows how to Google. In contrast, experiential and activity-based learning methods are known to result in better student engagement and outcomes.¹

In my experience, one of the most effective ways to facilitate experiential learning is through makerspaces, or collaborative, community-driven workspaces designed for hands-on experimentation and learning. The makerspace at Case Western Reserve University (CWRU) is called Sears think[box]. This publicly accessible, free-to-use space hosts more than \$5 million of equipment across seven floors, ranging from 3D printers and laser cutters to mills and waterjets. The only barriers to building and creating are your own effort, initiative, and creativity.

During my four years at CWRU, I have made extensive extracurricular and curricular use of think[box]. My former use comes primarily from being a competitor in the Baja SAE design competition, which challenges student teams to design and build off-road vehicles.² During my first two years at CWRU, I spent countless hours laying up carbon fiber panels; applying coatings to molds, frames, and components; and helping component designers with materials selection and manufacturing considerations (Figure 1).

My curricular engagements with think[box] have been as a student and teaching assistant in several lab courses. These courses made use of think[box]'s resources to enable complex hands-on learning experiences in topics ranging from stereolithography to metal sintering to computer-aided design. From a teaching perspective, the engagement these activities encourage is invaluable because you can intuitively see which students are on track and which need more attention to help them succeed. Having been a teaching assistant for lecture-based



Credit: Shelley Wei

Figure 1. CWRU Baja SAE team member Shelley Wei using a manual mill in Sears think[box]'s fabrication floor metal shop.

courses as well, I can attest that assessing how well a student is doing with tests and homework alone is far more difficult. A bad score on a test or missing homework could just mean a bad day, and large language models paired with the unreliability of artificial intelligence checkers make academic integrity something you hope for but cannot easily verify.

Beyond being a productive learning environment, having easy access to fabrication tools through think[box] enables more demonstrations and experimental setups. I have used think[box] to do everything from fabricating sample holders for glass ion-exchange experiments to using the band saw to prep metal stock for casting demonstrations. Beyond lab courses, I have had professors who used think[box] to make models that help explain everything from interstitial sites in crystal lattices to the concept of measurements in quantum mechanics.

My own research is on making nanosheets, a scale at which the laser cutters and computer numerical control mills available at think[box] are not particularly useful. But I know colleagues whose research would have been far more expensive and logistically challenging were it not for think[box].

There are many challenges ahead across various industrial sectors, but by developing and supporting hands-on learning resources, we can successfully train the next generation of hard-working, initiative-taking, creative engineers.

References

¹R. Gavillet, "Experiential learning and its impact on college students," *Texas Education Review* 2018, 7(1): 140-149.

²Baja SAE, <https://www.bajasae.net>

Ryan Eaton is a May 2026 graduate of Case Western Reserve University with a B.S. in materials science and engineering. This fall, he will begin pursuing an M.S. in materials engineering at the University of Illinois Urbana-Champaign. Aside from his nanosheet research and serving as a teaching assistant, Ryan is a jazz pianist, habitual hobbyist, generally outdoorsy fellow, and far too busy. ■

Graduate and Doctoral Student membership addresses the professional and career development needs of graduate and doctoral-level research students who have a primary interest in ceramics and glass. Learn more at <https://www.ceramics.org/gds>.

Vitrification of nuclear waste: The case of chlorine

By Yanis Daoud



Nuclear energy allows France to have one of the least carbon-intensive electricity grids in the world.¹ However, this method of power generation remains controversial, in part due to the question of nuclear waste.

Currently, vitrification, i.e., the melting of nuclear waste with glass frit to produce a stable amorphous waste form, is the most common method to treat this waste. There are industrial-scale vitrification plants deployed in most countries operating nuclear plants, yet where this waste will be stored in the long term remains an open question.

In France, the current plan is to encapsulate the vitrified waste in metal containers and store it 500 meters underground. But before this waste can be put underground, researchers must ensure that the material is stable in the chemical environment it is likely to encounter. As such, both its homogeneity and durability require thorough examination.

Some common elements contained in nuclear waste can lead to issues with the vitrification process or the waste's stability. For example, volatile radionuclides such as chlorine, fluorine, and sulphate are difficult to vitrify. Having a better understanding of these complex atoms and their impact on the vitrification process would greatly help the nuclear industry deal with its waste.

As part of Daniel R. Neuville's group at the Institute of Earth Physics of Paris and Laurent Cormier's group at Sorbonne University, I focus on one particular volatile: chlorine. Specifically, the radioactive beta emitter ³⁶Cl is generated during the reprocessing of spent nuclear fuel or found in the graphite of first-generation nuclear power plant reactors. More ³⁶Cl may be produced in the future, as some new reactors use chlorine-containing salts as a heat carrier.³

Currently, borosilicate glasses are used to vitrify nuclear waste worldwide, but these glasses present low solubility levels for chlorine. Studies on numerous other borosilicate and aluminosilicate compositions also struggled with relatively low solubility or were too difficult to implement at a larger scale.

The iron-phosphate glass system is another possibility because these glasses present a high chemical durability in aqueous solutions and a high tolerance to volatiles.² However, they can be corrosive to the refractories used in the melter, which can lead to operational issues.

My project explores these and other glass compositions to overcome the challenges with chlorine incorporation. My work

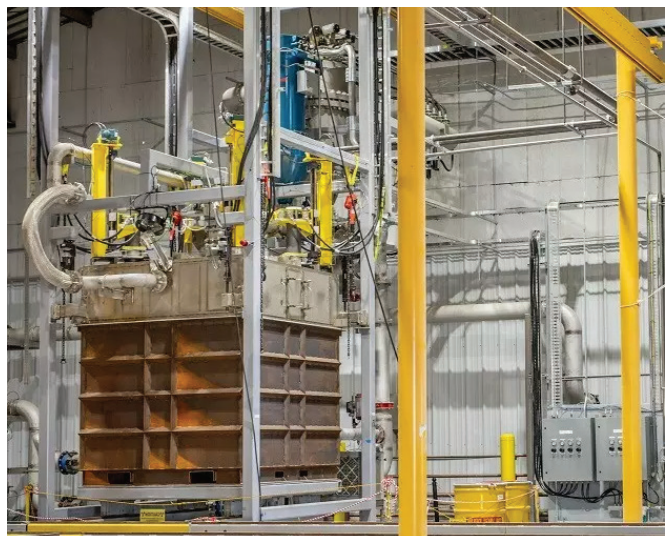


Figure 1. Geomelt® melter in Andrews, Texas.⁴ It is used to melt radioactive waste coming from Idaho National Laboratory.

is supported by Veolia Nuclear Solutions, which is developing a vitrification process called Geomelt® (Figure 1).⁴ In this process, the glass melt is heated by the Joule effect, using four graphite electrodes plunged into the batch. Because Veolia's solution involves cooling the glass down in the crucible, it removes the need to pour the glass as well as the need for corrosion-resistant refractories, as the crucible will be used only once.

By studying how chlorine incorporates in glass, as well as how it affects durability and the glass network, I hope to help handle chlorine-containing waste in a way that ensures both environmental safety and public acceptance of nuclear energy.

References

- ¹B. W. Ang and B. Su, "Carbon emission intensity in electricity production: A global analysis," *Energy Policy* 2016, **94**: 56–63.
- ²C.-W. Kim and D. E. Day, D. E. "Immobilization of Hanford LAW in iron phosphate glasses," *Journal of Non-Crystalline Solids* 2003, **331**(1–3): 20–31.
- ³L. Xiao et al., "Fuel supply and synthesis/fabrication needs, issues, and options for a generic 300-MWe-class molten stable salt small modular reactor in Canada," *Journal of Nuclear Engineering and Radiation Science* 2026, **12**(2): 021301.
- ⁴"Hazardous waste: Veolia starts operations of a state-of-the-art Geomelt® nuclear waste vitrification facility in Texas to treat legacy waste," Veolia Nuclear Solutions. Published 20 Dec. 2022. <https://bit.ly/3R9Icpf>

Yanis Daoud is a Ph.D. student in materials science at the Institute of Earth Physics of Paris. His research focuses on chlorine incorporation in glass and its effect on physical and chemical properties. Outside of his studies, Yanis likes hiking, climbing, and spontaneous adventures. ■

ACerS Young Professionals Network (YPN) aims to provide support, community, and leadership opportunities to members as they transition from students to successful professionals in the broader ceramics society. Learn more at <https://ceramics.org/ypn>.

Empowering emerging researchers: Cements Division Rising Star Webinar Series

By Alessandra Fujii Yamagata



Emerging professionals often struggle to promote their research, while companies frequently face difficulties connecting

with the budding talent who bring new ideas and a vision to advance. The Rising Star Webinar Series by ACerS Cements Division helps answer both needs.

This series was launched in 2023 by then Cements Division Young Professionals Network (YPN) liaison Juan Pablo Gevaudan, assistant professor of architectural engineering at The Pennsylvania State University. The idea was to offer opportunities for young cements researchers to gain visibility on their excellent work.

As of April 2026, nine young researchers have presented talks on a range of recent advancements in cement-based materials (Figure 1), including alternative binders, supplementary cementitious materials, advanced characterization techniques, and concrete 3D printing. The series has not only provided visibility to these emerging professionals, but it has also provided a platform for industry professionals and attendees from other ACerS Divisions to connect.

The presentations are given live through Zoom, followed by a Q&A session, where the audience can ask questions and interact with the presenter. Some of the webinars have drawn up to nearly 80 live viewers, and the feedback is highly positive.

For example, attendees have said that watching these high-quality presentations awakens their excitement and curiosity for the various topics covered. This effect



Credit: Yamagata

Figure 1. The nine speakers who have participated in the Rising Star Webinar Series so far. Top row, from left: Erika La Plante (University of California, Davis), Chengcheng Tao (Purdue University), Agnieszka Jędrzejewska (Silesian University of Technology), and Nishant Garg (University of Illinois Urbana-Champaign). Bottom row, from left: Chelsea Heveran (Montana State University), Matthew Asmussen (Pacific Northwest National Laboratory), Juan Pablo Gevaudan (The Pennsylvania State University), Hee-Jeong Kim (University of Arizona), and Cesar Romano (University of São Paulo).

is especially true for those attending the webinars for the first time, and many students have been convinced to attend the Cement Division's annual meeting, *Advances in Cement-Based Materials*, held every summer.

Ultimately, the Rising Star Webinar Series is all about expanding connections within the ceramics community. A prime example of this impact is Agnieszka Jędrzejewska, associate professor and deputy head of the Department of Structural Engineering at Silesian University of Technology in Poland. She gave a talk on hydration-induced cracking in February 2025, and afterward, another professor who attended the webinar reached out to her. This connection turned into a collaboration that only 10 months later yielded a publication in the *Journal of Building Engineering* as well as an open database of laboratory and field cases. This example demonstrates that the structure of the webinar series is on the right track.

When I became the Cements Division YPN liaison in 2024, the former liaison held a one-on-one meeting

with me to clarify the role and suggest achievable goals, including growing the Rising Star Webinar Series. When I step down from this role in September 2026, I plan to do the same by helping the next liaison feel welcome and included.

Since the Rising Star Webinar Series began, we have seen other YPN liaisons initiate their own webinar programs to promote their Division's young professionals. I am proud that the Cements Division has inspired and supported the ACerS YPN program as a whole—we look forward to developing more initiatives that inspire the community!

View recordings of previous Rising Star Webinar Series events at <https://ceramics.org/education/webinars>.

Alessandra Fujii Yamagata serves as R&D manager for Chryso North America, part of Saint-Gobain's Construction Chemicals Division. She drives innovation in developing advanced chemical technologies that address the cement and concrete industries' challenges. Outside work, she enjoys ice skating and trying new restaurants. ■

IGNITE MSE: Igniting student passion for materials research

For many ACerS members, their passion for materials research is driven by a desire to create a positive impact on society through their scientific endeavors. ACerS student members can share this passion at ACerS conferences through IGNITE MSE, a special student professional development event organized by the Ceramic and Glass Industry Foundation.

IGNITE MSE poster sessions are designed to showcase the human side of research, with submissions focused on outreach and community engagement; technology for social good; and inclusivity, diversity, and ethics in research.

Drawing on this format, we have invited student-written articles from each of these topic areas for the June/July *Bulletin*. Read the articles below and learn more about IGNITE MSE by visiting <https://foundation.ceramics.org/ignite-mse>.

One small tweak to the lens of materials research, one giant leap for mankind

TECHNOLOGY FOR SOCIAL GOOD

By Rishabh Kundu and Ryan C. Eaton

One of the clearest existential threats facing humanity is anthropogenic climate change. The dire consequences to ecological stability and human prosperity if the status quo is maintained are thoroughly supported by data.¹ We as a society now stand at a crossroads—do we give up in the face of this existential threat and deal with the consequences, or do we adjust course toward a more livable future?

The good news is that humans excel at overcoming adversity, as demonstrated time and again throughout history. In many cases, the development of new materials redefined the technological and societal baselines for the better, as evidenced by human eras being named after specific material innovations (think the Stone Age, the Bronze Age).

Regarding the current threat, many of the necessary technical and material solutions are largely already in hand. Thus, we propose that the rate-limiting step for solving sustainability challenges may not be ideation but rather interdisciplinary communication and the implementation of existing tools.²

Consider life cycle assessments (LCAs). Integrating LCA frameworks into early-stage materials development allows engineers to weigh functional performance against environmental impact before a design ever reaches scale. This front-loaded approach is consequential: Sustainability trade-offs identified at the design phase are orders of magnitude cheaper to resolve than those discovered

during or after scale-up. Incorporating this concept into existing workflows makes data-backed planning for sustainability and circularity far easier for engineers as they scale up new materials systems and processing methods.

Degradation and service lifetime present a second, equally tractable opportunity. A mechanistic understanding of how and why materials fail enables the design of more durable systems, optimized maintenance schedules, and smarter replacement cycles. Every year of additional service life extracted from a component is a year of raw material extraction, processing, and emissions deferred or avoided entirely. Plus, providing digestible data for end users is critical in encouraging the use and reuse of materials, components, and whole systems. This information also helps handle systems at their inevitable end of life.

Advances in characterization techniques, sorting technologies, and process optimization are steadily making high-value material recovery more viable at scale. By planning for material end-of-life pathways with pragmatic data, it is easier to close material loops, reduce dependence on virgin feedstocks, divert waste from landfills, and accelerate the transition toward circular material flows that the economy will eventually require to operate.

None of these approaches demand a fundamental reinvention of how materials science and engineering is practiced. They are, at their core, refine-



ments—embedding sustainability metrics across an established lifecycle from synthesis to disposal. The disproportionate societal return on these incremental shifts is precisely what makes them so compelling.

The way in which we calibrate and communicate materials research will define the future. The only question worth asking now is whether we will maintain the status quo or change for the better.

References

¹“Reports,” Intergovernmental Panel on Climate Change. <https://www.ipcc.ch/reports>

²R. Kundu et al., “Evidence-based sustainable development and circularity of materials,” *Am. Ceram. Soc. Bull.* 2023, 102(7): 3.

Rishabh Kundu is a graduate student and Ryan C. Eaton is a recently graduated bachelor's student (May 2026) at Case Western Reserve University (Cleveland, Ohio). Kundu's research focuses on using data science to elucidate capacitor degradation, and he is also an active advocate for sustainability and outreach in materials science. Eaton's research at CWRU involved nanosheets, and outside of working as a teaching assistant, he is a jazz pianist, habitual hobbyist, and generally outdoorsy fellow. ■

Microwave firing: Inspiring young scientists through rapid ceramic demos

By Grace Dunham



My passion for ceramics began in middle school at a community art fair, where I first tried throwing clay on a wheel.

Unbeknownst to me, this passion would sustain my patience throughout the lengthy turnaround times common in ceramics production.

Hands-on experiential learning of ceramic processing is crucial; however, the firing step often occurs away from students. The best way I have found to demonstrate the entire ceramics production process in a space-limited, time-limited environment is by harnessing the technique of microwave firing.

Microwave firing involves installing a refractory box inside a conventional microwave. The box contains susceptors that strongly absorb microwaves and generate the thermal energy needed for firing small objects in just a few minutes.

I learned the technique of microwave firing from Holly Shulman, professor and director of the Space Materials Institute in the New York State College of Ceramics at Alfred University. She uses microwave firing to investigate creating landing pads and structures on the lunar surface, but she helped me use this technique to experiment on Egyptian faience.

Egyptian faience is a unique self-glazing material first used in the early fourth millennium BCE to create amulets, figures, beads, and other precious objects.¹ The material is heated to around 850–950°C so that the alkali-rich surface forms a melt with the bulk silicate body. Upon cooling, this melt undergoes a glass transition, and Cu²⁺ colors the glassy surface a brilliant blue.

I recently used microwave firing to create modern versions of Egyptian faience as a demonstration during Engineering Week at the Rochester Museum Science Center. Both children and guardians alike were enamored by

OUTREACH AND COMMUNITY ENGAGEMENT

the glow emanating from inside the box. I felt honored that through this one-hour demonstration, I could help inspire a love for the process, beauty, and scientific potential of ceramics, just like what I experienced the first time I touched clay.

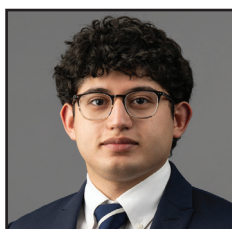
References

¹Z. Taj-Eddin, “Egyptian faience: ancient making methods and consideration of technical challenges in sculptural practice,” Ph.D. thesis, University of Westminster, 2014.

Grace Dunham is a Ph.D. candidate in ceramic engineering at Alfred University. Their work with Prof. William Carty merges materials science, artistry, and community outreach to uncover hidden secrets within early European porcelain artifacts in the Smithsonian’s collection. They are an avid rockhound and mushroom forager, exploring the state forests of western New York. ■

Shaping materials science through policy engagement

By Hossein Libre



In summer 2025, as the Pacific sunset blurred past the bus window on the way back from the beach, I found myself—as I often do—falling down a Wikipedia rabbit hole.

At the time, I was participating in an undergraduate research experience through the National Science Foundation’s Materials Research Science and Engineering Center (MRSEC) at the University of California, Irvine, studying self-assembling block copolymers. Earlier that week, my curiosity had been piqued by a conversation with my advisor regarding the funding process for all the MRSECs spread across the U.S., leading me to trade the sunset views for a foray into the history of federal funding.

Growing up and attending university in the city of Rolla, Mo., it was hard not to perceive the field of materials

science and engineering as a permanent fixture of the U.S. research and innovation landscape. But that has not always been the case. In 1958, President Dwight D. Eisenhower’s Science Advisory Committee recommended a massive coordination of materials research to ensure national competitiveness during the Cold War era. This recommendation led to a 1959 Executive Order and the eventual establishment of Interdisciplinary Laboratories in 1960, which were the direct ancestors of the modern MRSEC system. These policy decisions led to the explosion of materials science and engineering departments across the country by the 1970s.¹

This realization that science requires both a lab and legislature inspired me to try dipping my toes in the policy arena. In March 2026, I joined students from across the four University of Missouri System schools to speak directly with Missouri legislators in the state capitol. I presented my research on ceramic matrix composites and discussed the future of aerospace and

INCLUSIVITY, DIVERSITY, AND ETHICS IN RESEARCH

national defense. A month later, I met legislators during the Materials Advantage Congressional Visit Day in Washington, D.C., to advocate for the federal investments that sustain our discipline.

We as scientists often view ourselves primarily as people who create materials to enable novel technologies or solutions. But we must also be the people who help create the institutions that make this science possible.

References

¹National Research Council, *Advancing Materials Research*. The National Academies Press, 1987.

Hossein Libre is a second-year undergraduate student double majoring in ceramic engineering and chemistry at Missouri University of Science and Technology. He studies ultrahigh-temperature ceramics under Prof. Greg Hilmas and electrocatalysis under Prof. Shelley Minter. When not on campus grounds, Hossein can be found hiking, taking road trips, or playing soccer. ■

The American Ceramic Society represents all people involved in the global ceramics and glass community. Learn more about how you cultivate an environment of fair access and opportunity for all on ACerS "Promoting full participation in science" resource page at <https://ceramics.org/fostering-member-engagement>.

Hope and resilience: The unbroken thread of science

By Kartik Nemani

A quiet, powerful force has carried humanity through every epoch of uncertainty. Not technology, not policy, not even genius. It is *hope*, or the active choice to look toward a better future. And woven alongside it comes *resilience*, the stubborn refusal to stop.

Hope and resilience are perhaps the most underappreciated instruments in the scientist's toolkit. But together, they have guided civilizations through natural disasters, pandemics, and economic collapses.

The COVID-19 pandemic offers one of the most striking modern examples of these two forces' power. When conferences were canceled, collaborations severed, and laboratories shuttered for months, scientists did not simply pause—they improvised. Researchers found meaning in smaller, quieter victories: a paper finished, a new virtual collaboration, or a student mentored over a video call. When I look back now, what felt like interruption was, in many ways, a reinvention of our scientific processes to make them more adaptable to the realities of the modern world.

During the inaugural ACerS Spring Meeting in Bellevue, Wash., in April 2026, something quite remarkable happened. Tucked into the middle of busy technical symposia schedules was a roundtable discussion on the resilience of research in the United States. The session drew a full room, with attendees and panelists spanning the full range of scientific contributors, from students and early-career faculty to veteran academicians who have weathered decades of scientific funding cycles.

This kind of gathering matters more than it might seem. Science can be isolating, and the pressures of grant deadlines, publication records, and institutional metrics often make hope and

resilience feel like a private struggle. But moments such as these are what make science more intertwined and communal in spirit.

A poignant observation emerged from the discussion, one that resonated deeply with me. It was the reminder that we survived the dot-com collapse of 2001, the financial crisis of 2008, and the pandemic of 2020. So, we can survive the current deficit in federal funding for U.S. scientific research, too.

However, there is a difference between those past crises and the current uncertainty around federal funding for science. Those past events were not aimed at science itself, but the current situation strikes directly at the foundation of scientific research by questioning the value of fundamental studies.

The basic questions we ask at the lab bench today become the seeds for all applied innovations in the future. Consider the development of thermal barrier coatings. Basic research into the thermal and phase stability of yttria-stabilized zirconia in the 1970s laid the groundwork for the development of modern coatings, which today allow jet turbine blades to operate at temperatures 300°C above what the underlying metal could survive alone.

When society erodes the belief in basic science's value, we do not just delay scientific breakthroughs but sometimes compromise them entirely. As a result, there is genuine concern among today's researchers because while economic downturns correct themselves, mindset shifts can take generations to be undone.

And yet, hope is not lost because scientists are, by nature and training, adaptive. Those who lose their funding in one domain can find footing in another, emerging as phoenixes in adjacent fields. They carry their expertise into these new contexts, seeding disci-

plines they never originally intended to enter. This adaptability is not a failure of the system but an honest mirror to the intellectual versatility of the people who chose this path.

When I started pursuing a Ph.D., I found that the scientific community has always been more than its funding lines. It is a culture, a set of values, a commitment to truth-seeking that outlasts any particular political or economic moment. The gathering in Bellevue was proof of that. People did not fill that room because they had solutions but because they refused to be alone in this uncertainty.

Ultimately, the most durable source of hope in science is not policy reform or budget restoration, though both matter enormously. I believe it is the people who show up despite the uncertainty, from graduate students who find creative ways to run experiments despite the funding restrictions to professors who continue submitting proposals even after the previous ones were returned unfunded.

I strongly believe that resilience is not the absence of hardship but a perennial presence of purpose despite it. And as long as that purpose survives, as long as we continue to ask hard questions, mentor the next generation, and refuse to let curiosity be extinguished by circumstance, the very foundation—however shaken—will hold.

About the author

Kartik Nemani is a postdoctoral fellow at the University of Alabama at Birmingham and an aspiring faculty candidate in materials engineering. He is passionate about science and policy, and he actively engages in initiatives that broaden participation, empower students, and strengthen the scientific community. Contact Nemani at snemani@purdue.edu. ■

Glass Strengthening Competition levels up student learning at conferences

By Lisa McDonald

When students attend an ACerS conference, they will find an array of events designed to support their scientific and social development within the ceramics and glass community. From networking luncheons to poster session bingo contests, students have ample opportunities to work on their soft skills during each day of the conference.

Designing events that support technical skills development can be a bit more challenging, however, due to the limited time available for any given conference event. For example, the beloved shot glass drop competition at the International Conference and Exposition on Advanced Ceramics and Composites challenges participants to protect a shot glass from harm by wrapping it in pipe cleaners, but the about 10 minutes available for wrapping is not long enough to consider the pros and cons of different approaches in depth.

Inspired by the shot glass competition, Alfred University Ph.D. candidate Amir Ashjari had the idea to create a competition that focused more directly on the science and engineering of glass fracture strength. While it would still involve dropping shot glasses on the floor from increasing heights, participants would be sent commercially available shot glasses beforehand to strengthen using their own technical approaches, such as ion exchange and thermal tempering. They would then bring the strengthened glass to the conference, where it would be dropped without any external form of protection to determine the effectiveness of the chosen strengthening process.

In an email, Ashjari says his initial idea was “very well received” by the Ceramic and Glass Industry Foundation (CGIF) and by the President’s Council of Student Advisors (PCSA) Conference Programming and Competitions Committee. After developing the idea further in fall 2025, they decided that direct drop tests with shot glasses could introduce inconsistencies in the testing conditions. So instead, they decided to use commercial soda–lime–silica glass

sheets together with a controlled ball-drop tester to create a more standardized impact-resistance evaluation process.

Ashjari worked with Simon Whitney and Albert Baker in the Alfred University machine shop to create the impact tester setup during the first few months of 2026. Then in April, the setup was shipped to Bellevue, Wash., to be used at the first Glass Strengthening Competition at the inaugural ACerS Spring Meeting.

A total of 10 teams participated in the first edition of this competition, representing several universities and a national laboratory from across the United States. Before the drop tests, each team first explained their strengthening approach, processing method, and the scientific reasoning behind their design strategy, which “helped make the competition more educational and technically engaging rather than being purely demonstration-based,” Ashjari says. In addition to the oral presentations, all teams were required to upload a brief written research abstract as well.

Following the drop tests, the teams that came out on top at the first Glass Strengthening Competition were

First place: Team B – Missouri S&T
Maximum drop: 155 cm
Team members: Adekunle Olatunde Adesanya and Elisha Joshua Lengendo

Second place: Exchange Students – Alfred University
Maximum drop: 150 cm
Team members: Jacob Kasprzyk, Dan Kutzik, Marcella Moran Peccorini, and Benjamin Rondeau

Third place: Team A – Missouri S&T
Maximum drop: 102 cm
Team members: Reese Hutchins

“Overall, I am very happy with how the first edition of the competition turned out, especially considering the relatively tight timeline we had for organizing it,” Ashjari says. “For a first-year event, I believe it was very successful and exceeded expectations in many aspects, although there is certainly room for improvement moving forward.”



Amir Ashjari (far left) and CGIF Program Manager Nathan McIlwaine (far right) stand with representatives of the winning teams from the inaugural Glass Strengthening Competition in April 2026. Center three, from left: Reese Hutchins, Adekunle Olatunde Adesanya, and Benjamin Rondeau.

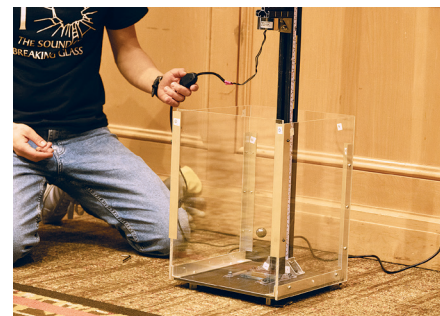
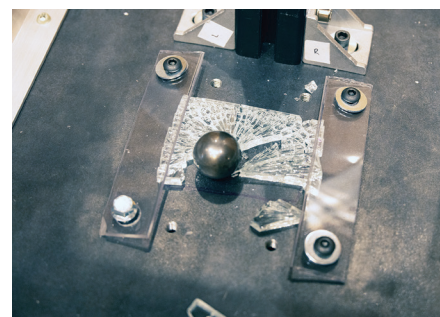


Photo of the impact tester setup as the ball drops toward a strengthened glass sheet.



Example of a shattered strengthened glass sheet after impact.

Ashjari says the CGIF and PCSA plan to continue and expand the Glass Strengthening Competition as an annual event during future Spring Meetings, with support from the Glass & Optical Materials Division. Learn more about the competition at <https://foundation.ceramics.org/student-resources/glass-strengthening-competition>. ■



37th
ITCC & ITES 2026 CONFERENCE

September 29 – October 1, 2026 | Columbus, OH
Renaissance Columbus Westerville-Polaris Hotel

Hosted by:
Orton Hot Disk®

ceramics.org/itcc2026

SEPT. 29–OCT. 1, 2026

**RENAISSANCE COLUMBUS WESTERVILLE-POLARIS HOTEL,
COLUMBUS, OHIO**

The ITCC and the ITES are premier international meetings on the thermo-physical properties of materials. They bring together researchers, engineers, and industry professionals from around the world to exchange knowledge on thermal conductivity, diffusivity, expansion, and related phenomena.

Register now!



Technical Meeting and Exhibition
MS&T26
MATERIALS SCIENCE & TECHNOLOGY

**ACerS 128th Annual Meeting
with Materials Science and
Technology 2026**

ceramics.org/annual-meeting2026

OCT. 4–7, 2026

**DAVID L. LAWRENCE CONVENTION CENTER,
PITTSBURGH, PA.**

The Materials Science & Technology (MS&T) technical meeting and exhibition series is a long-standing, recognized forum for fostering technical innovation at the intersection of materials science, engineering, and application.

Register soon!



join us at the
**51st INTERNATIONAL CONFERENCE
AND EXPO ON ADVANCED CERAMICS
AND COMPOSITES (ICACC 2027)**

The American Ceramic Society
ceramics.org

**JAN.
24-29,
2027**
HILTON DAYTONA BEACH
OCEANFRONT RESORT
DAYTONA BEACH, FLA.

ceramics.org/icacc2027

JAN. 24–29, 2027

**HILTON DAYTONA BEACH OCEANFRONT RESORT,
DAYTONA BEACH, FLA.**

Join us for the 51st International Conference and Expo on Advanced Ceramics and Composites (ICACC 2027) in Daytona Beach, Fla.

Submit your abstract!

LEGEND: A red circle ● denotes a new event in this issue. A star ★ denotes an ACerS short course.

June 2026

★ ACERS COURSE

1-Aug. 15 Ceramic Essentials: A Technician Workshop – On-site at companies requesting the training; <https://ceramics.org/course/greschuk-ceramics-essentials>

ENDORSED EVENT

7-12 Solid State Studies in Ceramic Science Gordon Research Conference – Mount Holyoke College, South Hadley, Mass.; <https://www.grc.org/solid-state-studies-in-ceramics-conference/2026>

ACERS EVENT

8-10 Structural Clay Products Division & Southwest Section Meeting 2026 – DoubleTree by Hilton Canton Downtown, Canton, Ohio; <https://ceramics.org/clay2026>

ACERS EVENT

10-12 16th Advances in Cement-Based Materials – University of Miami, Coral Gables, Fla.; <https://ceramics.org/cements2026>

ENDORSED EVENT

15-25 CIMTEC 2026 – Perugia, Italy; <https://ceramics.org/event/cimte-2026>

ENDORSED EVENT

24-26 Electronic Materials Conference – University of Michigan, Ann Arbor, Mich.; <https://2026.emc-conference.org>

July 2026

ENDORSED EVENT

8-10 International Conference on Self-Healing Materials – Drexel University, Philadelphia, Pa.; <https://icshm2026.org>

ENDORSED EVENT

12-16 American Conference on Neutron Scattering 2026 – Detroit Marriott at the Renaissance Center, Detroit, Mich.; <https://ceramics.org/acns2026>

★ ACERS COURSE

14-18 Properties and Testing of Refractories – Westerville, Ohio; <https://ceramics.org/course/homeny-properties-and-testing-refractories>

August 2026

ENDORSED EVENT

31-Sept. 1 The International Conference on Sintering – Eurogress Aachen, Aachen, Germany; <https://www.sintering2026.org/en>

September 2026

ENDORSED EVENT

6-11 11th International Congress on Ceramics – Sapporo Convention Center, Sapporo, Japan; <https://www.ceramic.or.jp/icc11>

● ★ ACERS COURSE

14-15 Tools for Visualizing and Understanding the Structure of Crystalline Ceramics – Virtual <https://ceramics.org/course/sparks-crystalline-ceramics>

ENDORSED EVENT

29-Oct. 1 International Thermal Conductivity Conference and International Thermal Expansion Symposium 2026 – Renaissance Columbus Westerville-Polaris Hotel, Westerville, Ohio; <https://ceramics.org/itcc2026>

October 2026

ACERS EVENT

4-7 ACerS 128th Annual Meeting with Materials Science and Technology 2026 – David L. Lawrence Convention Center, Pittsburgh, Pa.; <https://ceramics.org/annual-meeting2026>

January 2027

ACERS EVENT

24-29 51st International Conference and Expo on Advanced Ceramics and Composites – Hilton Daytona Beach Oceanfront Resort, Daytona Beach, Fla.; <https://ceramics.org/icacc2027>



ACerS Learning Center
[CERAMICS.ORG/EDUCATION/SHORT-COURSES](https://ceramics.org/education/short-courses)

Career Opportunities

QUALITY EXECUTIVE SEARCH, INC.
 Recruiting and Search Consultants
Specializing in
Ceramics, Refractories and Metals
JOE DRAPCHO
 (440) 773-5937
 www.qualityexec.com
 E-mail: joedrapcho@yahoo.com

Business Opportunities

Refractory/Industrial Ceramics Business for Sale

- Long Term operating business with over 150,000 sf of manufacturing and office space, and 10 acres.
- Grinding, sizing capabilities as well as pressing, drying and high firing.
- 5 Bickley kilns (2 Shuttles and 3 Bell).
- Independent gas line into facility with unlimited gas supply.
- 30 minutes to Big 10 University.


Please send serious inquiries to info@firebricks.com

Business Services

custom finishing/machining

BOMAS
67
Years
 1959-2026

Precision Machining of Advanced Ceramics and Composite Materials
 Joe Annese • Mark Annese


 ITAR Registered
bomas.com

Custom Machining
Five Modern CNC Routers
 Two Shifts a Day, Five Days a Week!
Low Mass, High Temp. Products
 Ours or Yours!



Free Samples!

Zircar CERAMICS
 Contact Us Today!
 Tel: (845) 651-6600
 Email: sales@zircarceramics.com
www.zircarceramics.com

custom/toll processing services


TOLL FIRING & LAB RUNS



- Carbon Steels / Stainless Steels
- Non-Oxide Ceramics including SiC, Si₃N₄, AlN, B₄C, BN, AlON.
- Carbon / Graphite / CFC's
- Refractory Metals
- MIM
- 3D Print/Additive Manufacturing

- Debinding, Sintering, Heat Treating, Annealing, and Brazing.
- Temperatures to 2000°C in Vacuum, Ar, N₂, and Hydrogen Gas - Refractory Metal Hot Zone
- Temperatures to 2300°C in Vacuum, and Ar, N₂ Gas - Graphite Hot Zone.
- Volumes up to 6"x6"x15" (150x150x380mm)

55 Northeastern Blvd.
 Nashua, NH 03062
 Ph: 603-595-7233
sales@centorr.com
www.centorr.com

CENTORR
 Vacuum Industries 

HIGH-TEMP VACUUM FURNACES

Zircar
 Zirconia, Inc.



CUSTOM MACHINED ZYF - ZIRCONIA FELT GASKETS

Insulation to 2200°C
 Rigid Boards

Felts & Fabrics
 Bulk Fibers & Powders

sales@zircarzirconia.com
www.zircarzirconia.com

ISO 9001:2015
 (845) 651-3040

CeramicTechToday
 FROM THE AMERICAN CERAMIC SOCIETY 

Stay up-to-date on the latest ceramic and glass materials news by following ACerS' newsletter *Ceramic Tech Today*.

<https://ceramics.org/ceramic-tech-today>

Subscribe at <https://acers.my.site.com/Forms/CTT>

firing/melting/drying

TOLL FIRING

SERVICES

- Sintering, calcining, heat treating to 1700°C
- Bulk materials and shapes
- R&D, pilot production
- One-time or ongoing



EQUIPMENT

- Atmosphere electric batch kilns to 27 cu. ft.
- Gas batch kilns to 57 cu. ft.



Columbus, Ohio
614-231-3621
www.harropusa.com
sales@harropusa.com

laboratory/testing services

Thermal Analysis Materials Testing

- Dilatometry
- Firing Facilities
- Custom Testing
- Glass Testing
- DTA/TGA
- Thermal Gradient
- ASTM Testing
- Refractories Creep
- Clay testing

HARROP

INDUSTRIES, INC.

3470 E. Fifth Ave., Columbus, Ohio 43219-1797
(614) 231-3621 Fax: (614) 235-3699
E-mail: sales@harropusa.com

ACerS-NIST PHASE EQUILIBRIA DIAGRAMS
NIST Standard Reference Database 31

The American Ceramic Society
NIST
PHASE Equilibria Diagrams
www.ceramics.org/phase

maintenance/repair services



AFTERMARKET SERVICES

- Spare Parts and Field Service Installation
- Vacuum Leak Testing and Repair
- Preventative Maintenance
- Used and Rebuilt Furnaces

55 Northeastern Blvd, Nashua, NH 03062
Ph: 603-595-7233 Fax: 603-595-9220
sales@centorr.com
www.centorr.com

Alan Fostier - afostier@centorr.com
Joe Pelkey - jpelkey@centorr.com

CUSTOM HIGH-TEMPERATURE VACUUM FURNACES



Upgrade to

ACerS Corporate Partner

- Corporate
- Sapphire
- Diamond

- Booth discounts at ACerS expos
- Member-priced ACerS Learning Center courses
- Complimentary ACerS meeting registrations
- Unlimited Career Center job postings
- Individual ACerS memberships for employees

Visit ceramics.org/corporate-partners for pricing and a complete list of benefits.

GET RESULTS

Advertise in the **Bulletin** print and online!

Learn more at

bulletin.ceramics.org

DISPLAY ADVERTISERS

AdValue Technology	www.advaluetech.com	11
Alfred University	www.alfred.edu/CACT	34, 35
American Elements	www.americanelements.com	Outside back cover
Deltech Inc.	www.deltechfurnaces.com	5
Harrop Industries Inc.	www.harropusa.com	Inside front cover
I Squared R Element Co., Inc.	www.isquaredrelement.com	11
Mo-Sci LLC	www.mo-sci.com	4
Paul O. Abbe Inc.	www.pauloabbe.com	13
TevTech LLC	www.tevtechllc.com	3
The American Ceramic Society	www.ceramics.org	9, Inside back cover

CLASSIFIED ADVERTISERS

* Business Service advertisers

* Bomas	www.bomas.com	46
* Centorr Vacuum Industries Inc.	www.centorr.com	46, 47
* Harrop Industries Inc.	www.harropusa.com	47
Quality Executive Search	www.qualityexec.com	46
Firebricks.com	www.firebricks.com	46
* Zircar Ceramics Inc.	www.zircarceramics.com	46
* Zircar Zirconia Inc.	www.zircarzirconia.com	46

Advertising Sales

Mona Thiel, National Sales Director
 mthiel@ceramics.org
 ph: 614-794-5834

Advertising Assistant

Pam Wilson
 pwilson@ceramics.org
 ph: 614-794-5826

Call for contributing editors for ACerS-NIST Phase Equilibria Diagrams Program

Professors, researchers, retirees, post-docs, and graduate students ...

The general editors of the reference series *Phase Equilibria Diagrams* are in need of individuals from the ceramics community to critically evaluate published articles containing phase equilibria diagrams. Additional contributing editors are needed to edit new phase diagrams and write short commentaries to accompany each phase diagram being added to the reference series. Especially needed are persons knowledgeable in foreign languages including German, French, Russian, Azerbaijani, Chinese, and Japanese.

RECOGNITION:

The Contributing Editor's name will be given at the end of each PED Figure that is published.

QUALIFICATIONS:

Understanding of the Gibbs phase rule and experimental procedures for determination of phase equilibria diagrams and/or knowledge of theoretical methods to calculate phase diagrams.

COMPENSATION for papers covering one chemical system:

\$150 for the commentary, plus \$10 for each diagram.

COMPENSATION for papers covering multiple chemical systems:

\$150 for the first commentary, plus \$10 for each diagram.

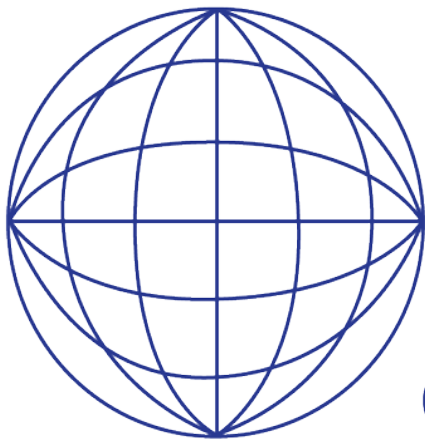
\$50 for each additional commentary, plus \$10 for each diagram.

FOR DETAILS PLEASE CONTACT:

Kimberly Hill
 NIST MS 8520
 Gaithersburg, MD 20899, USA
 301-975-6009 | phase2@nist.gov



NIST



CXC

CERAMICXCHANGE

Brought to you by The American Ceramic Society

**The place to find
ceramic & glass products,
equipment,
services,
and connections.**



ceramicxchange.org



THE MATERIALS SCIENCE MANUFACTURER®

99.9999% aluminum oxide

organometallics

borophene

osmium

surface functionalized nanoparticles

nanodispersions

refractory ceramics

titanium aluminum carbide

aluminum oxide powders

silver nanoparticles

zirconium carbide

hafnium chloride

transparent ceramics

UHP fluorides

scandium powder

chalcogenides

radiation shielding

lead zirconate titanate

biosynthetics

carbon nanotubes

yttrium oxide

Now Invent.™

CVD precursors

endohedral fullerenes

deposition slugs

gold nanocubes

thin film

laser crystals

silicon carbide

aluminum nitride

The Next Generation of Ceramic Materials Manufacturers

superconductors

Bulk & lab scale manufacturers of over 35,000 certified high purity chemicals, metals, and nanoparticles, including ceramic compounds and precursors for our advanced ceramic manufacturing customers serving industries such as aerospace, automotive, military, pharmaceutical, and electronics.

InGaAs

graphene oxide

ultra high purity materials

metallic glass

pyrolytic graphite

American Elements Opens a World of Possibilities.... Now Invent!



www.americanelements.com

metallocenes

metals

silica 99.99999% mercury

li-ion battery materials

SOFC powder

© 1997-2026. American Elements is a U.S. Registered Trademark