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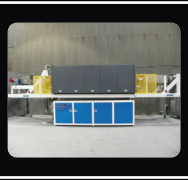

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Nature-inspired vascular cementitious composites: A path to self-thermal responsive buildings

Animals such as jackrabbits and elephants have ingenious vascular systems in their ears to regulate temperature, which can inspire the design of better thermal control in buildings.

by Mohammad Houshmand and Amir Farnam

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The Jewel Rain Vortex, located in the Jewel Changi Airport in Singapore, is the world's largest indoor waterfall. Credit: L_B_Photography / Shutterstock

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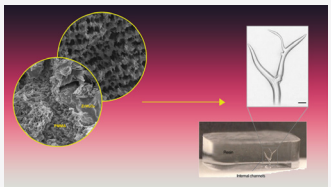


Credit: (left) White et al., *International Journal of Applied Ceramic Technology*; (right) Garg et al., *Advanced Science* (CC BY 4.0)

Ice templating of biomimetic materials: Roots in ceramic fabrication

Advancements in the ceramics field have often supported innovation and discoveries in other fields. Now, knowledge gained from early work on ice-templated ceramics is aiding in the development of soft, bioinspired materials for medical applications.

Read more at https://ceramics.org/ice-templating

Also see our ACerS journals...

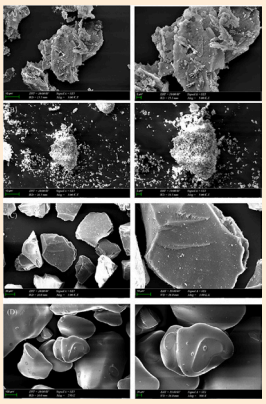
These articles are part of the November 2025 issue of *Journal of the American Ceramic Society*, which features a special section on nature-inspired design.

Enhancement of mechanical and antimicrobial properties of silica, zeolite, and silver-modified hydroxyapatite composites for biomedical applications
By N. M. Ergul, R. B. Sulutas, E. Kaya, et al.
Journal of the American Ceramic Society

Biomimetic design of advanced ceramics for hard tissue repair
By K. Lu, Y. Xu, S. Gao, et al.
Journal of the American Ceramic Society

Sol-gel derived S53P4 bioactive glass
By J. Zheng, H. Pilsworth, J. V. Hanna, and J. R. Jones
Journal of the American Ceramic Society

Sustainable structural materials inspired by nature
By M. Mirkhalaf
Journal of the American Ceramic Society



Credit: Ergul et al., *JACerS*

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ACSBA7, Vol. 104, No. 9, pp. 1–48. All feature articles are covered in Current Contents.

Chipping in on chip development: Universities launch new semiconductor research facilities

In the four decades since a toaster was first connected to the internet, there are now more than 18 billion connected Internet of Things devices around the world. With billions more expected to be added by the end of this decade, it is crucial that new and improved semiconductor technologies be developed to handle the growing demands on data storage, transport, and processing infrastructure.

Governments around the world have dedicated more funding to semiconductor manufacturing, and universities are following their lead by launching new laboratories and institutes focused on semiconductor research and development. Below is an overview of some of the facilities announced since the beginning of 2025.

Prototyping and advanced packaging piloting facility at ASU

On January 6, Arizona State University announced that it had been selected by the U.S. Commerce Department and Natcast as the site of the co-located NSTC Prototyping and NAPMP Advanced Packaging Piloting Facility. The facility will combine semiconductor research and prototyping for front-end manufacturing and packaging capabilities. It is expected to be operational as early as the fourth quarter of 2028. Learn more: https://bit.ly/4o0mLmf

Semiconductor thin film laboratory at Penn State

On February 26, The Pennsylvania State University announced plans to establish an advanced laboratory for semiconductor thin films and device research in the Materials Research Institute's facilities in the Millennium Science Complex at University Park. At the heart of the new facility, made possible by funding from regional microelectronics consortium MMEC, will be a metal-organic chemical vapor deposition tool. This instrument will enable the deposition of semiconductor thin films on multiple wafers at a time. Learn more: https://bit.ly/47ppNuj

Nanofabrication Lab at Nevada

On April 8, the University of Nevada, Reno announced the grand opening of the Nanofabrication Lab in the Davidson Foundation Cleanroom in the William N. Pennington Engineering Building. The facility is equipped with tools for lithography, deposition, etching, wire bonding, and metrology, which can be used to manufacture electronic, photonic, and quantum devices. Learn more: https://bit.ly/3KQ4JEz

MUT–Imperial SABER Lab at Imperial College London

On June 6, Imperial College London announced the opening of the MUT–Imperial Semiconductor AI & BioSensor Electronics Research Lab. The facility, opened in collaboration with Mahanakorn University of Technology, will bring together Imperial's expertise in integrated circuit design and biomedical electronics and MUT's state-of-the-art training facilities and electronics design. Learn more: https://bit.ly/4q7SSBW

TSMC–UTokyo Lab at the University of Tokyo

On June 12, the University of Tokyo and Taiwan Semiconductor Manufacturing Company announced the opening of the TSMC-UTokyo Lab, which is dedicated to advancing semiconductor research, education, and talent incubation. This facility builds on a collaboration between the two organizations that has been ongoing since 2019. Learn more: https://pr.tsmc.com/english/news/3243

Newly merged research institute at TU/e

On June 19, Eindhoven University of Technology announced it is establishing a research institute dedicated to the development of high-tech systems and chips of the future. The new institute merges one existing institute with two initiatives: the Eindhoven Hendrik Casimir Institute, the High Tech Systems Center, and the Future Chips Flagship. Learn more: https://bit.ly/4hdtBlZ

Semiconductor research and development facility at Stony Brook University

On July 17, New York State Governor Kathy Hochul announced that Stony Brook University and onsemi, the largest U.S.-based manufacturer of silicon carbide power semiconductors, will construct a $20 million, state-of-the-art semiconductor research and development facility on the Stony Brook University campus. Research at the new center will aim to unlock the full potential of silicon carbide chips. The center is expected to be fully operational in early 2027. Learn more: https://bit.ly/3KHVaaT

MOCVD Laboratory at UW-Madison

On August 5, the University of Wisconsin-Madison's Ultrawide Bandgap Semiconductor Metal-Organic Chemical Vapor Deposition Laboratory officially opened. The facility will serve as the cornerstone of the College of Engineering-led focus on III-nitride semiconductors, which can handle much higher voltages than silicon-based semiconductors. Learn more: https://bit.ly/4mXFRIh

CREST Center for Ultrawide Bandgap Semiconductor Device Materials at TXST

On August 13, Texas State University announced that it received a $7.5 million award from the U.S. National Science Foundation to establish the CREST Center for Ultrawide Bandgap Semiconductor Device Materials. The five-year initiative will unite faculty experts, students, and industry collaborators to advance ultrawide bandgap materials and devices with high speed, performance, and energy efficiency. Learn more: https://bit.ly/4olkdz0

Semiconductor workforce center at Boise State

On September 17, Boise State University announced that it was awarded $7.4 million from the U.S. National Science Foundation to fund the creation of AWESOME, the Center for Advancing Workforce Experience through Semiconductors, Outreach, and Mentoring Excellence. The primary goals of this center are to drastically lower the energy cost of artificial intelligence through research, establish Boise State's national research competitiveness as a leader in semiconductor research and education, and improve the opportunity and educational experiences of students going into semiconductor industries. Learn more: https://bit.ly/4nU1QkS

Materials-to-Fab Center at ASU

On October 9, Arizona State University again made headlines when it and semiconductor manufacturing equipment supplier Applied Materials announced the official opening of the Materials-to-Fab Center, a shared world-class $270 million research, development, and prototyping facility inside the university's MacroTechnology Works at the ASU Research Park in Tempe. The center will serve as a critical research and development hub for future-generation semiconductor technologies and act as a test bed for transitioning microelectronics discoveries from early-stage research to industry-ready applications. Learn more: https://bit.ly/3Jbo1Un ■

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Corporate Partner news

Advanced Energy Minerals signs distribution agreement with Korean company

Advanced Energy Minerals (AEM), a leading global producer of high-purity alumina and aluminium hydroxides based in Montreal, Québec, Canada, signed a distribution agreement with Republic of Korea-based Yeeyoung Cerachem Co., Ltd., a distributor of specialty chemicals and advanced materials. The agreement aims to help AEM expand into the Korean technology market and support manufacturing in the region. Read more: https://aemhpa.com/news/tag/press-release ■

CeramTec subsidiary positions itself with new brand identity

Emil Müller GmbH, a subsidiary of the CeramTec Group, announced a new brand identity: EMG – The Saltcore Experts. This branding will help affirm EMG's position as a leading international specialist for salt cores. The announcement includes a new corporate design, logo, and updated website. Read more: https://www.ceramtec-group.com/en/news-events ■

GCA earns global recognition at the A' Design Award and Competition

GCA earned the bronze award in the packaging design category of the A' Design Award and Competition 2025, which was held in July 2025 at Como, Italy. GCA received the award for their exclusive bottle design developed for Avoya sparkling mineral water. Read more: https://gca.com/en/media/press-release ■

Keystone Space Innovation Challenge awards $200K to Pennsylvania businesses

Five Pennsylvania businesses were awarded a combined $200,000 through the first Keystone Space Innovation Challenge, which is designed to explore untapped potential in space technology and commercial research and development. Awardees competed in two categories: Commercial Space Technology Concepts and In-Space Research and Development Commercial Concepts. The funding was provided by the Pennsylvania Department of Community and Economic Development. Read more: https://keystonespace.org/news/#in-the-news ■

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New model explicitly outlines each step of the materials science research process

To date, little has been explicitly written about the steps, methodologies, and strategies that STEM researchers use to advance their field's collective knowledge. But in a recent open-access paper, two materials scientists propose a comprehensive model for the research cycle that "can improve the experience of both those early-career and established researchers by providing common expectations, increase the return-on-investment for research sponsors by encouraging robust planning, and increase the impact of our collective research work by encouraging knowledge development."

The authors are Jennifer Carter, faculty director of the Swagelok Center for Surface Analysis of Materials at Case Western Reserve University, and Marian Kennedy, associate professor of materials science and engineering at Clemson University. In their paper, Carter and Kennedy note that previous researchers have represented the research cycle as a six-step process:

1. Identify a gap in knowledge needed by the community through a review of existing knowledge.
2. Construct the cycle objective or hypothesis.
3. Design and develop a methodology based on validated laboratory or computational experimental methods.
4. Apply this methodology to the candidate solution.
5. Evaluate testing results.
6. Communicate the results to the greater community of practice.

They note that not all experiments can progress through this idealized cycle. For example, "the characterization techniques needed to produce new knowledge may not be currently available, and researchers will first need to invest significant time to develop the needed technique," they explain.

Even in those cases, though, proceeding with "a carefully edited" hypothesis based on perceived gaps in knowledge and "a specially assigned methodology" that allows for replication and verification will enable a higher "return-on-investment for research stakeholders," they write.

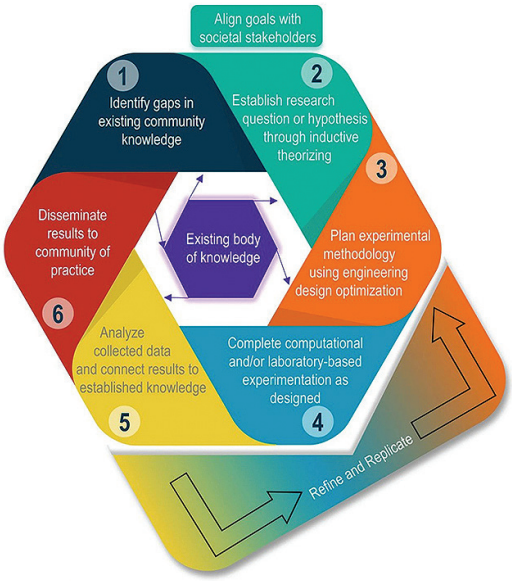
Based on this understanding of the limitations of the idealized cycle, Carter and Kennedy argue that a materials researcher be defined as "one who engages with any part of the research cycle with the intent of developing new structure–properties–performance–processing knowledge," regardless of whether they can participate in all aspects of the research cycle.

In a similar vein, they also suggest broadly defining "new knowledge" to include both knowledge related to processing–structure–properties–performance relationships as well as knowledge that enables those discoveries.

Carter and Kennedy then spend several sections describing in detail each step of the research cycle, including showing explicitly how the incorporation of engineering principles within the planning of the experimental methodology can result in an optimized methodology.

Based on these discussions and clarifications, Carter and Kennedy end by presenting a revised research cycle called the Research+ cycle. This cycle, illustrated in Figure 1, includes three critical steps not often explicitly discussed:

1. **Understand the existing body of knowledge**: Carter and Kennedy state that understanding this knowledge is "foundational to all aspects of being a researcher," and so they placed it at the center of the methodology.
2. **Explicitly state how research questions are aligned with societal goals**: Carter and Kennedy note that changes in societal focus often lead to tumultuous shifts in research agendas.



Credit: Carter and Kennedy, *MRS Bulletin*, (CC BY 4.0)

Figure 1. Illustration of the Research+ cycle, which outlines the steps that materials scientists can use to advance their field's collective knowledge.

3. **Refine methodologies and replicate results**: Carter and Kennedy explain that methodology design is often iteratively refined using tacit knowledge. Thus, "It is helpful for early-career researchers to develop this tacit knowledge by asking questions about the resolution, sensitivity, time, cost, and availability of various methods before adopting them," they write.

In a LinkedIn post announcing the new model, Carter says this study is "the most important paper I have ever written," and she hopes to be "remembered as an academic who 'Engineers the next Engineer-Scientist.'"

In that same post, Kennedy says she is "Thankful for the opportunity to collaborate with Jennifer and many reviewers who strengthened this article."

The open-access paper, published in *MRS Bulletin*, is "Conceptualizing the research cycle for the field of materials science and engineering" (DOI: 10.1557/s43577-025-00931-w). ■

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Tissue engineering and regeneration: Technologies and global markets

The global market for tissue engineering and regeneration technologies was valued at $4.8 billion in 2024 and is expected to grow at a compound annual growth rate (CAGR) of 12.8% to reach $9.8 billion by the end of 2030.

Tissue engineering and regeneration is a multidisciplinary field focused on producing biological substitutes to restore, maintain, or enhance tissue and organ function. Several emerging technologies are gaining ground as main areas for research and development:

- **3D bioprinting** combines bioinks (natural or synthetic) with living cells to build tissue-like structures.
- **Organs-on-chips** are microfluidic systems that contain engineered or natural miniature tissues, allowing precise control of the cell environment to replicate human physiology.
- **Smart biomaterials** respond to physiological changes and external stimuli, such as temperature and pH.
- **Artificial intelligence** aids in biomaterial development by analyzing vast datasets to simulate biological behavior, personalize treatments, and reduce regulatory delays.

The high prevalence of musculoskeletal disorders, combined with a growing geriatric population, contributes to the dominance of the orthopedics and musculoskeletal disorders segment (Table 1).

The competitive landscape of the tissue engineering market comprises many companies, with the top five leading manufacturers in 2024 shown in Table 2.

The Asia-Pacific region has one of the highest burdens of non-communicable diseases worldwide. As a result, the region has witnessed an expanding biotechnology sector and more government policies supporting tissue engineering research.

Table 1. Global market for tissue engineering and regeneration, by application, through 2030 ($ millions)

Application	2024	2025	2030	CAGR % (2025–2030)
Orthopedics and musculoskeletal disorders	2,062.1	2,349.0	4,578.4	14.3
Dermatology and wound care	1,581.9	1,777.7	3,215.0	12.6
Dental disorders	446.6	489.8	778.7	9.7
Cardiovascular diseases	379.5	422.1	722.0	11.3
Others*	331.8	358.6	542.1	8.6
Total	4,802.0	5,397.2	9,836.2	12.8

*Other applications include neurological, ocular, reconstruction surgery, and gastrointestinal disorders.

Table 2. Top five leading manufacturers of tissue engineering and regeneration market, 2024

Ranking	Company	Strengths
1	Organogenesis Inc.	Leverages robust R&D and established platform technologies, including bioengineered cellular products and antimicrobial solutions, to support a diverse product portfolio.
2	Integra LifeSciences	Provides solutions to complex wounds, surgical reconstruction, and nerve repair through a regenerative platform based on bovine collagen, bovine dermis, porcine urinary bladder, human amniotic tissue, and resorbable synthetic mesh.
3	Smith+Nephew	Has an advanced skin substitute portfolio that support wound healing across acute, chronic, and surgical applications.
4	MiMedx	Offers a broad portfolio of placental-based allografts, supported by extensive clinical evidence and reimbursement services.
5	Johnson & Johnson	Leverages its global MedTech leadership, advanced biomaterial expertise, and strong bone tissue engineering portfolio to support tissue repair and regeneration.

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 utkantha.srivastava@bccresearch.com.

Resource

BCC Publishing Staff, "Tissue engineering and regeneration: Technologies and global markets," BCC Research Report HLC101E, July 2025. https://bit.ly/July-2025-tissue-engineering ■

By Gemma Harvey
Guest columnist

Sustainable development and design: Inspiration from landscape-shaping creatures

Animals are not just passive inhabitants of their environment. Many are architects of the natural world, actively shaping landforms and water bodies as they move around, feed, build homes, and reproduce.

This impact by animals on different biomes has traditionally been overlooked in the environmental sciences. But scientists and engineers can draw inspiration from such animals, emulating the forms and processes used in their landscape engineering efforts to design innovative and sustainable buildings and materials.

Zimbabwe's Eastgate Center—a huge, multi-use shopping and office space—is a prime example of biomimetic construction inspired by an animal landscape engineer: termites. Mound-building termites live in Africa, Australia, and South America. They work cooperatively in large colonies, binding soil and dung with their saliva to construct mounds that often reach several meters high. The internal mound architecture is equally remarkable—tunnels, chambers, and chimneys work in combination with the termites' porous building material to ventilate the landform and regulate its temperature.

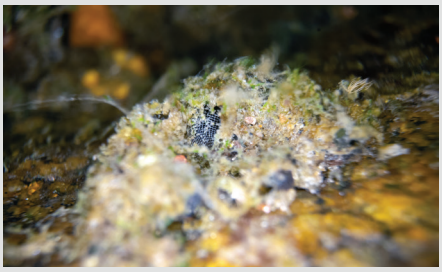
The Eastgate Center mimics these forms and processes. Its porous fabric absorbs heat without substantially increasing the interior temperature. The building's architecture works in alliance with daily temperature fluctuations, drawing dense, cool night air into large floor cavities and passively expelling rising warm air through chimneys as temperatures increase through the day. This form of biomimicry contributes to climate change mitigation and adaptation by reducing energy-related emissions and helping create climate-resilient buildings.

Materials scientists can also find inspiration from animal architects that live under water. Caddisfly larvae inhabit the bottoms of streams and rivers worldwide. They produce silk to bind together grains of riverbed sand and gravel, creating cases or nets for shelter and feeding (Figure 1).[1] Silk in general is a desirable biomaterial, delivering a combination of stickiness, strength, extensibility, and elasticity. While other animals also produce silk, most live on land. Caddisfly silk has the added benefit of being adhesive under water, meaning its physical and chemical makeup is potentially useful for biomedical applications.

These examples are just the tip of the animal architect iceberg. In a recent paper,[2] my colleagues and I revealed that animal architects are much more diverse and globally widespread than previously recognized. Our comprehensive list of animal architects included 500 species spanning insects, mammals, fish, birds, reptiles, and crustaceans across all land and freshwater biomes. We estimated that the collective power of these animals in shaping landscapes is equivalent to the energy of hundreds of thousands of river floods.

Ants move billions of tons of soil a year globally,[3] soil-disturbing marsupials bring lush pockets to otherwise parched landscapes, and hippopotamus trails can create entirely new drainage networks in wetlands. In freshwater, mass-spawning salmon can move as much gravel as floods and reshape river form, while tiny ghost-like crustaceans influence the water storage capacity of underground rock by moving around within void spaces.

Countless more animals will likely be revealed as architects as research in this area grows. Critically, though, our research shows that a quarter of landscape-shaping animals are threatened or vulnerable in some way, meaning their effects could disappear before we fully understand them or identify how much we rely on them.



Credit: Greg Cairns / Cairns Film Inc.

Figure 1. Example of a Caddisfly larvae silk net at Cherry Creek in Madison County, Mont.

Biomimicry that draws on animal landscape engineers can offer impactful pathways to sustainable design and materials, helping us mitigate and adapt to climate change, address biodiversity loss, and improve human wellbeing. So far, we have only scratched the surface. We still have much to learn about—and from—these fascinating animal architects.

About the author

Gemma Harvey is professor of physical geography at Queen Mary University of London. The work described in this column is a collaboration with university researchers from the United States (Montana State University) and United Kingdom (Queen Mary, Nottingham, Oxford, Manchester Metropolitan universities), all of whom undertake research on animal impacts on landscapes. Contact Harvey at g.l.harvey@qmul.ac.uk.

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By David Holthaus
Industry reporter

Bioactive glass continues to transform medical care decades after first hitting the market

Almost 60 years ago, a chance meeting led to pioneering work that has improved medical care and seeded future innovations.

In the late 1960s, a young professor named Larry Hench traveled to a conference in Sagamore, N.Y., where he happened to sit next to a U.S. Army colonel who was interested in finding better ways to treat the battlefield wounds he was seeing in the Vietnam War. Their conversations led to the then-speculative topic of replacing bone with synthetic materials that the body would not reject. Returning to his laboratory, Hench eventually developed a calcium sodium phosphosilicate glass composition that had properties enabling it to bond tightly with bone and stimulate the regeneration of damaged tissue.

What he invented was Bioglass 45S5, the first patented bioactive glass. This material initiated a revolution in health care and paved the way for remarkable developments in regenerative medicine driven by advances in various types of bioactive and biocompatible materials.

Before the discovery of bioactive glass, synthetic implants were typically inert, meaning they just survived in the body without actively interacting. But bioactive glass demonstrated that synthetic implants could not only bond strongly with living tissue but also have beneficial interactions beyond simple integration.

The first bioactive glass-based medical device—an implant for middle ear ossicular repair—received FDA approval in 1985.[1] In the 40 years since, numerous other bioactive glass-based products have reached market, as well as several other patented bioactive glass compositions.[2]

MO SCI LLC, based in Rolla, Mo., is one company that has helped push the bounds of bioactive glass since the technology's conception. Founded in 1985, the same year as the first FDA-approved bioactive glass product, MO SCI has developed a range of bioactive glasses for different applications.

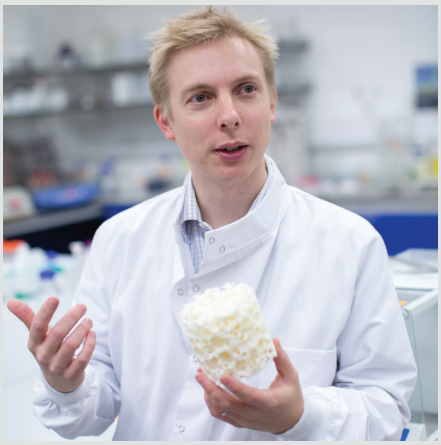
Therasphere, a radioactive glass microsphere for inoperable liver tumor treatment, was one of the company's first bioactive glass products. More recently, the bioactive glass-based wound care product Mirragen, which earned FDA approval in 2017, has been shown to aid in the healing of chronic diabetic ulcers.[3]

Other companies working with bioactive glass include

- NovaBone Products (Alachua, Fla.) received FDA approval for its Wound Matrix product,[4] an animal collagen and bioactive glass product that can treat pressure ulcers, diabetic ulcers, and surgical wounds.
- Bonalive Ltd. (Turku, Finland) distributes a granular material that inhibits bacterial growth.[5] It has been found to be especially useful in filling bone cavities in patients managing chronic osteomyelitis.
- Synergy Biomedical LLC (Wayne, Pa.) makes a flexible and moldable bone graft material used in orthopedic and spinal surgery.[6]

Bioactive glass is also used in everyday medical products, such as toothpaste. NovaMin is the brand name for a bioactive glass made by GSK plc that triggers a reaction that deposits enamel-like material on the teeth. Its use in toothpaste has not been approved in the U.S. yet, but another bioactive glass-containing toothpaste made by BioMin did receive FDA premarket clearance in 2021.[7]

Besides industrial developments, academic researchers continue to explore new uses for bioactive glass and seek ways to make it more durable. ACerS Fellow Julian Jones has researched the material for 25 years. He studied under and worked for Larry Hench at Imperial College London, where he is now a professor of biomaterials and associate head of the Department of Research.



Credit: Julian Jones

ACerS Fellow Julian Jones, professor at Imperial College London, holds a sample of Bouncy Bioglass, a bioactive glass material invented by him and his colleagues.

Jones leads a team looking for ways to regenerate relatively large holes in bones. As part of this research, he and his colleagues invented Bouncy Bioglass. It works the same way as the original but includes a polymeric component that allows it to treat larger injuries.

"We actually grow the polymer at the same time as we grow the glass, and they're interlocking at the molecular level," Jones says in an interview. "That design choice enables us to have this tight relationship that creates real synergy in the properties."

Bouncy Bioglass is made via sol-gel chemistry, which makes it possible to mix polymers into bioactive glass on the molecular level, growing them together through a series of chemical reactions. The resulting product can be inserted into relatively large gaps in bone, such as those found in trauma victims, and can withstand the regular wear and tear that body parts must endure.

"For bone regeneration, we need properties that match the bone so it can take the cyclic loading," Jones says. "If you put a big piece of porous glass in there, of course it can be brittle, it's going to break. So, we need ones that

can take cyclic loading." The "bouncy" hybrid material that Jones and his colleagues invented does that.

The researchers also discovered that the 3D-printed material can stimulate cartilage regeneration, which is especially beneficial for knee injuries, so common in youth athletes, "weekend warriors," and people over the age of 50. Other techniques can help regenerate cartilage, but the result acts more like scar tissue, which can be inelastic.

"We're getting real articular cartilage regeneration," Jones says. That can be a boon for treating injuries such as a torn meniscus in the knee, vertebral disc injuries, or the common problem of arthritis in the aged.

To promote its commercialization, the technology was recently licensed to Orthox, Ltd., a small company based in Oxford, England, that is developing medical implants to repair damaged knees and other orthopedic injuries.

It has been 10 years since Hench's death in December 2015, but as bioactive glass compositions and applications continue to evolve, his legacy lives on through the advances in tissue regeneration, wound healing, and other novel medical treatments.

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.

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*All references verified as of Oct. 13, 2025.

The American Ceramic Society ceramics.org

ACerS Learning Center

Course Feature: Understanding Why Ceramics Fail and Designing for Safety

Instructed by Stephen Freiman, Ph.D.
9 lessons | 3.5 hours with lesson slides included | On-Demand

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SOCIETY DIVISION SECTION CHAPTER NEWS

Welcome new ACerS Corporate Partner

ACerS is pleased to welcome its newest Corporate Partner:

Schunk Technical Ceramics

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. ■

ACerS Pittsburgh Section Annual 2025 Golf Outing: Photos and results

The ACerS Pittsburgh Section held the Annual Pittsburgh Golf Outing on Monday, Sept. 8, 2025, at the Birdsfoot Golf Course in Freepost, Pa. The day featured wonderful weather and kicked off with a bag piper who began playing on the ridge and then walked down to join the group of players.

Each year, all proceeds from the outing go toward the Pittsburgh Sections' J. Earl Frazier Memorial Scholarship Fund, which is awarded to a college senior majoring in ceramics, materials science, and/or engineering. This year, the Section raised $3,363 for the fund.

Thank you to all the winners, participants, and staff at Birdsfoot Golf Course for helping make this year's annual outing a huge success. ■

First place team from Elkem.

Second place team from Plibrico Company.

Third place team from Furnace Products and Services.

FOR MORE INFORMATION:

ceramics.org/spotlight

2025 YouTube video contest winners announced

The winning submissions of the annual Bioceramics Division YouTube video contest showcase recent innovations and technological advancements in the field of bioceramics. Congratulations to the winners!

First place:
"Through the lens of XMT: Exploring the effect of a fluoride bioactive glass varnish," by Emily Sara Thambi, Queen Mary University of London

Watch: https://www.youtube.com/watch?v=Kd-Y1k_GW48

**Thambi thanks Graham Davis and David Mills for their support with the X-ray microtomography*

Second place:
"Simulations-guided design of bioactive materials and scaffolds for bone regeneration," by Hanmant Gaikwad, North Dakota State University

Watch: https://www.youtube.com/watch?v=jhUlPN4tLu0 ■

ICACC 2026: Registration waiver program and childcare grant initiative

Students or young professionals who are giving a presentation at the Golden Jubilee Celebration of the 50th International Conference and Expo on Advanced Ceramics and Composites may be eligible to apply for a registration waiver through the ICACC 2026 Student and Young Professionals Registration Waiver Program.

This program will support the attendance of students and young professionals at ICACC 2026, which takes place Jan. 25–30, 2026, in Daytona Beach, Fla. The aim of the program is to develop and foster cooperation among students and young professionals from all over the world.

For more information, including the application, visit https://ceramics.org/ICACC2026-Registration-Waiver-Program.

The Engineering Ceramics Division is also offering childcare grants for those attending ICACC 2026. Grants of up to $400 will be given to selected registered meeting attendees who are bringing one or more young children to the conference or who incur extra expenses in leaving them at home (e.g., added hours of daycare or babysitting services).

For more information, including the application, visit https://ceramics.org/ICACC2026-childcare-grants. ■

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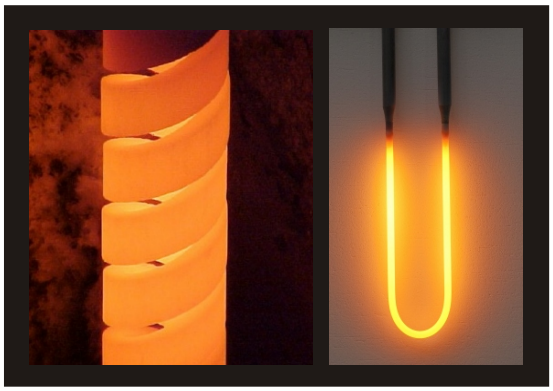

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2025 Ceramographic Exhibit winners

Roland B. Snow Award for Best in Show

Oxide dog on a snowy field, by **Pratyush Chettri**, Purdue University, West Lafayette, Ind.

Optical microscopy category

First: *Ceraphium: When crystals break, angels wake!* by **Oliver Preuss**, Technical University of Darmstadt, Germany

Second: *Cosmic quartz: A galaxy beneath the lens*, by **Metri Zughbi**, Lehigh University, Bethlehem, Pa.

Third: *Seeding dislocations in a new field*, by **Albert Zelenika**, Karlsruhe Institute of Technology, Germany

Scanning electron microscopy category

First: *Oxide dog on snowy field*, by **Pratyush Chettri**, Purdue University, West Lafayette, Ind.

Second: *MXene fish in a sea of sulfur unveils hidden art*, by **Amir Mirtaleb**, Michigan State University, East Lansing, Mich.

Third: *Ghostly tungsten family*, by **Wookyung Jin**, Lehigh University, Bethlehem, Pa.

Transmission electron microscopy category

First: *A chaotic 2D heart*, by **Krutarth Kamath**, Purdue University, West Lafayette, Ind.

Second: *Bond, grain bond*, by **Daniela Fonseca**, Lehigh University, Bethlehem, Pa.

Third: *A Tale of Time*, by **Krutarth Kamath**, Purdue University, West Lafayette, Ind.

Scanning probe microscopy category

First: *Fireworks: Spherulitic crystallization in* IN_2O_3, by **Ahrong Jeong**, Hokkaido University, Japan

Second: *Diphasic boundary energy: A kinetic knob for nucleation?* by **Koen J. H. Verrijt**, Lehigh University, Bethlehem, Pa.

Undergraduate category

First: *Microstructural forest*, by **Haley J. Bartosh**, Lehigh University, Bethlehem, Pa. ■

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WEBINAR LIBRARY

CHECK OUT THESE RECENT ADDITIONS TO THE ACERS WEBINAR ARCHIVE:

FROM COMPLEXITY TO CAPABILITY: EXPLORING THE LINKS BETWEEN STRUCTURE AND FUNCTION IN HIGH-ENTROPY OXIDES
Original air date: Aug. 29, 2025
Hosted by: Washington, D.C./Maryland/Virginia Section
Featured speaker: Christina Rost

ION CONDUCTING OXIDES FOR ELECTROCHEMICAL ENERGY CONVERSION AND STORAGE
Original air date: Sept. 26, 2025
Hosted by: Washington, D.C./Maryland/Virginia Section
Featured speakers: Eric D. Wachsman

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

2026 ACerS Mentor Programs applications open

We are excited to be entering into our eighth year of the ACerS Mentor Programs!

ACerS offers mentor programs for students, faculty, and professionals within industry. Each program is thoughtfully designed to provide participants with the tools, insights, and relationships they need to make a lasting impact on their careers and the field.

Many mentors and mentees return year after year, creating a legacy of growth and shared success. Meet one such pair—Todd Steyer and Sara Dockins—in the June/July 2025 issue of the *ACerS Bulletin*.

To date, the ACerS Mentor Program has facilitated connections between nearly 750 individuals. Become part of the 2026 Mentor Programs and start building your connections by registering at www.ceramics.org/mentorship. Registration is due by **Dec. 12, 2025.** ■

News from EPDC: Activities and 2025–26 leadership

Hello, ACerS members, from your Educational and Professional Development Council (EPDC)!

EPDC is the ACerS community dedicated to the promotion and improvement of education and professional development initiatives. Members of EPDC work together and with other ACerS communities to support ceramic and glass scientists and engineers throughout different stages of their careers.

For students and young professionals, we at EPDC collaborate with Keramos, Material Advantage, ACerS President's Council of Student Advisors, and the Young Professional Network on networking events and other professional development opportunities. We also assist in running the ACerS Student Mentor program, which pairs students with professional ACerS members to get advice on successful careers in ceramics and glass.

There is also the ACerS Industry and Faculty Mentor Programs, which we support as well. These programs help professionals advance in their existing careers or offer advice on making a career move.

The Awards Committee and the Accreditation Committee are two other ways that we support current and emerging ceramic and glass professionals through EPDC. The former committee helps celebrate our colleagues by annually selecting recipients for the four EPDC awards. The latter committee oversees Society efforts related to ABET, the nongovernmental organization that provides quality assurance for post-secondary programs, to ensure our university students are getting the skills they will need in their future careers.

Volunteers are always needed and welcome as mentors and committee members within EPDC. If you are interested in learning more about specific EPDC activities and becoming involved, visit ceramics.org/EPDC or contact Yolanda Natividad, associate director of membership and industry relations, at (614) 794-5827 or ynatividad@ceramics.org.

EPDC 2025–26 leadership
Co-chairs: Manoj Mahapatra and Frank DelRio

As 2025 comes to a close, we look forward to keeping you updated on EPDC's activities in 2026!

Sincerely,
Brian Gorman and Manoj Mahapatra (2024–25 co-chairs) ■

MEMBER HIGHLIGHTS

IN MEMORIAM

Ray Johnson

FOR MORE INFORMATION:

ceramics.org/membership

Volunteer Spotlight: Yiquan Wu

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

Yiquan Wu is Inamori Professor of ceramic engineering at the New York State College of Ceramics at Alfred University. He received his B.E. in materials sciences and engineering from Wuhan University of Science and Technology, his M.S. in materials science from the University of Science & Technology of China, and his Ph.D. in materials from Imperial College London. He worked at Duke University and the University of Rochester as a postdoctoral research associate and assistant research professor, respectively, before moving to Alfred.

Wu's research focuses on advanced ceramic materials for energy, optical, and photonic applications. Transparent polycrystalline ceramics are a particular interest.

Wu has served ACerS in a variety of ways. He was conference chair of the 16th Pacific Rim Conference on Ceramic and Glass Technology, and he previously served as chair of the Basic Science Division and president of the Ceramic Education Council. Currently, he serves as a member of the ACerS Board of Directors as well as editor for *Journal of the American Ceramic Society* and as associate editor for *International Journal of Ceramic Engineering and Science*.

Wu has received several ACerS awards, including the ACerS Global Ambassador Award and the Global Star Award from the Engineering Ceramics Division. He is an ACerS Fellow and an Academician of the World Academy of Ceramics.

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

ACerStudent Engagement: Brooke Downing and Wayne Yeo

Brooke Downing and **Wayne Yeo** are second- and third-year Ph.D. students, respectively, in materials science at Colorado School of Mines. They conduct research on piezoelectric materials, with Downing focused on controlling microstructure evolution in piezoceramics and Yeo working on high-frequency piezoelectric thin films for acoustic applications.

Downing and Yeo are both delegates of ACerS President's Council of Student Advisors, and they used the skills developed through this program to help organize the 2025 Colorado Center for Advanced Ceramics (CCAC) Conference. This annual conference is a fully student-run event that gathers the Colorado ceramics community together to share breakthroughs and exchange ideas on ceramic science and technologies.

Downing's role in organizing the CCAC Conference was conference fundraising. She appreciated the experience because "It gave me exposure in connecting with companies and navigating the complexities of conference organizing," she says.

Congratulations to Downing and Yeo on the successful event!

All students can gain valuable skills and experiences like Downing and Yeo through ACerS student membership. Learn more at https://ceramics.org/membership/join. ■

Names in the News

Members—Would you like to be included in the Bulletin's Names in the News? Send a headshot and link to the article to mmartin@ceramics.org.

Cato Laurencin, FACerS, University Professor and Albert and Wilda Van Dusen Distinguished Professor of Orthopaedic Surgery at the University of Connecticut and chief executive officer of The Cato T. Laurencin Institute on Regenerative Engineering, was named the winner of the 2025 Blaise Pascal Medal in Materials Science from the European Academy of Sciences. He will receive the award at the 2025 Symposium & Ceremony of the European Academy of Sciences, which will be held at CERN on Dec. 17–18, 2025, in Meyrin, Switzerland.

Martin Harmer, FACerS, DLM, Alcoa Foundation Professor Emeritus of Materials Science and Engineering and director of the Nano|Human Interfaces Presidential Research Initiative at Lehigh University, was named among The Falling Walls Foundation's Top 10 Breakthroughs of the Year 2025 in Physical Sciences for his pioneering work on copper-based superalloys. The Falling Walls Foundation, based in Berlin, Germany, takes its name from the fall of the Berlin Wall in 1989—a symbol of overcoming barriers. Each year, the organization recognizes breakthroughs across disciplines that "break walls" in science and society.

In honor of **L. David Pye**, DLM, FACerS, dean emeritus and professor emeritus of glass science at The New York State College of Ceramics at Alfred University, the L. David Pye Hall of Glass endowed fund was established to fuel the future of engineering and art and design at Alfred University. This fund supports a range of high-impact initiatives, including scholarship support for the Summer Undergraduate Research Program. ■

Ceramic Tech Chat: Rod Trice

Hosted by ACerS Bulletin editors, Ceramic Tech Chat talks with ACerS members to learn about their unique and personal stories of how they found their way to careers in ceramics.

In the September 2025 episode of Ceramic Tech Chat, Rod Trice, professor of materials engineering at Purdue University, briefly overviews the history of hypersonic flight, describes current hypersonic vehicle design paradigms and materials, and shares his expectations for the future of this critical national defense sector.

Check out a preview from his episode, where he shares how he came to be an instructor in the government-funded ACerS–USACA hypersonic training program.

"During the COVID-19 pandemic, I developed this course on materials for hypersonics. It was pretty broad; it covered a lot of the areas. And I've taught this course at Purdue many times now, and so it is pretty mature. I ran into Eileen De Guire at MS&T, and she mentioned that ACerS had gotten some money and was looking to develop a course on hypersonics. And of course I volunteered my services, and this is really what started my teaching relationship with ACerS."

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

AWARDS AND DEADLINES

Nomination deadlines for Society awards: Jan. 15, 21, 31, and March 1, 2026.

Contact: **Vicki Evans | vevans@ceramics.org**

Division	Award	Deadline	Description
AACS	Anna O Shepard	January 15	Recognizes an individual(s) who has made outstanding contributions to materials science applied to art, archaeology, architecture, or cultural heritage.
BSD	Early Discovery	March 1	Recognizes an ACerS early career member who has demonstrated a contribution to basic ceramic and glass science.
BIO	Young Scholar	January 31	Recognizes excellence in research among current degree-seeking graduate students and postdoctoral research associates.
BIO	Global Young Bioceramicist	January 31	Recognizes a young ceramic engineer or materials scientist who has made significant contributions to the area of bioceramics for human healthcare around the globe.
BIO	Larry L. Hench Lifetime Achievement	January 31	Recognizes an individual's lifetime dedication, vision, and accomplishments in advancing the field of bioceramics, particularly toward innovation in the field and contribution of that innovation to the translation of technology toward clinical use.
BIO	Tadashi Kokubo	January 31	Recognizes an individual's outstanding achievements in the field of bioceramics research and development.
CEMENTS	Early Career	January 31	Recognizes an outstanding early career scientist who is conducting research in the field of cement and concrete in academia, industry, or a government-funded laboratory.
GOMD	Norbert J. Kriedl	January 21	Recognizes a young engineer or materials scientist who has conducted excellent research in glass science. Nominations are open to all degree-seeking graduate students (M.S. or Ph.D.) or those who have graduated within a 12-month period of the annual GOMD meeting.
GOMD	George W. Morey	January 21	Recognizes new and original work in the field of glass science and technology. The criterion for winning the award is excellence in publication of work, either experimental or theoretical, done by an individual.
GOMD	L. David Pye Glass Hall of Fame	January 21	Recognizes an individual's lifetime of dedication, vision, and accomplishments in advancing the fields of glass science, glass engineering, and glass art.
GOMD	Stookey Lecture	January 21	Recognizes an individual's lifetime of innovative exploratory work or noteworthy contributions to outstanding research on new materials, phenomena, or processes involving glass that have commercial significance or the potential for commercial impact.
MFG	John E. Marquis Memorial Award	January 15	Recognizes the author(s) of a paper on research, engineering, or plant practices relating to manufacturing in ceramics and glass, published in the prior calendar year in a publication of the Society, that is judged to be of greatest value to the members and to the industry.

Individual **Membership**

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Student leadership: PCSA Annual Business Meeting 2025

In September 2025, students from 29 universities across seven countries gathered in Columbus, Ohio, for the ACerS President's Council of Student Advisors (PCSA) Annual Business Meeting.

Supported by the Ceramic and Glass Industry Foundation (CGIF), the PCSA Annual Business Meeting is designed to maximize idea-sharing and collaboration. Delegates work in committees to set achievable, high-impact goals for the year ahead while also building networks that will strengthen the future of the field.

For many of the 46 students who attended the three-day event, it marked the moment they stepped into leadership within the ceramics and glass community, finding their voices alongside peers and mentors in a professional setting.

Building connections and confidence

The PCSA Annual Business Meeting opened on Friday, Sept. 26 with introductions and an interactive icebreaker led by Scott McCormack, PCSA mentor-at-large and professor at the University of California, Davis. Students quickly found common ground, sharing both personal interests and professional goals.

The evening continued with committee rotations, where delegates explored opportunities to contribute in areas such as educational outreach, communications, recruitment and retention, professional development, and conference programming.

Leadership in action

Saturday was a full day of leadership and strategy. Delegates finalized committee placements, elected committee chairs, and began developing SMART goals for the year ahead.

A highlight of the day was lunch with the ACerS Board of Directors, where students engaged with professionals from industry, academia, and national labs. The conversations provided valuable insights into leadership and career pathways while helping students build connections that will support their futures.

On Sunday, the focus shifted to communication and long-term planning. During the research pitch session, students sharpened their science communication skills while presenting on topics ranging from high-temperature ceramics to energy storage and battery materials.

The day also included a hands-on outreach activity with the Education Committee, where students worked with the CGIF's popular materials science kits. The meeting concluded with reflections from outgoing officers and vision statements from the incoming leadership team for the 2025–26 year.

A lasting impact

Toward the end of the Annual Business Meeting, Pattiya Pibulchinda, fourth-year PCSA delegate and out-going vice council chair, reflected on her time with the organization.

The outgoing and incoming council chairs, Nathan McIlwaine and Randi Swanson, respectively, stand in the front of the 46-person delegation during the PCSA Annual Business Meeting.

Scott McCormack (right), PCSA mentor-at-large and UC Davis professor, leads the group in an icebreaker activity designed to encourage networking and creative problem solving.

"The PCSA is the platform for ceramics- and glass-focused students to connect and strengthen their professional network, not just within the PCSA but also through the activities the PCSA organizes," she said.

As the meeting closed, students left Columbus energized, connected, and ready to lead. Throughout the year, they will continue collaborating online, at their universities, and at scientific conferences, advancing the goals and programs established at the in-person meeting. With the continued support of the CGIF, the PCSA will carry forward its mission of developing student leaders who will shape the future of ceramics and glass.

Visit https://ceramics.org/pcsa to learn more about the PCSA and become involved.

Help us continue to empower the next generation of ceramic and glass professionals by giving now at https://ceramics.org/donate. ■

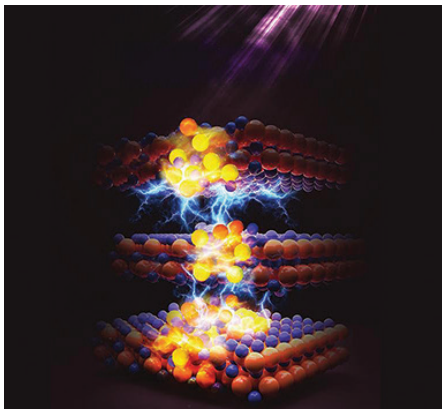
Ferroic indium selenide achieves solid-state crystal-to-glass transition

Researchers from the University of Pennsylvania, along with colleagues from Massachusetts Institute of Technology and Indian Institute of Science, Bengaluru, published a paper in *Nature* describing a novel capability of ferroelectric β″-phase indium selenide: the ability to undergo solid-state amorphization through direct-current stimulation.

Indium selenide is sometimes called the "golden" semiconductor due to its combination of graphene-like (extreme thinness) and silicon-like (high electron mobility) properties. In contrast to these other materials, however, indium selenide exhibits a remarkably tunable bandgap, due in part to its multiple stable crystalline phases.

Large-scale production of 2D indium selenide for wafer-scale integration has remained elusive due to difficulties maintaining an ideal atomic ratio between indium and selenium during synthesis. While some groups work on overcoming this hurdle, others continue to investigate the full extent of indium selenide's unique properties and capabilities—such as the authors of the recent paper.

When first author Gaurav Modi, former Ph.D. student at the University of Pennsylvania, first attempted electrical stimulation of indium selenide nanowires, he was shocked to observe that the solid-state transition could be induced through continuous, rather than pulsed, current.



Credit: Aakanksha Jain; Indian Institute of Science, Bengaluru

Artist's impression of electrically driven solid-state amorphization in ferroelectric β″-phase indium selenide. The lightning bolts indicate electrical spikes from piezoelectricity-induced mechanical shocks, which transition the material to a glassy phase.

"I actually thought that I might have damaged the material," he says in a press release. "Normally, you would need electrical pulses to induce any kind of amorphization, and here, a continuous current had disrupted the crystalline structure, which shouldn't have happened."

Modi and his coauthors then used a suite of in-situ microscopy tools to uncover the mechanism enabling this transition.

They discovered that when a continuous current is passed parallel to the 2D indium selenide's layers, the layers slide against each other in different directions. This sliding causes the formation of many domains bound by defective regions, and when multiple defects intersect in a small nanoscopic region, the structural integrity of the crystal collapses to form glass locally.

The collapse of these local regions triggers an avalanche effect, whereby more domain boundaries are created and then collapse. The avalanche stops when the entire material turns into glass.

"It's just goosebumps stuff to see all of these factors come to life and play together, at different length scales in an electron microscope," says second author Shubham Parate, Ph.D. student at Indian Institute of Science, Bengaluru, in the press release.

This discovery could greatly reduce the amount of power needed for optical storage media devices, such as CDs, DVDs, and Blu-ray discs. These devices store and erase data by switching a material between its crystalline and glassy phases. Currently, this switch is triggered using laser pulses to rapidly heat and quench the phase-change material, during which time it passes through an intermediate liquid phase. Using electricity to induce a solid-state transition instead would make the process less energy intensive.

The paper, published in *Nature*, is "Electrically driven long-range solid-state amorphization in ferroic In_2Se_3" (DOI: 10.1038/s41586-024-08156-8). ■

Materials in the news

Paper-thin light glows like the sun

Hefei University of Technology researchers developed an ultrathin, paper-like LED that emits a warm, sunlike glow. They achieved this light quality, which is close to natural sunlight, by engineering a balance of red, yellow–green, and blue quantum dots. The emitted light had more intensity in red wavelengths and less intensity in blue wavelengths, which is better for sleep and eye health. These light sources required only 8 V to reach maximum light output, and about 80% exceeded the target brightness for computer monitors. For more information, visit https://www.sciencedaily.com/releases/2025/10/251010091543.htm.

Unlock the quantum magic hidden in diamonds

Researchers at Hebrew University of Jerusalem and Humboldt University in Berlin developed a way to capture nearly all the light emitted from tiny diamond defects known as color centers. Using hybrid nanoantennas consisting of metal and dielectric materials, they precisely guided light from nanodiamonds into a single direction, achieving 80% efficiency at room temperature. The innovation could make practical quantum sensors and secure communication devices much closer to reality. For more information, visit https://www.sciencedaily.com/releases/2025/10/251007081833.htm.

Decade-long effort sheds light on how oxide catalysts can sustain themselves

In a groundbreaking paper that was 10 years in the making, a multi-institution team provided direct visualizations of the Mars-van Krevelen mechanism.

The Mars-van Krevelen mechanism is widely applied in processes that involve solid catalysts (typically metal oxides) and gaseous reactants, such as hydrocarbon oxidation and catalytic cracking. This cyclical redox mechanism involves several steps:

- The reduction of the catalyst by a (typically organic) reactant. Oxygen is lost from the lattice, leaving oxygen vacancies on the catalyst's surface.
- The reduced catalyst is reoxidized by reacting with gaseous oxygen, which fills the vacant sites on the catalyst surface.
- The catalytic reaction cycle repeats, with another round of reduction and reoxidation.

Athough the explanation above makes the Mars-van Krevelen mechanism sound like a well-understood process, there is scant experimental evidence proving the details of this reaction. Prior studies largely inferred oxygen dynamics and transient surface states indirectly, lacking the spatiotemporal resolution to correlate surface restructuring with reactivity in real time.

The authors of the recent study addressed this gap in the literature by integrating in-situ environmental transmission electron microscopy (TEM) with multimodal spectroscopy and computational modeling to better understand the mechanism at atomic resolution.

"From the experiment, we can see the phenomena and reaction now," says project leader Guangwen Zhou, SUNY Distinguished Professor and deputy director of materials science and engineering at the State University of New York at Binghamton, in a news release. "From the modeling side, we can better understand how much energy we need to supply to make it happen first."

The study focused on cupric oxide (CuO) catalysts under hydrogen exposure. This metal oxide is considered a model system for reactions such as the water–gas shift and methanol synthesis due to its industrial relevance.

The in-situ TEM experiments involved two sequential steps:

1. In-situ formation of CuO inside the environmental TEM by oxidizing metallic copper at 300°C in 0.5 Pa of oxygen pressure.
2. Switching to hydrogen gas flow (0.5 Pa) to induce the oxide reduction reaction.

The researchers observed oscillatory redox behavior due to the Mars–van Krevelen mechanism. But they also observed a previously unknown, unique behavior of the metal oxide catalyst that allows it to self-regulate.

During the first step of the redox reaction, when most of the oxide's topmost oxygen layer is pulled away, the oxygen embedded within the oxide's internal structure begins to diffuse upward. This inner oxygen, along with the gaseous environmental oxygen, repopulates the oxide's surface area—thus helping restart the cycle of reactivity. Process details:

- Gaseous hydrogen molecules react with surface-level lattice oxygen, which consist mainly of Cu_8O_7. The reaction forms water molecules that desorb from the surface at elevated temperatures, while at the same time, oxygen vacancies are created at the oxide surface.
- As lattice oxygen are lost, Cu_8O_2 forms on the surface. Experiments confirmed that both Cu_8O_7 and Cu_8O_2 exhibited high surface stability and were not prone to transform into other compositions.
- Because the Cu_8O_2 surface is stable, the subsurface oxygen can refill oxygen vacancies at the surface, helping convert the surface back to Cu_8O_7.

The researchers plan to investigate reaction conditions to see if there are other ways to change or even control the oscillatory behavior.

The paper, published in *Proceedings of the National Academy of Sciences*, is "Oscillatory redox behavior in oxides: Cyclic surface reconstruction and reactivity modulation via the Mars–van Krevelen mechanism" (DOI: 10.1073/pnas.2422711122). ■

AI reveals what fusion sensors cannot see

Developed by Princeton scientists and international collaborators, a powerful new artificial intelligence tool called Diag2Diag aids fusion research by filling in missing plasma data with synthetic yet highly detailed information. This system uses sensor input to predict readings other diagnostics cannot capture, especially in the crucial plasma edge region where stability determines performance. The researchers also found that the synthetic data supports a leading theory about how one method for stopping plasma disruptions works.
For more information, visit https://www.pppl.gov/news

Perovskite camera can see inside the human body

Researchers led by Northwestern University and Soochow University built a perovskite-based detector that can capture individual gamma rays for single-photon emission computed tomography imaging with record-breaking precision. It can also sense extremely faint signals from a medical radiotracer and distinguish incredibly fine features, producing crisp images that can separate tiny radioactive sources spaced just a few millimeters apart. For patients, this innovation could mean shorter scan times, clearer results, and lower doses of radiation. For more information, visit https://news.northwestern.edu/stories/2025. ■

First sample of MXene-enhanced UHTCs confirms potential of this materials design pathway

In a open-access paper, researchers at Purdue University and Colorado School of Mines moved beyond fundamental investigations and created the first MXene-enhanced ultrahigh-temperature ceramic (UHTC) for experimental testing.

UHTCs are a class of materials comprised of borides, carbides, and nitrides of transition metals with very high melting points, generally above 2,000°C. UHTCs have been a subject of extensive research since the 1960s, and some of these materials now have established industrial uses. However, the use of UHTC borides and carbides with melting points above 3,000°C for aerospace applications—such as leading edges and nose caps in hypersonic aircraft—remains a nascent field of research.

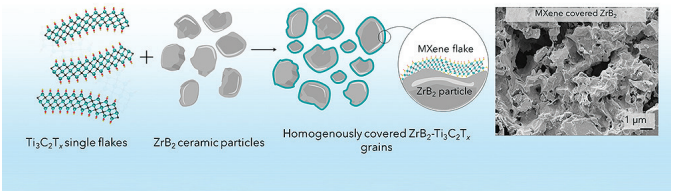
One of the challenges with using UHTCs in the aerospace sector is the fact that, like other ceramics, UHTCs can suffer from intrinsic brittleness. Thus, manufacturers need ways to improve the strength and fracture toughness of UHTCs.

MXenes are one promising solution to improve the mechanical properties of UHTCs. MXenes are a family of 2D early transition metal carbides and nitrides with a wide degree of tunability in their chemistry. This tunability has enabled MXenes to be applied in areas ranging from energy storage and conversion to flexible optoelectronics to wearable biosensors.

MXenes have the potential to be used as additives in traditional UHTC materials or even as standalone materials in extreme environments. But until now, only fundamental studies on this potential application have taken place.

For this first experimental study, the researchers chose zirconium diboride as the model system. Zirconium diboride offers the benefits of high melting point (>3,200°C) and high strength at elevated temperatures (up to 800 MPa at 1,600°C), but it suffers from inherent brittleness, poor sinterability, and is prone to oxidation.

To create the MXene-enhanced UHTC, the researchers developed a self-assembly-driven green body synthesis method to conformally cover the zirconium diboride grains with titanium carbide MXene ($Ti_3C_2T_x$). The method uses electrostatic interactions in aqueous solutions to achieve the conditions necessary for successful self-assembly.



Credit: Nemani et al., *Advanced Science* (CC BY 4.0)

Schematic of the MXene-enhanced ultrahigh-temperature ceramics synthesis process alongside a scanning electron microscopy image of 2.5 wt.% MXene-enhanced zirconium diboride green bodies.

Analysis of the MXene-enhanced zirconium diboride samples showed that even just a small addition of MXene into the UHTC, as low as just 0.5 wt.%, improved densification from about 88% in pure zirconium diboride to about 96% for the encapsulated grains after spark plasma sintering.

Furthermore, the zirconium diboride's mechanical properties improved substantially after encapsulation, including a 36% increase in hardness, an about 12% enhancement in Young's modulus, and an about 15% increase in flexural strength at 2.5 wt.% MXene loading.

Based on these results, the researchers drew two conclusions:

- The MXene-enhanced UHTCs produced using this process demonstrate enhanced mechanical properties and strengthening mechanisms, which should facilitate their use in high-temperature aerospace and energy applications.
- Because the new self-assembly process does not require any surfactants or stabilizing agents, it should be applicable to other MXenes and UHTCs.

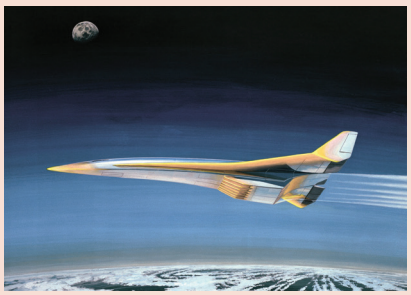
"Our findings mark a key step in bridging fundamental studies with practical applications, demonstrating MXenes' real potential in UHTCs," says lead author Kartik Nemani, post-doctoral research fellow at the University of Alabama at Birmingham, in an email.

The open-access paper, published in *Advanced Science*, is "$Ti_3C_2T_x$ MXene–zirconium diboride based ultra-high temperature ceramics" (DOI: 10.1002/advs.202500487). ■

Learn more about UHTCs in the Hypersonic Training Program

In August 2025, The American Ceramic Society and the United States Advanced Ceramics Association were awarded a two-year extension of funding from the Department of Defense for their successful "Professional Development for Hypersonic Materials" program. This funding will enable both ACerS and USACA to build upon the strong foundation established through the January 2024 contract award under DOD's Industrial Base Analysis and Sustainment Program.

Learn more about the program and get involved by visiting https://ceramics.org/education/hypersonic-training-program. ■



Credit: NASA

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Fabrication approaches to nacre-like ceramic–metal composites

By Sourabh Kumar and Hortense Le Ferrand

Credit: Peter Hermes Furian / Shutterstock

Amongst the various composite materials, nacre-like composites propose to leverage the brick-and-mortar microstructure found in the nacreous layers of seashells to achieve an unusually high combination of strength and toughness.[1]

Nacre consists of 95 vol.% aragonite, a crystallographic form of $CaCO_3$, and 5 vol.% of organic matter, mostly protein and chitin. Although pure aragonite microplatelets are hard and brittle, the addition of a thin organic layer between them endows nacre with a fracture toughness three to nine times higher than that of the hard $CaCO_3$ tiles, in dry and hydrated states, respectively.[2]

Numerous nacre-inspired composites have been developed, with the common feature that they all reproduce some kind of alignment of 2D microreinforcements, such as ceramic microplatelets or other 2D nanosheets.[3] However, these composites may not display all the microstructural key features of nacre when they contain low concentrations of reinforcing elements dispersed in a softer matrix.

Nacre-like ceramic composites with a metallic mortar could combine the excellent toughness of metals with the high-temperature resistance of ceramics (Figure 1). To assess whether these expectations for nacre-like ceramic–metal composites can be achieved, this paper reviews the existing developments in the processing of such composites.

General overview of fabrication approaches

With the increasing research in nacre-like ceramic–metal composites, a variety of fabrication processes have been explored, revealing two main routes (Figure 2A):

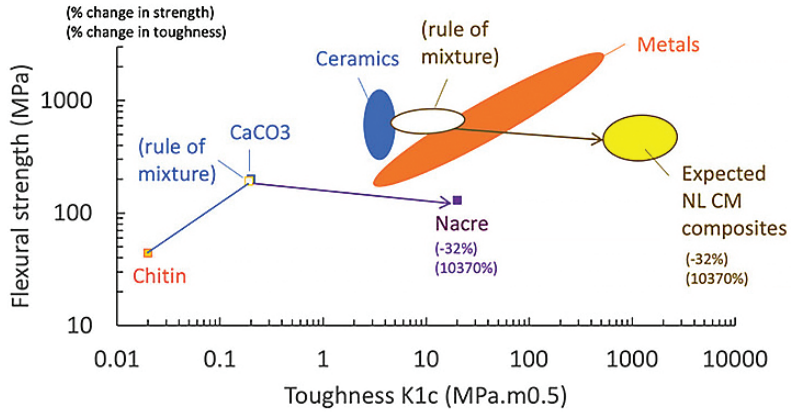
- **Route I** consists of fabricating a continuous ceramic scaffold first, then infiltrating that ceramic scaffold with molten metal, either with or without the use of pressure. A hot-pressing step can serve as a final densifying and consolidating step.
- **Route II** consists of co-assembling ceramic and metal powders followed by their compaction, typically using a high-temperature pressing step.

Route I processes are very similar to the processes used for making nacre-like ceramic–polymer composites, where a thermosetting resin is infiltrated into a ceramic scaffold and

*This article is excerpted from "Nacre-like ceramic–metal composites: State-of-the-art, challenges, and opportunities," *JACerS* 2025, **108**(11): e20623. https://doi.org/10.1111/jace.20623

crosslinked. Route II processes resemble ceramic processes, where slurries containing various types of particles are processed and consolidated together.

These processing routes have been explored for developing various specific compositions. Figure 2B illustrates the development of various types of nacre-like ceramic–matrix composites over the years, revealing the accelerated development in the past decade.



Credit: Kumar and Le Ferrand, JACerS

Figure 1. Toughness–strength performance map representing natural nacre (purple) and the hypothetical nacre-like ceramic–metal (NL CM) composites (yellow). Natural nacre and nacre-like ceramic–metal composites outperform their individual components as well as the predictions from the rule of mixture (10,370% increase in toughness as compared to the rule). They do, however, demonstrate a slight decrease of -32% in flexural strength.

Route I fabrication: Ceramic scaffold and metal infiltration

Route I first builds a porous ceramic scaffold with aligned features, which is then infiltrated with molten metal and eventually pressed as a final densification step. There are three main processes reported for route I: freeze casting, 3D printing, and vacuum filtration.

Freeze casting

In a typical freeze-casting process, a suspension of ceramic particles in water is frozen under a controlled directional temperature gradient, leading to the growth of lamellar ice crystals. These unidirectional crystals create a unidirectional structure that imitates the aligned structure in nacre. Subsequently, the ice is removed via sublimation, leaving behind the porous ceramic scaffold. This scaffold is consolidated by sintering before being infiltrated by a molten metal, leading to the nacre-like ceramic–metal composite.

This method allows the development of materials with intricate microstructures, achieved by carefully regulating the freezing process and the kinetics of ice crystal solidification. Traditional unidirectional freeze casting, where cold is applied at the bottom surface of the vessel into which the suspension is deposited, can be tailored to create more complex freezing patterns. For example, bidirectional freeze casting can control the ice crystal structure in both longitudinal and transverse directions.[4]

3D printing

This process involves the 3D printing of ceramic scaffolds followed by infiltration with molten metal. Typically, computer-aided design is used to design the 3D porous geometry, which is then realized using stereolithographic 3D printing using polymeric inks containing ceramic particles. The 3D-printed green parts are sintered with supportive structures to prevent warping and distortion at high temperatures to yield the ceramic scaffold.

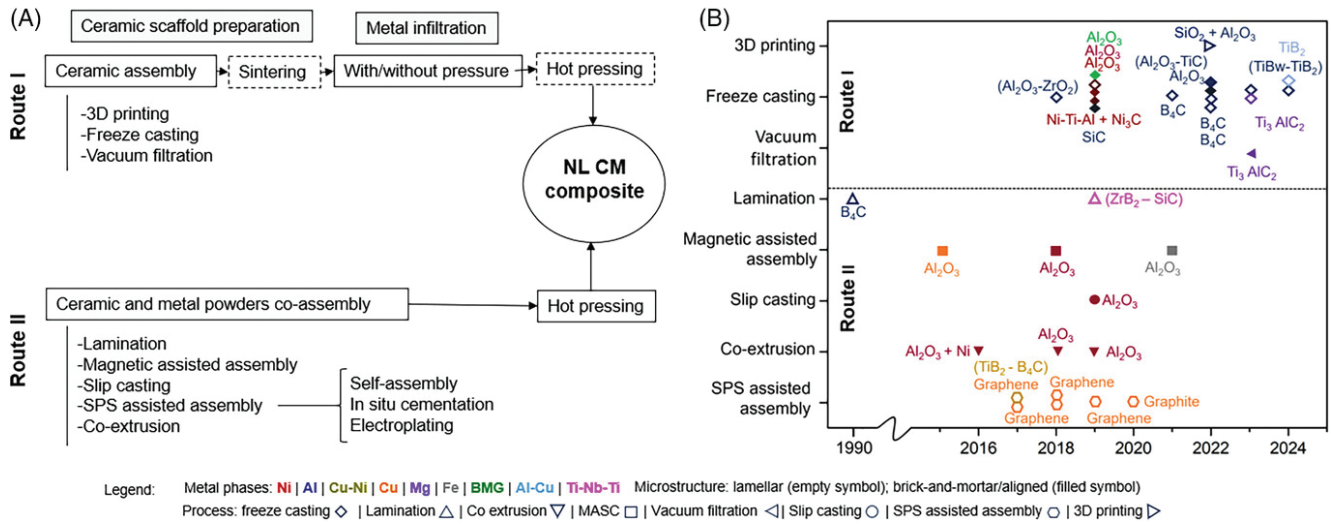
Before infiltrating the molten metal, the volume of the voids are calculated based on the density of the scaffold, and 15% more volume of metal than the estimated volume of voids is used to ensure complete infiltration. Khan et al.[5] used this strategy to print silica scaffold infiltrated with aluminum using centrifugal force. Although only stereolithography has been reported to be used for making nacre-like ceramic–metal composites, other 3D printing methods for making porous ceramics with aligned microstructures can be used, such as extrusion-based direct-ink writing or magnetic drop-on-demand 3D printing.

Vacuum filtration

Another approach for fabricating ceramic scaffolds involves the alignment of ceramic platelets by vacuum filtration, followed by partial sintering for consolidation. The scaffolds are then infiltrated with molten metal to form a nacre-like ceramic–metal composite.

This method was presented by Liu et al.,[6] where titanium aluminum carbide platelets of sizes ranging from 100 to 300 nm were dispersed in ethanol at a mass ratio of 3:40 through ultrasonication and ball milling. The suspension was poured into a funnel and filtered through a nylon membrane with a pore size of 0.1 µm under a vacuum pressure of about 0.06 MPa, promoting the horizontal alignment of the platelets as they deposited onto the membrane. The resulting bulk material was dried, subjected to vertical pressing at 72 MPa for one hour, and partially sintered in a flowing argon atmosphere at 900°C for one hour. The titanium aluminum carbide scaffold with open pores was subsequently infiltrated with molten AZ91D alloy in a flowing argon gas at 850°C, a temperature higher than the melting point of the alloy, and then naturally cooled in the furnace to obtain the nacre-like ceramic–metal composite.

Route I methods create aligned ceramic scaffolds. Other methods for creating such scaffolds than those described here exist, although they have not yet been employed for producing nacre-like ceramic–metal composites. For example, the electrical or magnetic orientation of particles can be used to assist the horizontal alignment of the particles.[7] The infiltration of the molten metal can also be done with or without the application of pressure.



Credit: Kumar and Le Ferrand, JACerS

Figure 2. Processing routes for making nacre-like ceramic–metal (NL CM) composites. (A) Schematic illustrating the various processing steps. (B) Overview of the processing steps developed over the years for various compositions. Different colors indicate different metal mortar phases: aluminum and aluminum alloy in blue, nickel in maroon, copper in orange, magnesium and magnesium alloys in purple, iron in grey, titanium–niobium–titanium in pink, copper–nickel in gold, aluminum–copper in light blue, bulk metallic glass (BMG) in green. The compositions of the ceramic phases are written on the graph next to their symbol.

Route II fabrication: Powders co-assembly and hot pressing

Route II processes co-assemble the ceramic and metallic components together at the same time and consolidate everything using hot pressing. There are five main processes reported for route II: lamination, slip casting, magnetically assisted slip casting (MASC), spark plasma sintering (SPS)-assisted assembly, and coextrusion.

Lamination

In this process, tapes made up of ceramics through tape casting are laminated with metal sheets to create a horizontally aligned structure. The laminated layers are then consolidated via hot pressing. During the hot pressing, the metallic foils melt and partially infiltrate the tape-casted ceramic scaffolds while making a continuous metallic phase. Metallic foils of various compositions can be used in this method as well as combined compositions.

This process was the first one utilized for the biomimetic design and processing of laminated boron carbide–aluminum composites.[8] This process has also been used to form nacre-like ceramic–metal composites made of zirconium boride–silicon carbide and titanium–niobium–titanium.[9]

Slip casting

Slip casting is another process derived from the ceramic industry, where a slurry containing particles is cast onto a porous mold that drains the liquid from the slurry before drying and sintering.

The method has been applied to slurries containing nickel-coated alumina microplatelets that aligned due to gravity during the slip casting.[10] The green bodies were rapidly sintered using SPS at 1,100°C or 1,200°C. Dewetting of the nickel mortar during sintering was prevented by using a mixture of nickel oxide-coated and nickel-coated alumina platelets. To obtain a high packing density in the green bodies, a high solid loading (50 wt.%) was employed in the slurry used for slip casting.

Magnetically assisted slip casting

MASC combines slip casting with the magnetic orientation of ceramic and metallic anisotropic particles. Nacre-like alumina–copper composites have been obtained by this process, followed by densification through hot-pressing at 1,150°C for 60 min at about 60 MPa pressure.[11]

This method has also been applied to slurries containing iron-coated alumina microplatelets, followed by pressure-assisted densification at 1,450°C to make nacre-like alumina–iron composites.[12] The iron coating of the alumina microplatelets was conducted using a nonaqueous sol–gel reaction using a metal–organic precursor dissolved in benzyl alcohol, followed by a reduction reaction in a 5 vol.% hydrogen–nitrogen atmosphere at high temperature. The volume fraction of the metal in the composite was controlled by tuning the relative amount of precursor used in the sol–gel reaction to ensure the coating, which effectively formed the metallic matrix after MASC and hot pressing.

A similar method used nickel-coated alumina microplatelets produced using electroless plating to create nacre-like alumina–nickel composites.[13]

Spark plasma sintering-assisted assembly

In this assembly method, ceramic platelets and metal flakes are mixed together and consolidated directly using SPS. The unidirectional pressure provides the force for the nacre-like horizontal alignment.

Fontoura et al. utilized this technique to consolidate multilayer graphene flakes with copper precipitates into a nacre-like ceramic–metal composite.[14] The flakes were dispersed in a solution of copper sulfate salt with acetic acid in deionized water. The acetic acid in the solution activated the surface of the flakes, imparting a partial negative charge that attracted the positively charged copper ions. A cementation reaction between magnesium and copper ions was then carried out, where more reactive magnesium oxidized, reducing the copper ions on the flakes' surface. The resulting multilayer graphene–copper powder was consolidated using a graphite die in SPS.

In a different approach, Cao et al. used flaky copper powders to promote the in-situ growth of graphene under a controlled atmosphere, yielding a graphene/flaky copper composite powder.[15] This powder was then mixed with graphite flakes and densely stacked into a graphite die, which was compressed at 900°C in a vacuum under a pressure of 50 MPa for one hour to produce a nacre-like graphene–copper composite.

Similarly, Yang et al. used a graphene oxide colloid with $Cu(CH_3COO)_2 \bullet H_2O$ to prepare reduced graphene oxide/copper composite powder after reducing the mixture of powders in hydrogen–argon gas.[16] The as-prepared composite powders were pressed and sintered using SPS at 600°C for five minutes under vacuum at a pressure of 40 MPa to form the layered reduced graphene oxide–copper composite. Similarly prepared reduced graphene oxide–copper nanocomposite powders were compacted by Hwang et al. in a graphite mold at 600°C for three minutes under vacuum in SPS at an applied pressure of 50 MPa.[17]

In another study, a layered composite was obtained by stacking layers of copper- and nickel-electroplated titanium boride–boron carbide plates under a hot pressing sintering apparatus.[18] The electroplating process was performed to obtain a layer of copper and nickel over the thin plates of titanium boride and boron carbide. The simplicity of the equipment for this process makes it popular.

Coextrusion

The coextrusion process provides a unique opportunity to fabricate brick and mortar structure by using a feed rod composed of a core and a shell around it. A filament is extruded from the feed rod, which consists of ceramics coming out from the core and a metallic layer around it extruding from the shell. Precise control of metallic coating over the ceramics is obtained through this process, resulting in high-ceramic and low-mortar volume fractions in the final microstructure.

The filaments are then segmented into individual units, representing bricks in the "brick-and-mortar" structure. These segmented filament units are further laminated to form billets with varied orientations and configurations, followed by hot pressing to achieve a densely packed nacre-like ceramic–metal composite.

Capabilities and challenges of current processing methods and alternative approaches

While the microstructures obtained are referred to as "nacre-like," in reality, there are three distinct types of microstructures obtained for the nacre-like ceramic–metal composites:

1. **Lamellar microstructures**, which correspond to alternating horizontal continuous layers. These lamellar microstructures are for most of the cases obtained by freeze casting or lamination.
2. **Brick-and-mortar microstructures**, which are the typical nacre-like structures desired to achieve high strength and toughness. These microstructures are obtained for most of the powder-based (route II) processes when the concentration of the ceramic phase is predominant.
3. **Aligned microstructures**, which are also obtained from the route II processes and have been mostly obtained through SPS-assisted assemblies. These microstructures do not have a high enough concentration of ceramic phase to form bricks, and the microstructures appear as ceramic particles dispersed in a matrix.

Some processes can produce more than one kind of microstructure or a combination of two microstructures. Freeze casting has produced both lamellar and brick-and-mortar structured nacre-like ceramic–metal composites with pressureless infiltration of molten metal into ice-templated ceramic scaffolds.[19] Along with that, bidirectional freeze casting followed by pressured metal infiltration had produced lamellar composites, which upon further hot pressing led to brick-and-mortar composites.[4]

The processes present various capabilities in terms of mortar and bricks' thicknesses, aspect ratio, mineral content, and quality of alignment defined by the fast Fourier transform ratio. It is noticeable that the thickness of the metal mortar varies linearly with the thickness of the ceramic brick, and this variation is independent of the process used or of the chemistry of the components. Nacre has a mortar thickness below 20 nm[20] for ceramic bricks of 200 nm to 1 μm.[21] It appears that only a couple of nacre-like ceramic–metal composites have achieved these dimensions: the nacre-like titanium aluminum carbide–magnesium with brick-and-mortar structure produced through vacuum filtration,[6] and the nacre-like alumina–nickel composites with both lamellar and brick-and-mortar microstructure produced by freeze casting[22] and SPS-assisted assembly.[13] All the other composites have higher thicknesses of bricks and mortar.

The mineral content in nacre-like ceramic–metal composites varies over a long range; however, in actual nacre, the mineral content is quite high, and only a few nacre-like ceramic–metal composites have reached those high values of mineral content. Coextrusion and MASC processes have consistently produced nacre-like ceramic–metal composites with high mineral content in brick-and-mortar microstructure, and a few composites through freeze casting in both lamellar and brick-and-mortar microstructure have also obtained mineral content in similar range. Furthermore, the aspect ratio of the bricks also does not show any obvious trend with composition and process, although the lamellar structure inevitably achieves a very large aspect ratio as per its definition.

The highest aspect ratio realized for the brick-and-mortar structure is about 6–7 and is obtained for processes involving hot pressing or SPS. These highest aspect ratios are obtained

for nacre-like ceramic–metal composites with high vol.% in ceramics, around 80 vol.%. The correlation between a high aspect ratio and high mineral vol.% is likely due to the use of hot-pressing that densifies the system quickly while preventing diffusion and grain growth.[23] Other methods such as coextrusion or freeze casting also achieve high density but without reaching a high aspect ratio. High relative density and high aspect ratio are two parameters desired in the composites in order to achieve high strength and high toughness.

Finally, alignment is also a parameter necessary to have nacre-like structures with high anisotropy and mechanical properties. The word "alignment" used here refers to the morphological arrangement of the ceramic and metal building blocks. In a nacre-like ceramic–metal composite, the ceramics exhibit a narrow distribution of crystalline orientations in one direction. This alignment is due to the shape anisotropy of the ceramic grains after sintering because of processing conditions, which on a micrometer scale looks like the microstructure of a nacre.

This alignment can be characterized using several methods that make use of crystalline anisotropy in the ceramic, or the shape anisotropy of its grains, such as electron backscattering diffraction in scanning electron microscopes or selected area electron diffraction in transmission electron microscopes. For large area characterization, X-ray diffraction can be used in the Θ to 2Θ scan method, four-axis diffractometer, Eulerian cradle, or rocking curves. Other characterization techniques are small angle X-ray scattering, neutron diffraction, and directional reflectance microscopy.

All structures have some degree of alignment because the fast Fourier transform ratio is higher than 1 for all. There is no obvious trend in alignment quality between the lamellar and the brick-and-mortar/aligned structures. However, the alumina–iron composite obtained using MASC followed by unidirectional hot pressing achieved the highest alignment. Three composites have the next highest alignment degree and were obtained by lamination, MASC, and SPS-assisted assembly, respectively, likely due to the use of unidirectional pressure as the final processing step.

In addition to these microstructural considerations, the presence of appropriate connections between the mineral phase is important to increase the strength and provide further energy dissipation mechanisms. Two major types of bridges can be recognized: (1) interpenetrated metal and ceramic phases due to the remaining porosity in the scaffolds before infiltration for route I processes and (2) mineral bridges or mineral connections due to the sintering for route II processes. These connections are either singular points or areas and are rather randomly distributed.

Finally, some nacre-like ceramic–metal composites present an interface layer that helps with the bonding between the metal and ceramic phases. Indeed, dewetting is a common problem between metal and ceramic due to higher contact angles, preventing the adhesion between the two phases. The work of adhesion of metal over ceramic is higher than the surface energy of metal. In that case, it is favorable for the metal to form droplets on the ceramic surface, minimizing the contact area between the two materials. High contact angles may also prevent pressureless infiltration, but in some cases, infiltration is accompanied by reactions that may result in an apparent decrease in the contact angle, facilitating pressureless infiltration. These reactions often result in brittle interfacial products that significantly degrade the properties of the composite.

Two main avenues have been developed to address these issues, both leading to the formation of an intermediate layer between the ceramic and the metal: (1) using coating or (2) by having a reaction between the metal and the ceramic. Examples of coating include coating alumina platelets with nickel oxide to improve interfacial bonding with nickel,[10] direct deposition of iron oxide and iron on alumina platelets using sol–gel chemistry,[12] and adding a thin layer of copper between titanium boride–boron carbide and nickel.[18]

The metal oxide coating on alumina platelets undergoes partial reduction, leading to the presence of controlled oxygen concentration, which reduces or eliminates the chance of dewetting during sintering without any interfacial reaction. In other works, in-situ formation of titanium boride with (titanium, niobium) carbon whiskers were used to alleviate interfacial residual stresses, improving the interfacial bonding strength.[9]

For creating a strong bonding between graphene and copper, copper (II) hydroxide and copper oxide were let to form during the process to allow good interfacial strength due to copper–oxide bond formation before reduction to copper during SPS.[16] In another approach, an in-situ cementation process was used to develop multilayer graphene–copper powders, where the surface of the multilayer graphene flakes is activated by acetic acid to deposit copper sulfate and copper ions on the flakes followed by reduction to copper with the use of magnesium.[14] Similarly, boron carbide was let to react with titanium hydride to decrease the contact angle and increase the wetting and interfacial bonding of the ceramic to a magnesium alloy.[24]

The various processes developed thus far to produce nacre-like ceramic–metal composites present a range of capabilities. The freeze-casting approach appears to be the method providing the highest flexibility in terms of microstructural control and volume fraction in ceramics. It is also the most employed method, which is why it has been tested for various composites.

Some other processes such as coextrusion and MASC exhibit more unique specificities, such as achieving a higher concentration of ceramics, smaller ceramic bricks, lesser mortar thickness, and higher quality of alignment. Vacuum filtration has been shown to produce the smallest ceramic bricks and the lowest mortar thickness but with lower mineral content compared with other processes.

Similarly, SPS-assisted assemblies have produced lower mineral content in nacre-like graphene–copper composites with thicker ceramic bricks. However, the same process has also produced nacre-like alumina–nickel composites with higher mineral content and thinner ceramic bricks.

Coextrusion, MASC, vacuum filtration, and SPS-assisted assembly have mostly produced nacre-like ceramic–metal composites with brick-and-mortar structure. On the other

hand, freeze casting is flexible enough to produce both lamellar and brick-and-mortar structures, while tape casting has predominantly produced lamellar-structured nacre-like ceramic–metal composites with larger ceramic brick sizes and higher mortar thickness.

There is still a large research space to explore more extensively across various combinations of metals and ceramics as well as to achieve brick-and-mortar structures with high aspect ratios and high mineral content. The high temperatures used during the sintering process pose a challenge to this aim due to the ceramic grain coarsening during densification.

The research on nacre-like ceramic–metal composites could build on the results of sintering methods of high-performance ceramics, for example, by exploring microwave sintering or ultrafast high-temperature sintering. Other features such as the surface roughness of the ceramic bricks that are found in nacreous seashells and reproduced in nacre-like ceramic–polymer composites could also be further explored with metallic mortars.

In the future, continued research on nacre-like ceramic–metal composites is essential to realize their potential in the development of advanced engineering materials, suitable for a wide range of applications.

About the authors

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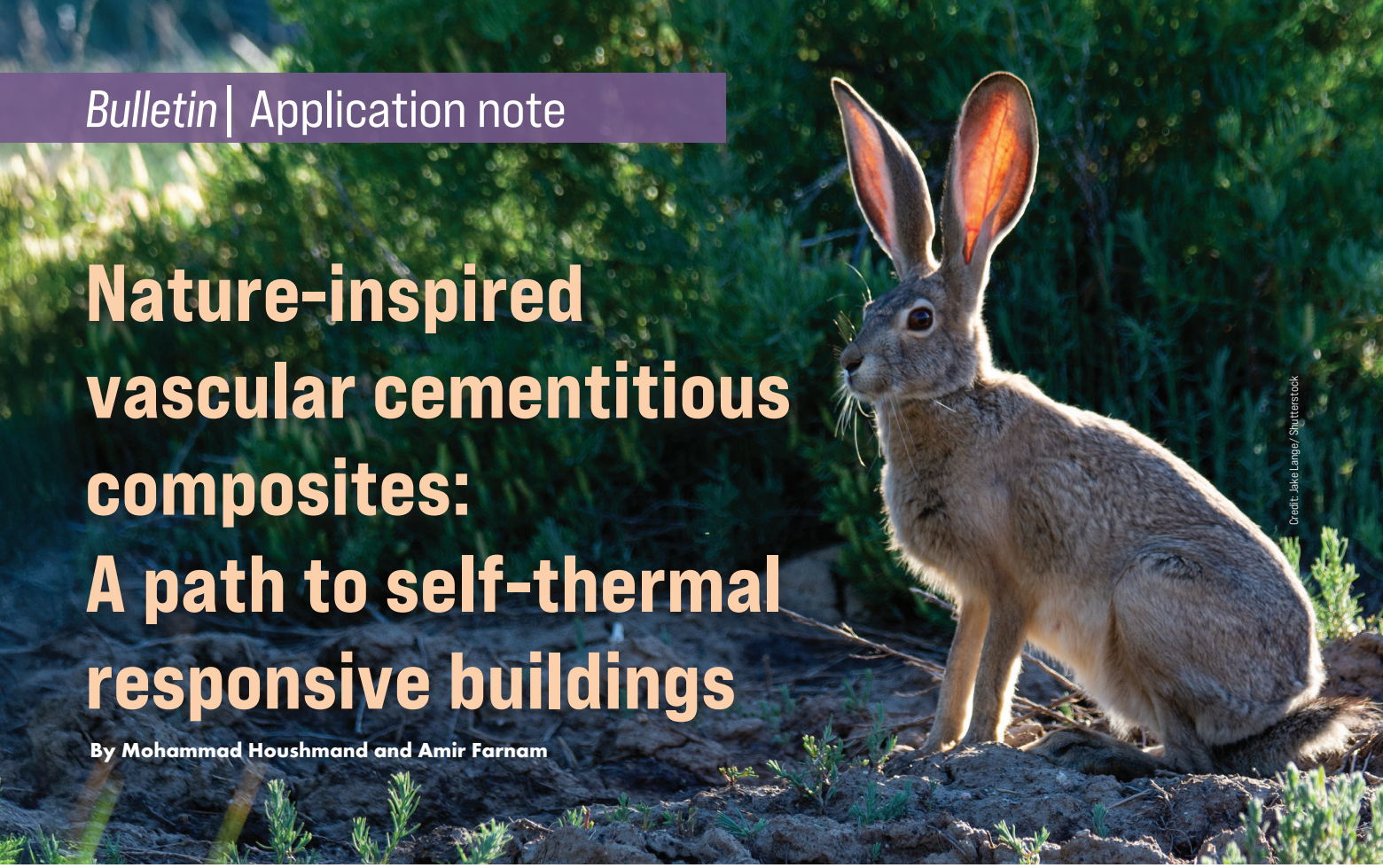
Nature-inspired vascular cementitious composites: A path to self-thermal responsive buildings

By Mohammad Houshmand and Amir Farnam



Credit: Jake Lange/ Shutterstock

Animals such as jackrabbits and elephants have ingenious vascular systems in their ears to regulate temperature, which can inspire the design of better thermal control in buildings.

Buildings consume nearly 40% of total energy in developed nations, with almost half of that energy dedicated to heating and cooling.[1]

This heavy reliance on thermoregulation not only drives energy demand but also contributes significantly to greenhouse gas emissions. Therefore, finding innovative, low-energy strategies for maintaining comfortable indoor environments has become a global priority.

Nature offers numerous sources of inspiration for developing low-energy thermal regulation strategies.[2] Across the animal kingdom, vascular systems regulate temperature, from elephant ears dissipating heat to jackrabbit ears acting as thermal windows.[3,4] Additionally, through a physics-based phase-change strategy, dogs and humans regulate their body temperature by, respectively, panting (air flow evaporates saliva from the mouth of dogs) and perspiration (sweat is released through pores and evaporates from our skin). These biological systems exchange heat with remarkable efficiency. Mimicking these strategies in engineered systems could transform the way we design energy-efficient buildings.[2]

At Drexel University, a pioneering team from the Advanced Infrastructure Materials (AIM) Lab used nature's thermal regulation systems as inspiration to design thermally responsive cementitious materials that could one day enable self-regulating, energy-efficient buildings.[5–7]

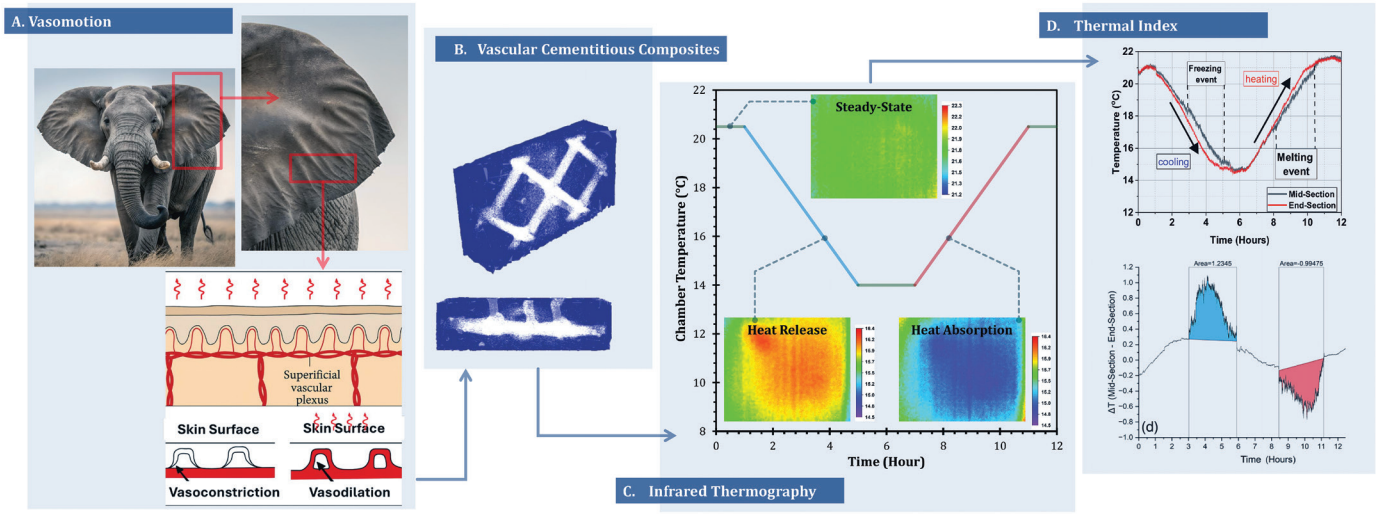
Integrating a vascular approach into cementitious composites

The new class of cementitious composites is called vascular self-thermal responsive composites, or VASCI (Figure 1). These materials integrate engineered vascular channels, or tiny hollow networks within the concrete, that can be filled with phase change materials (PCMs).

PCMs absorb and release heat as they melt and solidify, triggered by a rise and drop in temperature, respectively.[5–7] They can therefore provide a self-responsive thermal energy system within the engineered vascular channels of VASCI.

The vascular networks were created using sacrificial polymer scaffolds. These filaments dissolve harmlessly as the concrete sets, leaving behind intricate voids. Multiple geometries, including parallel, diagonal, and diamond-shaped networks, were tested to evaluate how architecture influences thermal and mechanical performance. Advanced 3D X-ray microcomputed tomography confirmed the successful creation of continuous vascular channels.

Mechanical tests showed that introducing channels naturally reduces the composite's strength due to added voids. However, we found that careful design



Credit: A (Elephant photo): DreamStudiopro / Shutterstock
A (Vascular drawing) and B–D: Osan et al., *Journal of Building Engineering* (CC BY-NC-ND 4.0)

Figure 1. (A) Vasomotion-driven thermoregulation in vascularized tissues of elephant ears. (B) 3D X-ray computed tomography of VASCI. (C) Infrared thermal images of VASCI specimens at different stages of thermal cycling. (D) Thermal index plots during cyclic testing, where red indicates exothermic heat release and blue indicates endothermic heat absorption.

mitigates these effects. Specifically, channels aligned diagonally or smaller than the size of aggregate particles minimized strength loss. Furthermore, diamond-shaped architectures demonstrated ductile fracture modes, a rare but valuable property in cementitious composites.

Thermal evaluation of the composites revealed striking benefits. We used infrared thermography to observe how vascular networks filled with a paraffin-based PCM stored heat during warming cycles and released it gradually during cooling. Multichannel diamond designs showed the highest thermal inertia, maintaining elevated temperatures for several hours, enough to shift building energy demand away from peak hours. Further research is being conducted at the Drexel AIM Lab to advance the design and manufacturing of VASCI.

Toward adaptive and sustainable infrastructure

By embedding vascular channels and PCMs into concrete, VASCI offers a path toward buildings that actively regulate their temperature with minimal external energy input. Beyond cold-climate heating, the same approach could be adapted for hot climates by selecting PCMs with higher melting points, or even for infrastructure applications such as ice-melting pavements and 3D-printed adaptive facades.

The potential is vast: energy-efficient buildings, resilient pavements, and climate-adaptive infrastructure. Future research will refine channel architectures, explore additive manufacturing for scalability, and test long-term durability in real environments. As climate challenges grow, materials that self-regulate may become central to sustainable construction.

About the authors

Mohammad Houshmand was a Ph.D. student at Drexel University and is now a postdoc at Johns Hopkins University. Yaghoob (Amir) Farnam is professor of civil, architectural, and environmental engineering at Drexel University. Houshmand and Farnam conducted this research along with Rhythm Osan (undergraduate student), Robin Deb (Ph.D. student), Parsa Namakiaraghi (postdoc), and Mohammad Irfan Iqbal (postdoc) at Drexel's AIM Lab. Contact Houshmand at mkhaneg1@jh.edu, and Farnam at yfarnam@drexel.edu.

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Biomimicry as second nature:

Research centers and degree programs encourage eco-friendly design

Header image: Geodesic biome domes at the Eden Project in Cornwall, U.K. The domes, which serve as the world's largest greenhouse, are an example of biomimetic design.

By Randy B. Hecht

The greatest research and development lab on Earth is the planet itself.

Nature provides countless examples of effective engineering practices, from the tough brick-and-mortar structure of natural nacre to the ingenious vascular systems that regulate temperature in some animals' ears. By modeling these biological entities and processes, humans can develop more efficient and economical approaches to addressing climate challenges.

As companies embrace emerging ideas designed to benefit the environment and the bottom line, biomimicry is gaining recognition as a design strategy across diverse industries. In a 2023 *Biomimetics* paper titled "Biomimicry industry and patent trends," Haejin Bae of Korea's National Institute of Ecology reports on a patent analysis of biomimicry-inspired solutions to technological problems that resulted in awards of 940 patents in Korea, the U.S., Japan, and Europe between 1975 and 2021.

"Based on the results of the patent analysis," she writes, "it was found that biomimicry technology is in a growth phase that is expected to continue in the future and that Korea and the United States are leading the development of this technology."

A GLOBAL COMMUNITY FOR COLLABORATION

One of the most exciting trends in biomimicry is the emergence of organizations and tools that facilitate research and development across sectors, borders—and even languages.

The Biomimicry Institute, headquartered in Bozeman, Mont., is a nonprofit organization founded in 2005 "to enable a nature-positive, inclusive, and regenerative world inspired and guided by nature's genius." Since 2008, the Institute has hosted AskNature.org, "an open-source database of deep biological knowledge, presented in accessible language." It includes case studies of "successful cutting-edge projects informed by biomimicry" as well as an essay collection for more in-depth exploration of biomimicry themes, trends, and patterns.

During Climate Week in September 2025, the Institute launched the beta version of its new AI-powered AskNature Chat (https://asknature.org/asknature-chat). This tool is designed "for people of all ages, education levels, professions, and languages to support the practice and study of biomimicry," the organization says in a press release (https://bit.ly/4nGM90g). The launch advances the Institute's 10-year strategy, announced during Climate Week 2024 as part of the organization's 20th anniversary, which supports its mission "to elevate biomimicry as a transformative solution to climate change, biodiversity loss, and the disconnection between people and nature" (https://bit.ly/47hM9Oi).

The Institute also serves as an accelerator through an annual six-month program that provides funding and in-kind services to 10 "high-impact nature-inspired startups." To date, the Institute counts more than 40 "thriving companies" in its portfolio. The 2025 cohort includes

- **Emboa Medical, Inc.**, a Purdue University-licensed start-up in West Lafayette, Ind., that invented "a boa constrictor fang-inspired" catheter tip that reduces procedure time in the removal of blood clots from narrow vessels; and
- **OptionV Energy**, a Boston, Mass. outgrowth of technology R&D conducted at the University of Massachusetts Lowell that "mimics the selective metal-binding biology of Amanita mushrooms to recover high-purity vanadium

from industrial waste cleanly, efficiently, and at low temperatures, enabling affordable long-duration energy storage and resilient critical mineral supply chains."

Learn more about the accelerator program and the 2025 cohort at https://biomimicry.org/innovation/accelerator.

BIOMIMICRY RESEARCH CENTERS WORLDWIDE

Research centers and institutes around the world are contributing to the global expansion and adoption of bio-inspired design.

United States

The Biomimicry Center in the Arizona State University School for Complex Adaptive Systems, part of the College of Global Futures, is a joint effort between the university and Montana-based consulting and professional training company Biomimicry 3.8 that is "aligned with the Global Futures Laboratory vision of creating conditions for a thriving life on a healthy planet." Learn more: https://globalfutures.asu.edu/biomimicry-center

The Biomimicry Research and Innovation Center at the University of Akron, Ohio, "is dedicated to connecting artists, businesspeople, designers, engineers, and scientists to catalyze biomimicry-based innovation" in areas such as "permanent/reversible adhesives, building construction techniques, color-producing additives/structures, robotic actuators/control systems, thermal management systems, water harvesting/repellent materials, and more." Learn more: https://www.uakron.edu/bric

The Center for Biologically Inspired Design at Georgia Institute of Technology is dedicated "to improving the ability of scientists, engineers, and other professionals to translate biological knowledge into innovative products and processes," which is accomplished "through fundamental research, novel interdisciplinary training and education, academic–industrial collaborations at all levels, and public outreach." Learn more: https://cbid.gatech.edu

Europe

Biomimicry Europa (https://biomimicry.eu/en) is a Belgium-based international nonprofit association whose activities include promoting biomimicry at exhibitions and conferences and collaborating with institutions and local authorities on research projects, studies, and reports conducted at the national or European level. The nonprofit founded Ceebios (https://ceebios.com), "a center for studies and expertise in biomimicry" in Senlis, France, to collaborate with academics, businesses, and communities on the development of "a framework (tools, methods & resources) to catalyze biomimetic innovation" and "to integrate biomimicry into industrial and territorial innovation."

The Max Planck Institute for Intelligent Systems in Germany seeks "to mimic the elegance of natural designs, propelling the development of energy-efficient, untethered, and easily controllable autonomous machines." Its Biomimetic Materials and Machines Group conducts research within three areas of focus: manufacturing functional materials, sustainable systems, and untethered machines. Learn more: https://is.mpg.de/bmm

The Biomimetics-Innovation-Centre at Bremen University of Applied Sciences "supports technology transfer from science to industry, especially concerning the national and international networking of different actors in the environment of Biomimetics." Learn more: https://bit.ly/Biomimetics-Innovation-Centre-Bremen

DEGREE PROGRAMS IN BIOMIMICRY

As interest in and demand for biomimicry-based innovation grows, degree programs have emerged to prepare professionals and students for careers in this field. For example:

Master of Science in Biomimicry (Arizona State University, est. 2015): Encompasses studies in biology, design thinking, chemistry, and sustainability, with an emphasis on interdisciplinary learning and practical application. Language of instruction: English. Learn more: https://asuonline.asu.edu/online-degree-programs/graduate/master-science-biomimicry

International Bachelor's in Biomimetics and Biomimetics Master's: Mobile Systems (Bremen University of Applied Sciences, est. 2003): Combines biological and engineering content to prepare students for the development of innovative technological solutions. Language of instruction: German. Learn more: https://bit.ly/Bremen-biomimetics-bachelors and https://bit.ly/Bremen-biomimetics-masters

Biomimetics coursework is also gaining a higher profile within degree programs for sustainability professionals. For example, the Minneapolis College of Art and Design offers a Master of Arts in Sustainable Design, and the curriculum includes the course Systems Thinking Biomimetic. The University of Akron offers the undergraduate courses Biomimicry Foundations and Biodesign, among others. Students can earn a certificate in biomimicry by taking these and other courses.

For middle and high school students interested in biomimicry, the Biomimicry Youth Design Challenge competition "is a free, hands-on, project-based learning experience that provides classroom and informal educators with a framework for introducing biomimicry and an interdisciplinary approach to science and environmental literacy." Winning 2024 projects can be found at https://www.youthchallenge.biomimicry.org/challenge-winners.

Biomimicry education begins during preschool at Green School Bali in Indonesia (https://bali.greenschool.org). The private school's curriculum adheres to the Green Literacies Framework "to prepare learners not only for the world as it is, but for the world they have the power to shape." Additional Green Schools have been opened in New Zealand (2020) and South Africa (2021).

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. ■

Black Hills Applied Ceramic Engineering:

Leveraging local geology for ceramic education

By Katrina Donovan and Sarah Keenan

Figure 1. BACE group picture at Mount Rushmore National Monument during the geological tour led by Sarah Keenan, fourth from left.
Figure 2. BACE group picture at the Pete Lien & Sons mineral processing facility in Rapid City, S.D.

For the past three years, South Dakota Mines faculty member Katrina Donovan has led ceramic engineering efforts at the university, ranging from new ceramic engineering curriculum to a ceramic engineering minor.

Most recently, she teamed up with Sarah Keenan, associate professor of geology and geological engineering, to propose a new National Science Foundation Research Experience for Undergraduates (REU) site at Mines.[1]

Their proposal, which was awarded NSF grant #2349313, is called Black Hills Applied Ceramic Engineering (BACE). BACE is a 10-week summer research program that leverages the local geological resources to promote a fundamental understanding and appreciation for the broad utility of ceramics. In summer 2025, the program commenced with its first cohort of students coming from across the United States and surrounding U.S. territories.

While the primary focus of the BACE program is research in geology and ceramic engineering, students also participate in professional and cultural development activities to improve their technical understanding and communication skills. Examples of these activities include geological tours of the Black Hills (Figure 1) and industry tours (Figure 2).

The BACE program culminated in the students presenting their posters at the 2025 South Dakota Mines Summer Research Symposium. The two projects described below highlight the spectrum of research projects within the BACE program (two projects were conducted directly with industry partners). Full abstracts can be found at https://sites.google.com/sdsmt.edu/sdm2025symposium/home.

Characteristics of claystone beds

Sage Robinson, third-year undergraduate student at Black Hills State University in Spearfish, S.D., investigated the chemical and physical characteristics of claystone beds of the White River Formation (Figure 3).

The objective of this study was to explore and characterize the chemical and physical properties of a few White River Formation clays near the Eocene–Oligocene climate transition boundary.[2] Little data is available on the properties of beds in this area despite the potential material resources and clues about the effects of this climatic event on the continental interior.

Samples were taken from six clay and mudstone beds exposed in an outcrop of the White River Formation. They were then analyzed using X-ray diffraction (to determine mineral phases), X-ray fluorescence (to determine general elemental chemistry), sediment settling rates (to determine grain size), and a variety of physical tests (to measure shrinkage and firing characteristics).

Results showed samples to be broadly similar in chemistry aside from calcium concentration, but they contrasted in their mineral phases and in the results of higher temperature firing. Specifically, the main clay phases shifted from montmorillonite to illite over time, and calcite appeared in the younger beds. High plasticity makes these clays good for ceramic arts, though without temper they have high shrinkage and low dry strength. Furthermore, the flux behavior of calcite in the upper beds make these clays natural glazes at higher kiln temperatures. They may also be useful as the clay component in other ceramics such as bricks.

Ultimately, these clays would have been impractical for early people potentially looking to produce functional ceramics because they require processing and modification to be turned into durable pottery.

Ceramic minerals for additive manufacturing

Calder Lange, second-year undergraduate student at Middlebury College in Vermont, traveled to South Dakota to investigate the viability of industrial Black Hills minerals for ceramic additive manufacturing. During the BACE program, Calder mentored third-year high school student Brayden Sanderson, an Army Education Outreach Program researcher (Figure 4).

This study focused on characterizing the rheological, chemical, and mechanical properties of Fuson Shale, a local clay material sourced from Rapid City, S.D. The shale was crushed into a fine powder and tested alongside a commercially available stoneware clay.

Shear and compressional rheology tests were performed on the two clays to investigate their viscoelastic behavior during extrusion. Following these tests, both the local and commercial samples were 3D printed and sintered at three different temperatures.

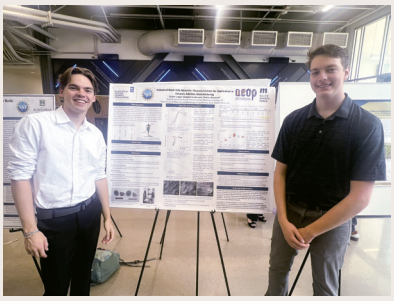
Mineralogical phases and structural transformations of the clay bodies at different firing temperatures were analyzed using X-ray diffraction. Scanning electron microscope imaging revealed temperature-based densification patterns, and ASTM c1161 three-point bend testing was performed on the 3D-printed clay to test flexural strength across the various firing conditions.

The local formulated clay body outperformed the commercial clay in flexural strength testing, highlighting the potential for local materials to be used in manufacturing. This finding is especially advantageous when applied in remote locations such as the Arctic or extraterrestrial environments.

Undergraduate students interested in this summer research opportunity can learn more about the program and apply to be part of the 2026 cohort at https://sites.google.com/sdsmt.edu/bace/home.

Credit: Scott Beeler

Figure 3. BACE student Sage Robinson, left, and Sarah Keenan, right, in the field outside of Wall, S.D., examining outcrops of mudstone in the White River Formation.



Credit: Katrina Donovan

Figure 4. BACE student Calder Lange, left, and his high school Army Education Outreach Program mentee Brayden Sanderson, right, stand next to their poster at the South Dakota Mines Summer Research Symposium.

Ackowledgments

The BACE REU site (NSF grant #2349313) is jointly funded by the Department of Defense in partnership with the Division of Earth Sciences (Directorate for Geosciences), the Established Program to Stimulate Competitive Research (EPSCoR), and the Division of Engineering Education and Centers (Directorate for Engineering). High school researchers working with BACE students were funded by the Army Education Outreach Program.

About the authors

Katrina Donovan and Sarah Keenan are faculty members at South Dakota Mines (Rapid City, S.D.). Contact Donovan at katrina.donovan@sdsmt.edu.

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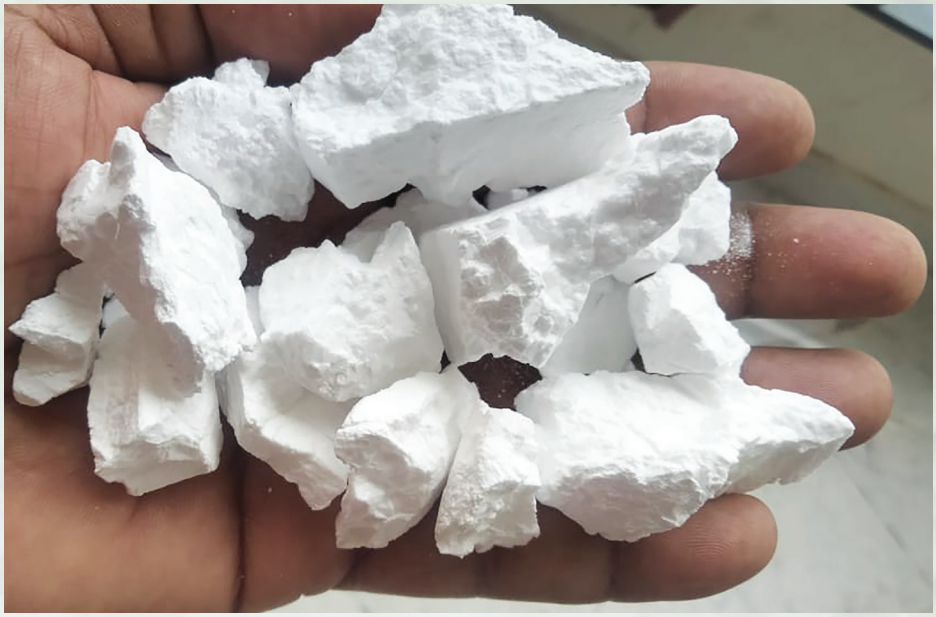


Credit: I. V. Subba Rao

Example of the sintered cristobalite synthesized through the new rotary kiln-based method. The use of a rotary kiln means no flux is required to achieve complete transformation of the quartz into cristobalite.

Sintered synthetic cristobalite: Innovative kiln-based thermal transformation of quartz

By I. V. Subba Rao

Cristobalite, a high-temperature polymorph of silica, is widely used in ceramics, glass, paints, refractories, and dental materials due to its low density, high whiteness, thermal expansion behavior, and mechanical stability.

Traditional cristobalite production methods rely on static sintering of finely ground quartz at high temperatures (~1,750°C) for extended durations (2–3 hours in burning zone, 6–7 hours from kiln inlet to outlet), which often results in incomplete transformation, high energy consumption, and impurity retention. This article presents a novel rotary kiln-based production route that utilizes mineralogical understanding and controlled thermal regimes to achieve efficient, continuous, and industrial-scale cristobalite production.

Transformation mechanics of quartz to cristobalite

Mineralogically, both quartz and cristobalite are composed of SiO_4 tetrahedra, but they differ in the way these tetrahedra are arranged. Quartz crystallizes in the trigonal system as α-quartz at room temperature. When heated above 573°C, α-quartz undergoes a reversible phase transition to β-quartz, which has a hexagonal crystal system. Cristobalite, on the other hand, crystallizes in the cubic system as β-cristobalite at high temperatures, typically forming above approximately 1,470°C under equilibrium conditions. Upon cooling, β-cristobalite transforms into a tetragonal form known as α-cristobalite at about 270°C, which is metastable at ambient conditions.

When transitioning from quartz to cristobalite, manufacturers must be wary of the formation of tridymite, another silica polymorph with a hexagonal or orthorhombic lattice that forms at temperatures between 870°C and 1,470°C. Avoiding tridymite

formation and promoting direct transformation of quartz to cristobalite is key to product purity and stability. Bypassing tridymite formation is possible via kinetic control and optimized thermal regime during processing, as demonstrated by the novel rotary kiln-based production method described in the next section.

Rotary kiln-based sintering of quartz for direct cristobalite formation

The novel cristobalite production method employs a rotary kiln divided into preheating, reaction, and sintering zones with controlled temperature gradients from 1,000°C to 1,700°C. Feed materials are continuously charged and sintered at 1,550–1,650°C for durations sufficient to enable structural conversion (6–7 hours from kiln inlet to outlet). The tumbling motion ensures uniform heat exposure and crystal nucleation, thus enabling efficient transformation.

The raw material used in this process is high-purity natural quartz or amorphous silica, optionally pretreated to remove impurities such as iron oxide, titania, and alumina. Grain size ranging from 3 mm to 30 mm is suitable for rotary processing.

Unlike conventional flux-assisted processes, this method relies solely on optimized thermal control and feedstock morphology to induce quartz-to-cristobalite transformation. No alkali fluxes or chemical catalysts are used.

Characterizing cristobalite quality

Through X-ray diffraction (XRD), scanning electron microscopy (SEM), and other methods, the cristobalite was confirmed to have high crystallinity (>95%) with minimal impurities.

XRD analysis

As seen in Figure 1, XRD of the sample sintered between 1,600°C and 1,650°C reveals almost complete cristobalite formation (~90 wt.%), matching the international reference pattern (ICDD Powder Diffraction File 04-002-6313). Minimal residual quartz peaks were observed (~10 wt.%), confirming phase purity. There were no amorphous humps typical of glassy phases in XRD, meaning glass phase content is negligible or below the detection limit.

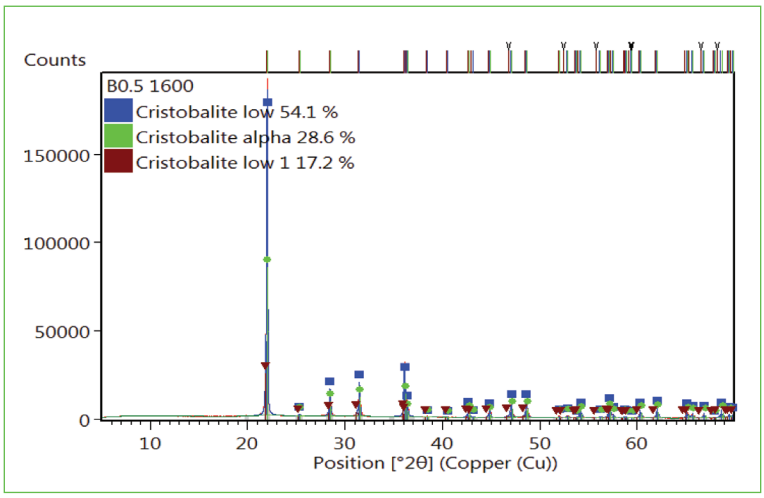
Based on the XRD results, all cristobalite in the sample had the tetragonal lattice (α-cristobalite). No cristobalite with a cubic lattice (β-cristobalite) was detected, which is expected when cristobalite has cooled below about 270°C.

Morphology and microstructure

Cristobalite crystals exhibit a dense, fine-grained microstructure under SEM, showing improved homogeneity and particle bonding (Figure 2). This microstructure favors mechanical strength and application-specific performance.

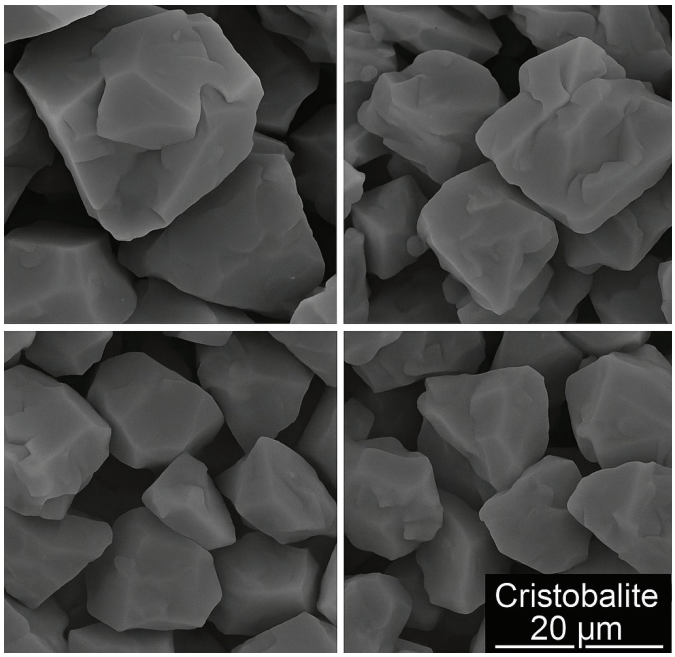
Chemical purity and brightness

Final sintered products show reduced levels of iron, titania, and alumina, which supports higher brightness and whiteness, a desirable property for optical and ceramic applications.



Credit: I. V. Subba Rao

Figure 1. X-ray diffraction pattern of the rotary kiln-sintered cristobalite.



Credit: I. V. Subba Rao

Figure 2. Scanning electron microscopy images of the rotary kiln-sintered cristobalite.

Conclusions

This work demonstrates a novel method for cristobalite synthesis using rotary kiln technology and flux-free sintering. The method achieves almost complete quartz transformation under optimized thermal regimes without the use of alkalis or additives, offering industrial viability, enhanced product quality, and broad application potential.

About the author

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Jonathon Foreman
ACerS journals managing editor (retired)

Bioinspired materials design and fabrication

Nature is a master designer, and recent years have seen more scientists and engineers drawing inspiration from the world around them when developing materials and technologies (Figure 1). In the November 2025 special issue of *Journal of the American Ceramic Society*, the promises and challenges of emulating nature are demonstrated through 30 research and review articles with the theme "Materials Design with Learning from Nature."

In the feature article "Nature-inspired hierarchical materials,"[1] the issue's lead editors frame the underlying discussion. Nature excels at using constrained production conditions (e.g., everyday temperature and pressure ranges) to convert limited types of building-block materials (e.g., proteins, minerals, and carbohydrates) into components with intricate structures that exhibit exceptional performance in areas such as toughness.

The authors focus on three specific characteristics of the naturally designed components: hierarchical structures, which enable improved mechanical properties; smart surfaces, such as wetting and self-cleaning properties; and adaptive functionality, including color-changing capabilities.

Regarding the first point, there are many types of hierarchical structures in nature. The authors provide examples of four major types and describe, among other things, how their structures affect toughening mechanisms.

- **Bone** is a composite of proteins and minerals organized across seven hierarchical levels. Each layer of the structure serves a unique purpose. For example, bone's dense outer layer provides structural support while the macroporous interior supports cellular functions such as blood flow.
- **Nacre** is the iridescent (pearly) substance that lines the interior of many mollusk shells and protects the animal. It has a "brick-and-mortar" construction with minerals serving as the bricks and organic materials as the mortar. Nacre's toughness arises from energy dissipation during deformation of the organic mortar.
- **Sea sponge** has layered organic (protein) and inorganic (hydrated amorphous silica) skeletal "spicules." The line-shaped spicules are arranged in a woven square grid pattern with diagonal supports. This structure enhances crack resistance and improves flexural strength well beyond that of monolithic silica.
- **Spider silk** exhibits a combination of toughness and stiffness superior to almost all other materials. It consists of multilayered protein fibers bundled in a core–shell design.

Products designed to mimic these natural structures are being developed in many areas, including healthcare (e.g., tissue replacement scaffolds), advanced energy (e.g., electrodes for batteries and supercapacitors), and construction (e.g., bridge cables). Researchers utilize modeling tools to enhance understanding of the underlying mechanisms and to predict new bioinspired designs.

For example, Meng et al. reviewed what has been learned about the lamellar structure of conch shells through numerical and theoretical modeling along with experimentation.[2] They first call out three levels of organization, with twinned aragonite building blocks stacked into tilted, rotated layers. They then describe how the toughness is greater than that of aragonite and nacre, attributing this behavior to multiple mechanisms including zig-zag cracks, debonding of organic interlayers, and lamellar pull-out.

Fabrication methods for these bioinspired designs include both traditional and advanced techniques. For example, Prötsch et al. produced nacre-inspired layered alumina via rapid sintering.[3] The nacre-structured layers acted to deflect cracks and limit their penetration compared to bulk alumina without the nacre.

Credit: Debu55y / Shutterstock

Figure 1. The Tower of Light in Manchester, U.K., is a biomimetic structure, with its lattice design based on geometries found in nature.

Researchers are also investigating fabrication methods that more closely resemble those in nature. Hu et al. explored biomineralization-inspired crystallization and densification of amorphous calcium carbonate (ACC) at low temperatures.[4] They found that, without external water, ACC converted directly to anhydrous aragonite (some calcite was found at lower pressures). With external water, ACC crystallized into metastable ikaite at 25°C. At 40–60°C, ACC crystallized into monohydrocalcite. At 80°C and higher pressures, both ikaite and monohydrocalcite transitioned to aragonite.

Many more insights into bioinspired materials design can be found in the *JACerS* special issue. View the full issue at https://ceramics.onlinelibrary.wiley.com/journal/15512916.

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[1]Q. Fu et al., "Nature-inspired hierarchical materials," *JACerS* 2025, **108**(11): e70156.

[2]Q. Meng et al., "Hierarchical crossed-lamellar structure in conch shells: Mechanics and biomimetics," *JACerS* 2025, **108**(11): e20465.

[3]T. Prötsch et al., "Bio-inspired damage-tolerant alumina-based layered ceramics through rapid sintering," *JACerS* 2025, **108**(11): e20706.

[4]H. Hu et al., "Bioprocessing-inspired cold sintering of amorphous calcium carbonate," *JACerS* 2025, **108**(11): e20682. ■

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OPPORTUNITIES FOR GROWTH GUIDE DISCUSSIONS AT MS&T25 IN COLUMBUS

The year 2025 has been filled with many conversations about the state of science research and funding in the U.S. and globally. But during ACerS 127th Annual Meeting at the Materials Science & Technology technical meeting and exhibition, which took place Sept. 28–Oct. 1, 2025, in Columbus, Ohio, attendees focused on the positives and discussed ways to support opportunities for growth in the coming years.

NURTURING OPPORTUNITIES FOR GROWTH AT ACERS

The American Ceramic Society made noticeable strides toward accomplishing the goals laid out in the 2025–2028 strategic plan, as reported by outgoing ACerS President Monica Ferraris during the Annual Business Meeting on Monday, Sept. 29.

Regarding the goal to enhance technical content, education, and professional development, ACerS announced in August 2025 that it received a two-year extension of funding from the Department of Defense for its "Professional Development for Hypersonic Materials" program, coordinated in collaboration with the United States Advanced Ceramics Association. The Society also finalized the details of its continued partnership with Wiley through 2033, which included assuming sole ownership of *International Journal of Applied Glass Science*.

ACerS also established several task forces to develop and revise various programs and initiatives to align with the evolving needs of industry, government labs, and international members. The impact of artificial intelligence on scientific research and scholarly publications is a topic of particular interest.

As the Society heads into its second year of the strategic plan, incoming ACerS President Mario Affatigato said his priorities in office will be guided by three "Fs": finances, fulfillment, and the future.

AWARD LECTURES HIGHLIGHT TECHNOLOGIES FOR A HEALTHIER FUTURE

Industrialization brought many benefits to society but also new challenges, such as emissions-driven climate changes and a rise in noncommunicable diseases due to increased longevity and more sedentary lifestyles. The award talks at this year's Annual Meeting profiled some of the technologies that can allow for healthier living with fewer environmental impacts.

The award talks started on Monday morning with the Navrotsky Award for Experimental Thermodynamics of Solids, given by Arizona State University postdoctoral researcher Konrad Burkmann. He talked about the possibility of using complex metal hydrides for chemical hydrogen storage, and he emphasized the importance of using calculations along with experiments to determine the potential of each option.

A session sponsored by the Bioceramics Division took place afterward and included three lectures by Bioceramics awardees. Antonia Ressler of Tampere University, who delivered the Global Young Bioceramicist Award, talked about developing multisubstituted calcium phosphate-based scaffolds for bone augmentation applications. Sayoni Sarkar of ETH Zürich, who delivered the Bioceramics Young Scholar Award, shared her research on the development of oxide bioceramics for use in multifunctional sunscreens. Aldo Boccaccini of the University of Erlangen-Nuremberg, who delivered the Larry L. Hench Lifetime Achievement Award, overviewed current and future applications of bioactive glass in his recorded presentation.

On Tuesday morning, Tatsuki Ohji, visiting professor at Yokohama National University and Nagoya Institute of Technology and emeritus research councilor at the National Institute of Advanced Industrial Science and Technology, delivered the Edward Orton Jr. Memorial Lecture on "Ceramics for structural applications: Overcoming the challenges of this formidable material." He concluded his talk with a beautiful tribute to Edwin Rudolph Fuller Jr., ACerS Fellow, Distinguished Life Member, and past president, who died in August 2025. Ohji made the analogy that both the strongest humans and materials have a softness to them, which allows them to adapt and function under stressful environments.

Later Tuesday morning, Morten Mattrup Smedskjaer of Aalborg University delivered the Cooper Session Distinguished Lecture on the deformation behavior of oxide glasses. He included a section on metal–organic frameworks as well, which coincidentally was the topic of this year's Nobel Prize in Chemistry. He was followed by this year's Cooper Scholar recipient, student Wuqian Zhang of Swarthmore College, who discussed the thermodynamic properties of the platinum–copper–phosphorus bulk metallic glass system.

On Tuesday afternoon, Ungyu Paik, distinguished professor in the Department of Energy Engineering at Hanyang University, Korea, delivered the Rustum Roy Lecture on the materials and processing methods used to fabricate high-energy-density lithium batteries. After his talk, Ferraris recognized Paik as an ACerS Global Ambassador.

The last award lecture took place on Wednesday afternoon. Sossina Haile of Northwestern University delivered the Robert B. Sosman Lecture on the surface chemistry of ceria, an important catalyst material.

EMERGING PROFESSIONALS GROW AS LEADERS THROUGH TARGETED COMPETITIONS AND EVENTS

Scientific conferences are a great opportunity for students and young professionals to grow their networks and knowledge. ACerS Annual Meeting always features several targeted events for this audience to help them grow as leaders within the materials science community.

On Sunday, students competed in the annual Undergraduate Student Speaking Contest, which provides students the opportunity to practice communicating their research to a broader audience. This year, Pavan Kumar Reddy Pothula of The Pennsylvania State University took home first place, Robert David Hiroshi Race of the University of Michigan placed second, Emma Eleson of The Pennsylvania State University placed third, and Casen Legreid of Iowa State University placed fourth.

On Monday, the Ceramic and Glass Industry Foundation hosted the IGNITE MSE symposium and luncheon. This program, which runs in conjunction with selected conferences affiliated with The American Ceramic Society, provides an opportunity for undergraduate and graduate students to explore professional development and career opportunities. It also includes the opportunity to submit a poster on the broader impacts of scientific research to the larger poster session on Tuesday.

The winners from this year's poster session include

Undergraduate posters

1. Emma Eleson, The Pennsylvania State University
2. David Gaetano, Yale University
3. Ryan McGinnis, Colorado School of Mines

Graduate posters

1. Yolmarie Del Valle Gonzalez, Argonne National Lab
2. Carter Fietek, The Ohio State University
3. Preston Guynup, Alfred University

This year, the IGNITE MSE luncheon was co-organized with the ACerS Mentor Programs, which are designed to equip participants with the insight, tools, and connections necessary to make a lasting impact in their future career.

The famous mug drop and disc golf competitions took place on Tuesday. These annual events, hosted by Keramos, challenge students to fabricate ceramics that can withstand heavy impacts, and each year conference attendees flock to witness the students' successes and failures.

This year, Dimitri Shultz from West Virginia University took home first place in the mug drop competition. Additionally, Dongyang Li from Wuhan University of Technology was announced as having the most aesthetic mug.

In the disc golf competition, Renard "Montie" Jenkins from Virginia Tech took home first place for longest successful throw. Meanwhile, Elena Granzeier from the University of Illinois Urbana-Champaign was announced as having the most aesthetic disc.

Events for emerging professionals wrapped up on Wednesday morning with a Young Professionals Network breakfast event. ACerS Corporate Partners were invited to attend as well to foster networking and discussions.

View more photos from ACerS Annual Meeting at MS&T25 by visiting ACerS Flickr page at https://bit.ly/MST25-Columbus. Pictures from the Awards Banquet can be found there as well. Next year, ACerS 128th Annual Meeting at MS&T26 will take place in Pittsburgh, Pa., from October 4–7. ■

ACerS President's Council of Student Advisors pose for a group photo during their annual business meeting on Saturday, Sept. 27. This year's delegates consist of 46 students from 29 universities, representing seven countries.

Outgoing ACerS President Monica Ferraris, left, passes the ceremonial ceramic gavel to incoming ACerS President Mario Affatigato during the Annual Board Meeting.

Tatsuki Ohji, left, accepts the Edward Orton Jr. Memorial Lecture certificate from outgoing ACerS President Monica Ferraris.

Finalists of the Undergraduate Student Speaking Contest. From left: Emma Eleson, Pavan Kumar Reddy Pothula, Casen Legreid, and Robert David Hiroshi Race.

All the competitors in this year's disc golf competition with their discs.

All photos credit: ACerS

UPCOMING DATES

HILTON DAYTONA BEACH OCEANFRONT RESORT,
DAYTONA BEACH, FLA.

Join us in Daytona Beach for the Golden Jubilee Celebration of the 50th International Conference and Expo on Advanced Ceramics and Composites (ICACC 2026).

HYATT REGENCY BELLEVUE ON SEATTLE'S EASTSIDE,
BELLEVUE, WASH.

Six ACerS Divisions are collaborating to host the first-ever ACerS Spring Meeting in Bellevue, Wash. Each of the six Divisions will create its own programming, though collaborative sessions will take place as well. One registration fee will allow you access to all programming and events.

SHERATON SAN DIEGO HOTEL & MARINA,
SAN DIEGO, CALIF.

Join us in San Diego for the combined 12th International Conference on High Temperature Ceramic Matrix Composites and 3rd Global Forum on Advanced Materials and Technologies for Sustainable Development.

THE RENAISSANCE CENTER,
DETROIT, MICH.

Join us in Detroit for the American Conference on Neutron Scattering. The conference will highlight the breadth and depth of recent worldwide research enabled by neutrons, along with the latest developments in neutron techniques and data analysis.

Calendar of events

January 2026

6–7 ★ Virtual Hypersonic Workshop 2026 – Virtual; https://ceramics.org/course/virtual-hypersonic-workshop-2026

25–30 Golden Jubilee Celebration of the 50th International Conference and Expo on Advanced Ceramics and Composites – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla.; https://ceramics.org/icacc2026

29–30 ★ Mechanical Properties of Ceramics and Glass – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla.; https://ceramics.org/course/quinn-mechanical-properties

March 2026

24–26 ➡ ceramitec 2026 – Trade Fair Center Messe, München, Germany; https://ceramics.org/event/ceramitec-2026

30–April 1 61st Annual Greater Missouri Section / Refractory Ceramics Division Symposium on Refractories – St. Louis, Mo.; https://ceramics.org/rcd2026

April 2026

12 ★ Introduction to Thermal Spray Coatings: Science, Engineering, and Applications – Bellevue, Wash.; https://ceramics.org/course/berndt-intro-thermal-spray-coatings

12 ★ Fractography of Ceramics and Glass: An Introduction – Bellevue, Wash.; https://ceramics.org/course/swab-fractography

12–16 ACerS Spring Meeting — Bellevue, Wash.; http://ceramics.org/acersspring

May 2026

5–6 ➡ Ceramics Expo 2026 – Cleveland, Ohio; https://ceramics.org/event/ceramics-expo-2026

31–June 5 12th International Conference on High Temperature Ceramic Matrix Composites and Global Forum on Advanced Materials and Technologies for Sustainable Development – Sheraton San Diego Hotel & Marina, San Diego, Calif.; https://ceramics.org/htcmc12_gfmat3

June 2026

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

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

10–12 16th Advances in Cement-Based Materials – Miami, Fla.; https://ceramics.org/cements2026

15–25 ➡ CIMTEC 2026 – Perugia, Italy; https://ceramics.org/event/cimtec-2026

July 2026

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

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

August 2026

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

October 2026

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

Dates in **RED** denote new event in this issue.

Entries in **BLUE** denote ACerS events.

➡ denotes meetings that ACerS cosponsors, endorses, or otherwise cooperates in organizing.

★ denotes a short course

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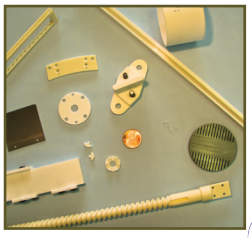

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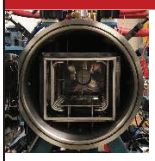

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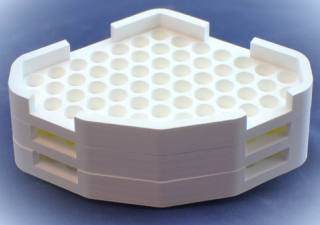

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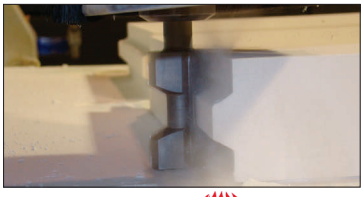

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By Bahareh Kheilnezhad

Guest columnist

When glass becomes medicine: Therapeutic ion delivery for regeneration

When people think of medical treatments, they often imagine pills, injections, or surgical procedures. Few would picture glass playing a role in healing the human body. Yet bioactive glasses emerge as powerful tools for regenerative medicine.

Why glass?

The idea that glass could be "bioactive" was first demonstrated in the late 1960s, when researchers discovered that certain glass compositions could form a strong bond with living bone. Unlike traditional implants, which the body treats as inert foreign objects, these glasses interact dynamically with their environment.

When special types of glass dissolve inside the body, they release tiny building blocks the body knows well: calcium, sodium, silicon, magnesium, selenium, zinc, boron, and phosphate. These ions are the same ones our bodies use every day. For instance, more than 99% of calcium is stored in bones and teeth, while the rest circulates in blood and tissues. Magnesium quietly supports hundreds of enzymes that drive metabolism, and boron is found in skin, muscles, bone, and even the liver.[1,2]

When glass releases these familiar ions, it sparks a cascade of biological responses. Cells begin to multiply, bone tissue starts to rebuild, and a stable layer of the mineral hydroxyapatite forms.[3] The discovery that glass could interact so positively with the body was revolutionary. It redefined glass as a form of "ionic medicine," capable of guiding the body's own repair processes rather than simply filling space.[1]

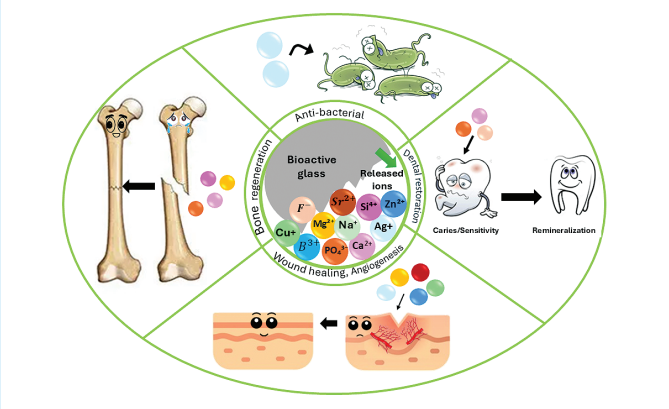
The importance of ion delivery

A key challenge in regenerative medicine is delivering therapeutic signals at just the right dosage to induce beneficial—but not harmful—effects. The effects of bioactive glasses can be carefully adjusted by changing their composition and structure.[1,2]

The addition of boron ions to bioactive glass, for example, can accelerate bone growth and muscle repair. However, these effects happen only at the right dose: Small amounts (0.1–1 mM) stimulate regeneration, while too much (2–2.5 mM) can be cytotoxic, damaging cells and slowing wound healing. Meanwhile, silicon (about 0.1–2.0 mM) supports muscle repair and protects against oxidative stress, helping cells survive and fuse together.

Zinc offers antioxidant and anti-inflammatory benefits, and its effects depend on concentration. Below 40 µM, zinc stimulates muscle cell differentiation, myotube formation, and transcription factor expression; above 40 µM, it promotes proliferation but blocks myotube formation.

Magnesium, at concentrations below 4 mM, enhances skeletal muscle cell growth and blood vessel formation. Adding 2.5 mM of magnesium to culture media has been shown to promote myogenic differentiation in muscle stem cells and support muscle injury repair.[1]



Credit: Bahareh Kheilnezhad

Figure 1. Major application areas of bioactive glasses.

In this way, each ion can be released at levels that mimic the body's natural environment, making bioactive glass a gentle partner in the healing process rather than a disruptive force.

Broader implications

Researchers are continuously exploring ways to improve and expand on the current applications of bioactive glass (Figure 1). For example, incorporating silver and copper ions opens new possibilities: Silver provides strong antibacterial activity, while copper supports angiogenesis and tissue repair and healing. In dentistry, fluoride-containing glasses not only strengthen enamel but also deliver antibacterial effects. These advances highlight how materials science can bridge engineering and medicine, creating solutions that are both functional and biocompatible.

Looking ahead

As part of the Penn State glass research group, I engineer bioactive glasses to deliver therapeutic ions at concentrations mimicking natural conditions. By studying delivery rates and dosages, we can help shape the future of bioactive glass design.

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Bahareh Kheilnezhad is a Ph.D. candidate in chemical engineering at The Pennsylvania State University. Her research involves designing and characterizing (bio)glass and glass-ceramic materials under the supervision of Professors Seong H. Kim and John C. Mauro. She enjoys dancing, fitness, and hanging out with friends in her free time. ■

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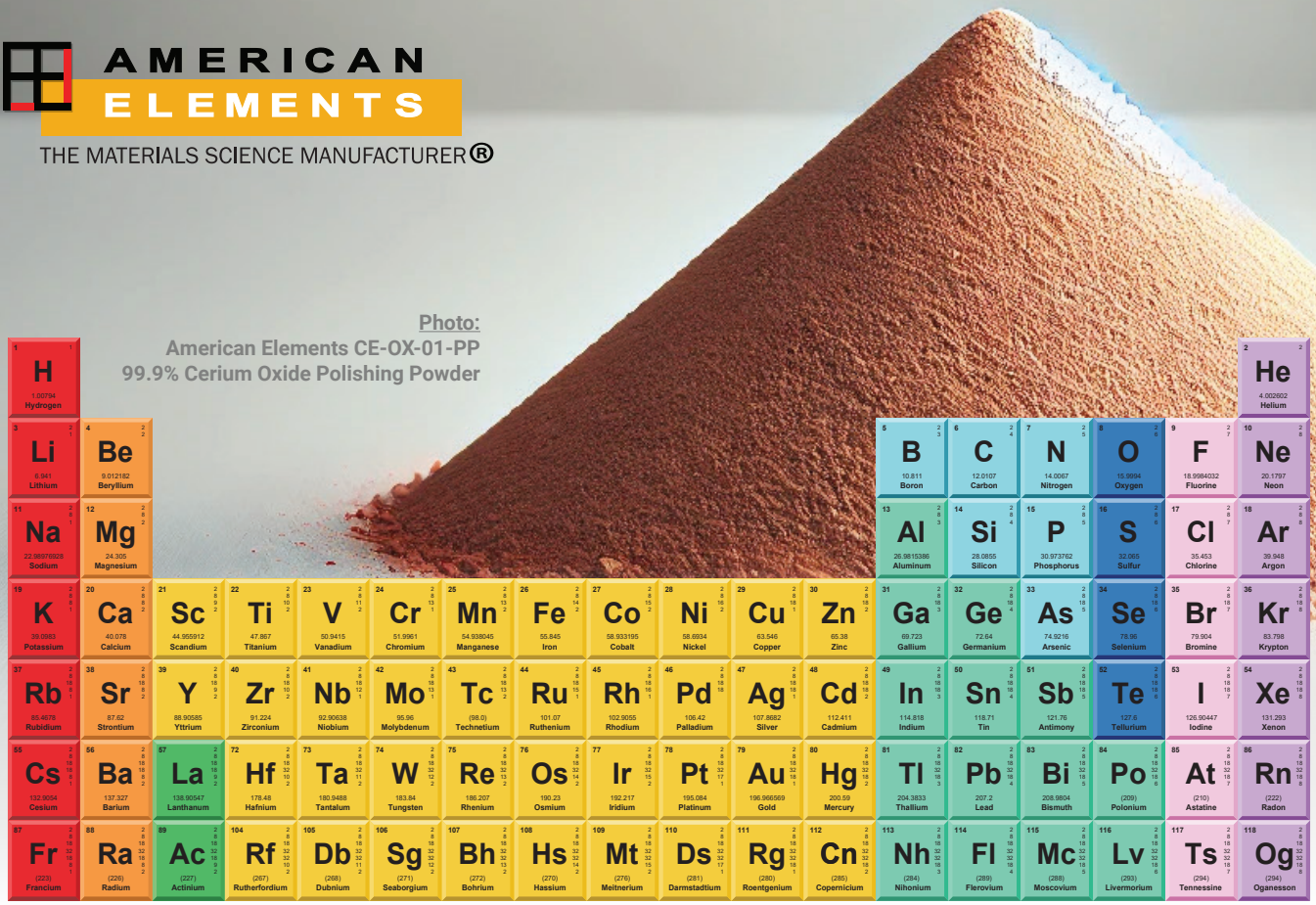

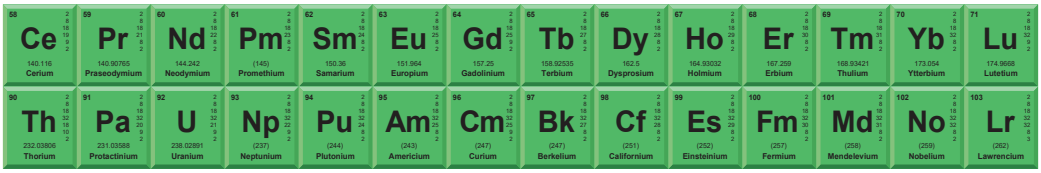

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