AMERICAN CERAMIC SOCIETY

bulletin

emerging ceramics & glass technology

JANUARY/FEBRUARY 2024

Manufacturing the impossible:

Supporting the development of a circular economy in the composites industry

Ceramic-based arts for mental health | Federal FY24 budget proposals | Meet ACerS president

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As seen on *Ceramic Tech Today*...

Credit: Pavel Neznanov, Unsplash

Embodied carbon of concrete in buildings: Study calls for more consistency and accuracy in reporting of carbon impacts

Players in the cement and concrete sectors are working diligently to achieve a reduction in emissions. But gaps in knowledge about the extent of these emissions makes it difficult to determine the effectiveness of new initiatives. Researchers from several U.K. universities are conducting a large-scale study to help fill this knowledge gap.

Read more at www.ceramics.org/embodied-carbon

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Tailoring doping locations and types for high-performance $CuFeO_2$-based photocatalysts
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Journal of the American Ceramic Society

The effect of foamed cement nanocomposite as counter electrode on the performance of dye-sensitized solar cell
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Perspectives on achievements and challenges of oxygen transport dual-functional membrane reactors
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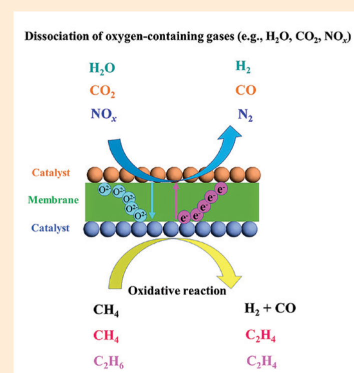
Journal of the American Ceramic Society



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news & trends

Federal budget 2024—Turmoil in the House stalls budget negotiations

By Lisa McDonald

Ever since the 118th United States Congress began in January 2023, it has faced some unusual challenges arising mainly from unprecedented turmoil in the House of Representatives.

The first instance occurred on January 3, when the House failed to elect a speaker on the first ballot for the first time in 100 years. It would take four days and 15 ballots before Kevin McCarthy (R-CA) was sworn in as speaker.

For McCarthy to gain the necessary votes to become speaker, he made several commitments to members of the House Republican Conference on the federal budget. These commitments led to a tense standoff between the House, Senate, and White House over the nation's statutory debt ceiling, which the House refused to raise unless big spending cuts were guaranteed in the fiscal year 2024 budget.

The resulting Fiscal Responsibility Act of 2023, which President Joe Biden signed into law on June 3, suspends the limit on federal debt through Jan. 1, 2025, but requires severe cuts in the fiscal year 2024 budget that disproportionately affect nondefense programs.

As the House and Senate started developing their respective proposals for the federal budget, the House experienced another upheaval when McCarthy was ousted as House Speaker in an October 3 vote. A new speaker, Mike Johnson (R-LA), was elected October 25 on the fourth ballot. Some members of the House Republican Conference are now calling for even steeper cuts to the federal budget beyond what was agreed to by McCarthy and Biden during the debt ceiling negotiations.

As of early December 2023, when this story was written, it is expected that the fiscal year 2024 budget will not be finalized until early 2024. If a decision is not reached by the time the current continuing resolution expires, House Speaker

Johnson has pledged that he will not pass any more short-term spending bills and will pursue a full-year stopgap measure instead.

A few highlights from the proposals:

Department of Defense

Limits placed on the Department of Defense budget for fiscal year 2024 are less stringent than those on nondefense agencies. However, they will check recent growth in the research, development, test, and evaluation (RDT&E) accounts, which at $144 billion is more than double its fiscal year 2016 level.

The overall RDT&E budget will likely experience a small increase, with House and Senate appropriators requesting increases of 4% and 2%, respectively. However, within this topline, spending is set to plunge for the Science and Technology portfolio under RDT&E, with House and Senate appropriators requesting decreases of 13% and 9%, respectively.

National Science Foundation

While the White House requested an increase of 15% to the current $9.9 billion annual budget of the National Science Foundation, both House and Senate appropriators proposed slight decreases of 2% and 4%, respectively.

Based on these proposals, the final fiscal year 2024 budget for NSF will almost certainly fail to meet the ambitious funding levels laid out for the agency in the CHIPS and Science Act of 2022. For perspective, even if the White House request is met, NSF's funding will fall short of the CHIPS authorizations for fiscal year 2024 by 27%.

Department of Energy

The White House requested to increase DOE's budget from $45.8 billion to $52 billion. Both the House and Senate proposals surpass this request, with recommended increases bringing the total budget to $58 billion and $58.1 billion, respectively.

Office of Science: Senate appropriators propose raising the DOE Office of Science budget by 4% to $8.4 billion, while House appropriators would hold the budget steady at $8.1 billion. These proposals fall short of the White House request to increase the budget by 9% to $8.8 billion. The final budget will likely not reach the funding levels authorized in the CHIPS and Science Act of 2022, meaning some planned initiatives will not take place, such as a major expansion to the Fusion Energy Sciences program. However, most major facility construction projects should receive the amounts requested by the White House.

Applied energy: As in previous years, the White House is requesting exceptionally large increases for the Office of Energy Efficiency and Renewable Energy (increase of 39%) and the Advanced Research Projects Agency–Energy (increase of 38%), which neither the House nor Senate proposals support. On the other hand, the White House requested that the Office of Nuclear Energy's budget be rolled back from $1.77 billion to $1.56 billion, which Senate appropriators agreed with while House appropriators recommended a small increase to $1.78 billion.

National Nuclear Security Administration: The NNSA budget would significantly increase from the current $22.2 billion under the various spending proposals for fiscal year 2024, with the White House, Senate, and House proposals all recommending increases to about $23.9 billion. Senate appropriators are seeking significantly more funding for R&D and nonproliferation programs than House appropriators, with a focus on inertial confinement fusion, advanced manufacturing, and advanced computing.

National Institute of Standards and Technology

While House appropriators propose increasing the $1.3 billion annual budget of the National Institute of Standards and Technology by 8%, Senate appropriators are requesting a 1% decrease.

NIST's budget is once again serving as a repository for earmarked projects unrelated to the agency's mission, as has happened since Congress removed a decade-long moratorium on earmarking funds in 2021. The House and Senate proposals are filled with earmarks for projects in congressmembers' home states while undershooting the amount requested by the White House to address severe maintenance backlogs at NIST's own facilities.

National Aeronautics and Space Administration

The House and Senate proposals for NASA's fiscal year 2024 science budget are almost perfectly reversed from the White House request. House and Senate appropriators propose cuts of 5% and 6%, respectively, while the White House requests an increase of 6% to the current $25.4 billion budget.

Table 1. FY24 budget proposals ($ in millions)*

	DOD S&T total	NSF	DOE Office of Science	NIST	NASA (science)	NIH
FY23 appropriation	22,326	9,874	8,100	1,259	7,795	48,959
White House	17,825 (-20%)	11,315 (15%)	8,800 (9%)	1,632 (30%)	8,261 (6%)	51,098 (4%)
House	19,387 (-13%)	9,630 (-2%)	8,100 (0%)	1,358 (8%)	7,380 (-5%)	45,123 (-8%)
Senate	20,367 (-9%)	9,500 (-4%)	8,430 (4%)	1,249 (-1%)	7,341 (-6%)	49,224 (1%)

*Data from the American Institute of Physics FYI "Federal Science Budget Tracker."

The Mars Sample Return mission is one point of contention between the House and Senate proposals. NASA's prioritization of this mission has already led it to defer requests for other projects, and its ballooning cost will likely push back future missions. The House proposal meets the White House request to increase funding for the Mars Sample Return mission, while Senate appropriators propose a severe cut for the mission and broach the prospect of cancellation.

National Institutes of Health

Senate appropriators are seeking a 1% increase to $49.2 billion for the National Institutes of Health while House appropriators are requesting a decrease of 8% to $45.1 billion. Significantly, the House proposal includes funding cuts of 66% for the new Advanced Projects Agency for Health and 17% for the Centers for Disease Control and Prevention. In contrast, the Senate proposal keeps the funding levels for these entities in line with fiscal year 2023 levels.

For more information on the federal budget, visit the American Institute of Physics FYI "Federal Science Budget Tracker" at https://ww2.aip.org/fyi/budget-tracker. ■

Years of slashed infrastructure spending culminates in crumbling concrete crisis in the UK

While infrastructure failure is sometimes due to design flaws, more often than not, failure occurs because materials are pushed to operate beyond their intended lifespan. Such is the case right now with reinforced autoclaved aerated concrete (RAAC) buildings in the United Kingdom.

RAAC is a lightweight and porous construction material that consists of about 80% air. It has several advantages over traditional concrete, such as being easier to transport and machine, but it easily absorbs water due to its porous structure. This property makes RAAC less durable than traditional concrete, so it only lasts for about 30 years in contrast to 50–100 years for reinforced concrete.

In the U.K., RAAC was used in the construction of hundreds of buildings between the 1950s and mid-1990s, including schools, hospitals and theaters. But the popularity of RAAC faded following the publication of numerous studies showing the material's risks, i.e., loss of strength when exposed to moisture and/or polluted air.

In recent years, buildings containing RAAC have started to experience structural failures, such as roof collapses. In 2022, a government agency issued a safety briefing on the situation. Yet over the past decade, the U.K's Conservative-led government has slashed spending on infrastructure, as detailed in *The New York Times* (https://nyti.ms/47EikW7).

At the end of August 2023, the problem of crumbling RAAC infrastructure reached a head when the U.K. government published a list of schools that were confirmed to contain RAAC. This announcement led to more than 100 schools having to shut down or close off areas only days before the new school year started.

Though many in the media blamed RAAC itself for the failures, construction experts pushed back against this characterization of the material.

"The problem with these panels is not so much the material itself. It's the fact that they've been used well beyond their expiry date," says Juan Sagaseta, a reader in structural robustness at the University of Surrey, in a *Wired* article (https://bit.ly/Wired-RAAC).

Learn more about the history of RAAC and the ideal way to use it in application at https://ceramics.org/aerated-concrete. ■

Wind turbines: Technologies, applications, and global markets

By BCC Publishing Staff

The global market for wind turbines reached a value of $85.3 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 6.5% to reach $116.6 billion by 2027.

The Global Wind Energy Council estimates that the world will need to install up to 280 GW of new wind energy annually from 2030 onwards to maintain a pathway compliant with meeting net zero by 2050. Fortunately, through technological developments (Table 1) and economies of scale, the global wind power market has nearly quadrupled in size over the past decade. Onshore wind capacity grew from 178 GW in 2010 to 707.4 GW in 2021, while offshore wind capacity grew from 3.1 GW in 2010 to 35.3 GW in 2021. Table 2 shows how the market is segmented based on end-use sector.

A modern utility-scale wind turbine can consist of up to 8,000 individual subcomponents. The major components are

- **Rotor**, including the blades, hub, and pitch drive.
- **Tower and electrical components**, including the tower, generator, power electronics, balance station, and installation.
- **Gearbox and drivetrain**, including the bearings, gearbox, and high-speed shaft.
- **Nacelle and controls**, including the nacelle frame, brakes, anemometer, and yaw drive.

While most of the materials used to produce wind turbines can be readily recycled or reused, it is extremely difficult to recycle the turbine blades as currently constructed. New materials and recycling methods are being developed to improve the sustainability of turbine blades, such as detailed on pages 24–27 in this issue, "Manufacturing the impossible: Supporting the development of a circular economy in the composites industry."

Table 2. Global market for wind turbines, by end-use sector, through 2027 ($ millions)

End-use sector	2021	2022	2027	CAGR % (2022–2027)
Residential	7,031.8	7,289.5	8,948.3	4.2
Industrial	15,788.5	16,722.7	23,857.9	7.4
Commercial	11,972.7	12,985.1	20,180.1	9.2
Utility	46,616.8	48,257.7	63,611.7	5.7
Total	81,409.8	85,255.0	116,598.9	6.5

Areas that experience an average annual wind speed of at least 13 miles per hour are considered good wind resources. These resources are found in many places around the world, but in the United States, the East Coast, Appalachian Mountains, Great Plains, and Pacific Northwest are relatively rich in wind resources.

About the author

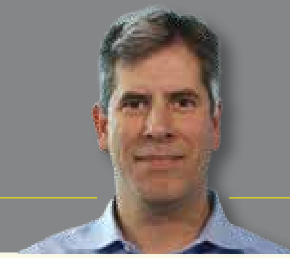
BCC Publishing Staff provides comprehensive analyses of global market sizing, forecasting, and industry intelligence, covering markets where advances in science and technology are improving the quality, standard, and sustainability of businesses, economies, and lives. Contact the staff at Helia.Jalili@bccresearch.com.

Resource

BCC Publishing Staff, "Wind turbines: Technologies, applications, and global markets" BCC Research Report EGY058D, April 2023. https://bit.ly/BCC-April-2023-wind-turbines

Table 1. Current achievements in the wind turbine industry, 2022

Achievement	Company	Specifications
Largest capacity for conventional-drive turbine	Vestas (V164-8.0 MW)	The Vestas V164 has an overall height of 220 m (722 ft) and a diameter of 164 m (538 ft). It has a rated capacity of 9 MW and is meant for offshore use.
Largest capacity for direct-drive turbine	SG (14-236 DD)	The SG 14-236 DD features a rotor diameter of 236 meters and has a capacity of up to 15 megawatts with a power boost.
Largest single-bladed turbine	SG (14-236 DD)	The SG 14-236 DD has 115-meter-long blades, a rotor diameter of 236 meters, and a swept area of 43,500 square meters.
Largest double-bladed turbine	Seawind (6-126)	The Seawind 6-126 has a rated capacity of 6.2 MW, rotor diameter of 126 meters, and rotor speed of 20.8 rpm at rated power.
Largest swept area	Goldwind (GWH 252-13.6 MW)	The Goldwind GWH 252-13.6 MW has a swept area of about 50,000 square meters.
Tallest	GE (Haliade-X 14.7 MW)	GE Haliade-X 14.7 MW has a 220-meter rotor, 107-meter blade, and height of 260 meters.
Highest tower	Vestas (V172-7.2 MW)	The Vestas V172-7.2MW has a hub height of 199 meters.
Largest floating wind turbine	Hywind Tampen	The Hywind Tampen floating wind farm, located about 140 kilometers (86.9 miles) off the coast of Norway, has a capacity of 88 MW.



Andy Thomas
Guest columnist

Accelerating time-to-market for new products by fostering a culture of collaboration

In today's fast-paced and highly competitive manufacturing landscape, innovation and speed-to-market are critical factors that determine a company's success. To stay ahead of the competition and meet ever-evolving customer demands, we must redefine the way we approach research and development (R&D).

Embracing certain agile R&D methodologies is not just about processes; it is about creating a culture of collaboration that fuels creative solutions, empowers teams, drives accelerated time-to-market for new products, and creates sustainable business growth.

The power of collaboration in R&D

Traditional R&D approaches, like the waterfall approach, make sense where customer requirements are locked and the internal product development effort focuses on a fixed set of requirements.

In reality, that is often not the case. When internal R&D occurs in parallel with ongoing customer product development, requirements can, and frequently do, change.

Agile R&D is a collaborative and iterative approach that emphasizes flexibility, responsiveness, and a customer-centric mindset. While agile methodologies have their roots in software development, their principles can be adapted and applied to R&D processes across various industries, including manufacturing.

Using the agile method and breaking down complex projects into smaller, manageable tasks allows for faster cycles of learning. The collaboration on these small teams enables the synthesis of ideas from various sources, leading to innovative solutions that may not have emerged otherwise. It provides opportunities to develop prototypes and gather customer feedback.

Agile R&D embraces change, empowering R&D teams to make data-driven decisions throughout the development process, pushing forward to the market phase.

Empowering teams for success

At the core of an agile R&D approach lies the empowerment of teams. Agile principles encourage decentralization of decision-making, allowing teams to take ownership and accountability for their projects. The freedom to make decisions, with defined parameters, fosters a sense of responsibility and ownership among team members.

When we empower our teams, we unleash their creative and innovative potential. Autonomy, combined with an environment that encourages open communication, allows team members to feel safe experimenting, taking risks, and sharing their learnings. Creating this collaborative and empowering culture can boost motivation, engagement, and productivity, resulting in quicker problem solving, which will ultimately create better product solutions more quickly.

Accelerating time-to-market

One of the primary advantages of adopting agile R&D in ceramics manufacturing is the significant reduction in time-to-market for new products. By the time a traditional, lengthy R&D process reaches its conclusion, customer needs may have shifted, driving a new cycle of development toward new customer requirements.

Agile principles allow for early detection of potential roadblocks. Small teams may then investigate multiple parallel solutions. The ability to pivot quickly based on market feedback ensures the greatest likelihood of success, minimizing financial risks and maximizing returns on investment.

Embracing change

Agile R&D is more than a methodology; it is a transformative force at CoorsTek. We recognize that innovation is not a solo endeavor; it flourishes when nurtured in a collaborative ecosystem. Tight connectedness with our customers ensures that the vision for our products aligns closely with customer needs, while also taking advantage of the collective wisdom and insights of our team members, to move the R&D process ahead to the market phase.

By embracing cross-functional teams, customer-centricity, and a willingness to quickly experiment, learn, and experiment again, we accelerate time-to-market for new products, respond effectively to market demands, and drive sustainable business growth. ■

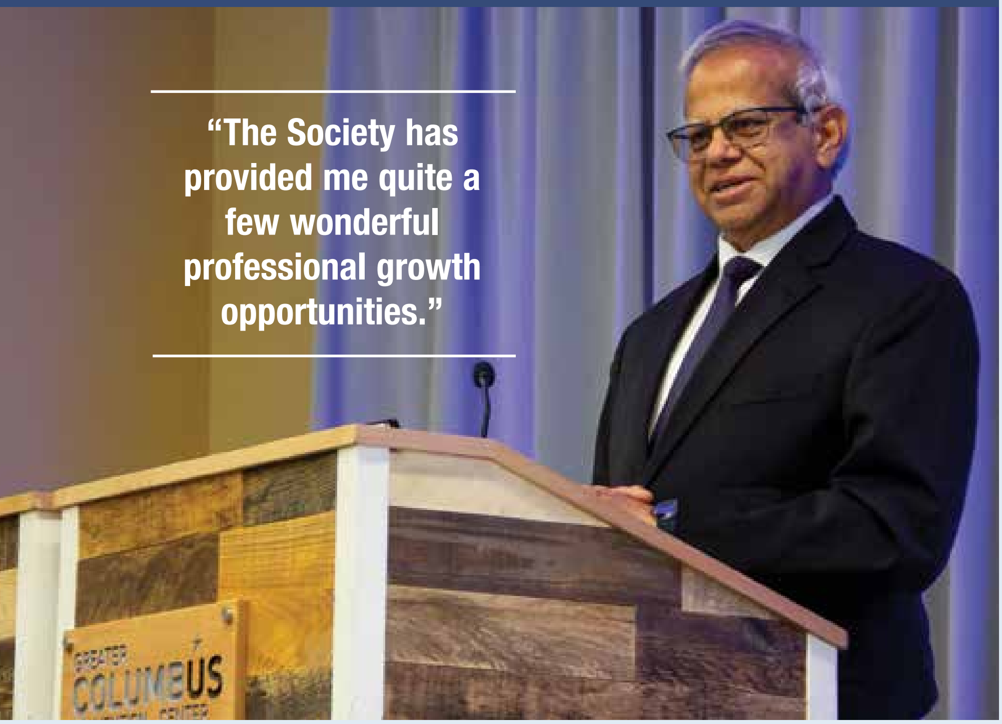
About the author

Andy Thomas is vice president of research and development at CoorsTek, Inc. (Golden, Colo.). Contact Thomas at athomas1@coorstek.com.

Meet ACerS president Rajendra Bordia

By Eileen De Guire

(Credit: ACerS)



> “The Society has provided me quite a few wonderful professional growth opportunities.”

Life rarely follows the path that a person initially plans on. But for Rajendra K. Bordia, ACerS president for the 2023–2024 term, his somewhat accidental journey to ceramic materials engineering has resulted in a “very happy” and fruitful career.

During his undergraduate years at Indian Institute of Technology in Kanpur, India, Bordia majored in mechanical engineering. The handful of materials courses in the curriculum intrigued him, and with guidance from an influential mentor and an elder brother who was already a professor, Bordia realized that he, too, wanted to pursue an academic career.

Bordia applied to mechanical engineering Ph.D. programs in the United States, including at Cornell University. Because he mentioned an interest in studying mechanical properties of materials, Cornell’s mechanical engineering department transferred his application to the materials science and engineering department. Soon Bordia found himself working in the lab of ACerS Distinguished Life Member Rishi Raj.

Bordia worked with Raj on fundamental problems in ceramics processing. Learning about the wide spectrum of applications in which ceramics are used grew his interest in materials science and, specifically, ceramics.

Bordia’s first position after earning his Ph.D. was as a researcher at DuPont Corporation (Wilmington, Del.). During his six years at DuPont, Bordia enjoyed working with George Scherer, a luminary scientist whom he greatly admired. He credits his time at DuPont as being critical to honing his ability to identify significant problems and formulate relevant fundamental questions.

While Bordia’s years at DuPont were highly productive from a research perspective, he still aspired to an academic appointment. He began his academic career as associate professor at the University of Washington. He is now at Clemson University in South Carolina, where he serves as the George J. Bishop, III Endowed Chair Professor of Ceramics and Materials Engineering.

Bordia’s current research group at Clemson aims to understand fundamental ceramic processing problems for the purpose of controlling microstructure and, ultimately, properties. Additionally, he and his team work to formulate the fundamental questions that relate to specific application areas, such as aerospace, energy conversion and storage, and biomedicine.

Bordia sees his role as a professor as much more than just teaching students. He enjoys mentoring students, and regarding Ph.D. students in particular, his goal is to help them transition from a student to a colleague through what he describes as a two-step process.

The first step, “taking ownership,” comes when students make a research problem their own by developing experiments and contributing ideas beyond the initial guidance. The second step comes when a student teaches him something important about the problem that he does not already know.

“At that point,” Bordia says, “you have become my colleague.”

Bordia credits the Society with helping him build a broad professional network, starting with his first conference in the early 1980s. He vividly recalls the experience of not knowing anybody but then being approached after his talk by the late, renowned Roland Cannon.

Since that modest start, Bordia has gone on to serve the Basic Science Division as a meeting organizer and through the Division’s leadership ranks. Additionally, he has served on the Society’s Panel of Fellows, Publications Committee, and Board of Directors.

Bordia’s term as president will be guided by the knowledge that the Society’s primary purpose is to serve the needs of all its members, with particular attention to the professional needs of the Society’s underrepresented groups. His approach is to listen to a broad spectrum of members and staff, which will serve him well as he leads the Society through its next strategic planning exercise.

Other priorities include taking the next steps with the Society’s journal publishing partnership, broadening the technical scope of publications and meetings, and developing mutually beneficial partnerships with other national ceramic societies and other professional organizations.

Bordia is also excited to partake in the travel that the president position entails.

“Traveling makes me feel like a child again. It brings out the curiosity and allows me to ask questions,” he says.

Bordia acknowledges that he has enjoyed enormous support from his family, which includes his wife, Nomita Kayastha, two sons, daughter-in-law, two grandchildren, and a very large extended family.

“I have been very happy with that somewhat accidental choice I made for ceramics,” he says. ■

Highlights from

ACerS 125th Annual Business Meeting

By Lisa McDonald

The American Ceramic Society held its 125th Annual Business Meeting on Monday, Oct. 2, during ACerS Annual Meeting at MS&T23 in Columbus, Ohio. ACerS Annual Meeting at MS&T brings together members from the whole Society as the meeting's technical content spans all aspects of ceramic and glass science, from energy applications and communications to bioceramics and more.

At the Annual Business Meeting, the ACerS president reports on the state of the Society, and the new president outlines plans for the coming year. President Sanjay Mathur summarized the Society's 2022–2023 accomplishments, including the launch of a new brand extension, ACerS International, which will be used to increase awareness of how ACerS serves the scientific and technological needs of the global ceramic and glass community outside the United States.

Treasurer Daniel Tipsord reported that the Society's balance sheet is recovering from the COVID-19 pandemic, with the Society having no long-term debt as of the end of 2022.

New officers were sworn-in, and outgoing officers were recognized and thanked for their service. Incoming president Rajendra Bordia outlined his vision and goals for his year as president (see details on previous page), which will center on enhancing the value of membership and planning for the Society's next strategic plan.

The Annual Awards Banquet took place that night at the Hyatt Regency Columbus. This year's awardees included 20 members elevated to Fellow Status and two members awarded the distinction of Distinguished Life Member, Edwin R. Fuller, Jr. and Curtis A. Johnson.

Incoming ACerS president Rajendra Bordia, right, accepts the ceramic gavel from outgoing ACerS president Sanjay Mathur during the Annual Business Meeting on Oct. 2, 2023.

Credit: ACerS

In addition to the Annual Business Meeting, other events that provide updates on different parts of the Society took place during MS&T, including meetings of the Board of Directors, Division executive committee and business meetings, and meetings of ACerS working committees and subcommittees. The Society's student leadership group, the President's Council of Student Advisors, also held its annual meeting. This year, the PCSA includes 38 students from 19 universities, representing five countries.

View pictures from ACerS 125th Annual Business Meeting at https://bit.ly/ACerSAnnualMeeting2023.

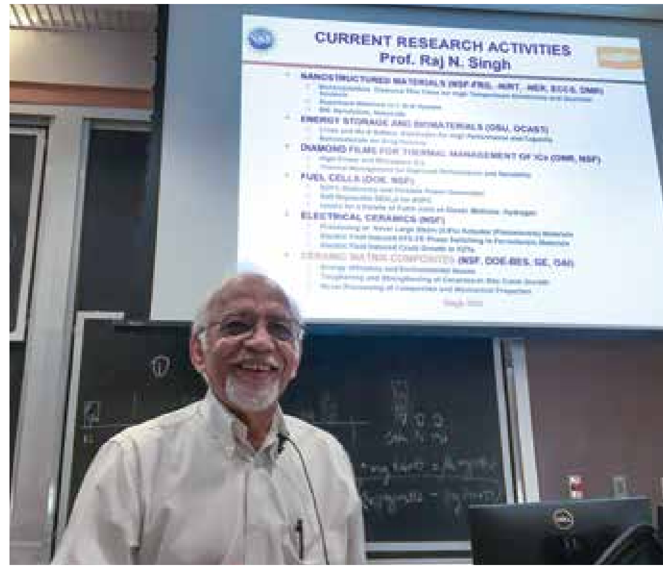
ACerS 126th Annual Meeting at MS&T24 will take place Oct. 6–10, 2024, in Pittsburgh, Pennsylvania.

acers spotlight

SOCIETY DIVISION SECTION CHAPTER NEWS

Dayton/Cincinnati/Northern Kentucky Section and the University of Cincinnati host talk by Raj Singh

In collaboration with ACerS Dayton/Cincinnati/Northern Kentucky Section, the University of Cincinnati arranged for FACerS Raj Singh to give a talk to students in the materials science and engineering program.

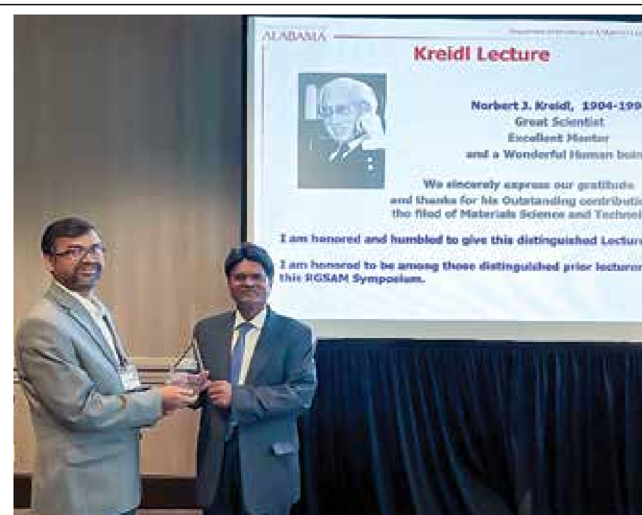


Raj Singh takes the podium for his presentation at the University of Cincinnati.

During the talk on Oct. 6, 2023, which was titled "Perspective on diamond as a wide band gap material for quantum devices and applications," Singh shed light on current advancements in wide band gap electronic materials for use in quantum devices. He also provided invaluable insights into the potential applications of ceramic matrix composites within the aerospace industry. ■

New Mexico Section sponsors 33rd Rio Grande Symposium on Advanced Materials

The 33rd Rio Grande Symposium on Advanced Materials was held on Oct. 23, 2023, at the Clyde Hotel in Downtown Albuquerque, New Mexico. More than 130 scientists and engineers attended the symposium. Several members of ACerS New Mexico Section helped with organizing and sponsoring the event.



Pankaj Kumar (left) presents the Kreidl Lecture Award to Ramana G. Reddy (right) during the 33rd Rio Grande Symposium on Advanced Materials.

Ramana G. Reddy of the University of Alabama, Tuscaloosa, delivered the Kreidl Memorial Lecture, titled "Innovative approaches in decarbonizing metals production." Several students, technologists, and postdocs were recognized with best presentation and poster awards at the end of the symposium. ■

FOR MORE INFORMATION:

ceramics.org

ACerS International Spain Chapter hosts workshop on vitreous and ceramic materials for high-technology applications

The ACerS International Spain Chapter hosted a workshop on vitreous and ceramic materials for high-technology applications on Oct. 26, 2023, at the University of Sevilla, Spain. About 25 people attended the workshop.

The workshop started with welcoming words by ACerS International Spain Chapter chair Arnaldo Moreno, followed by eight lectures. Topics covered in the talks included residual stresses in electrolytes for protonic conductive fuel cells, flash sintering of ceramic materials, graphene-based structures in zirconia ceramics, zirconia graphene composites for solid oxide fuel cell components, and lead-free low melting point glasses for structural and functional uses.

Speakers came from various centers linked to the Spanish National Research Council, such as the Nanomaterials & Nanotechnology Research Center, the Materials Science Institute of Madrid, and the Materials Science Institute of Sevilla. Other speakers were members of the Department of Condensed Matter Physics at the University of Sevilla, the Institute of Materials at the University of Santiago de Compostela, the University of Lyon INSA Lyon (France), and the Department of Metallurgical and Materials Engineering of Punjab Engineering College (India). ■

Attendees at the workshop organized by ACerS International Spain Chapter at the University of Sevilla, Spain.

ACerS International Germany Chapter hosts guest speaker from India

On Oct. 19, 2023, ACerS International Germany Chapter, in cooperation with the MRS Chapter Cologne, welcomed Rajiv Prakash from the Indian Institute of Technology (IIT), Bhilai. His visit started with a lab tour followed by a networking session with students, from bachelor's level through Ph.D. The students asked Prakash questions about his career path and what advice he could offer them for their lives over coffee and tea. Afterward, Prakash gave a lecture in which he talked about campus life at IIT Bhilai and his own research topics, including electronic polymers, nanocomposites, organic electronics, sensors, and energy storage devices. The lecture closed with a Q&A session. ■

acers spotlight

more SOCIETY DIVISION SECTION CHAPTER NEWS

Volunteer spotlight

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

Krista Carlson is associate professor of chemical and materials engineering at the University of Nevada, Reno (UNR). She received a B.S. in glass engineering science and Ph.D. in glass science from the New York State College of Ceramics at Alfred University.

Carlson works primarily on developing materials and processes to deal with the backend of the nuclear fuel cycle and waste generated from the nation's nuclear weapons program. As a lover of water in all forms, she has also focused her efforts on understanding the role of suboxide and disordered phases on the electrochemical behavior of titanium oxide electrodes for water purification.

Last year, Carlson served as chair of the Energy Materials & Systems Division (EMSD) and co-chair of the Education and Professional Development Council. She is currently the faculty advisor for the Material Advantage student chapter at UNR.

Carlson was recently recognized as a Global Ambassador for her work with EMSD and for being a co-lead organizer for MCARE 2023.

Arnaldo Moreno is full professor of chemical engineering at Jaume I University in Castellón de la Plana, Spain. He received a Ph.D. in chemical engineering from that university as well.

Moreno is a member of the Institute of Ceramic Technology at Jaume I University, where he studies sinter-crystallization of ceramic glazes and bodies.

Morena has been an ACerS member since 1995. He is affiliated with the Engineering Ceramics Division and is currently chair of the ACerS International Spain Chapter, a position he has held since 2019.

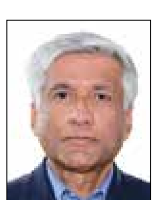
We extend our deep appreciation to Carlson and Moreno for their service to our Society! ■

Names in the news

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

Babak Anasori, professor of materials engineering and mechanical engineering at Purdue University, was ranked as the #1 scholar in mechanical engineering in the U.S. and #7 in the world according to a new ScholarGPS analysis that evaluated scholar impact based on publications in the past five years.

Michel Barsoum, Distinguished Professor of Materials Science and Engineering at Drexel University, was ranked as the #1 scholar in materials science and #124 for all research disciplines worldwide in 2022 according to an October 2023 Elsevier report titled "Updated science-wide author databases of standardized citation indicators."



Manoj Choudhary, adjunct professor of materials science and engineering at The Ohio State University, received several honors in 2023. He gave the Varshneya Frontiers of Glass Technology Lecture during the 2023 Glass & Optical Materials Division meeting in June, the M. G. Bhagat Lecture at the Indian Ceramic Society meeting in December, and was made a member of the World Academy of Ceramics. ■

IN MEMORIAM

Charles Roberts

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

Ceramic Tech Chat: Yoshiki Iwazaki and Shiho Kawashima

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

In the October 2023 episode of Ceramic Tech Chat, Yoshiki Iwazaki, senior principal scientist and general manager at Taiyo Yuden in Japan, describes his research on multilayer ceramic capacitors using first-principles calculations, discusses the changes that come with transitioning into a managerial role at work, and shares where he sees electroceramics research at Taiyo Yuden headed in the future.

Check out a preview from his episode.

> *"By enabling our customers to create energy-efficient products using our very small and high-capacity capacitors, we can help our customers' sustainability goals. And we also believe that by supporting the realization of better electronic vehicles with our electronic devices, we can contribute to reducing environmental impact from a global perspective."*

In the November 2023 episode of Ceramic Tech Chat, Shiho Kawashima, associate professor of civil engineering and engineering mechanics at Columbia University, identifies the main culprits behind high carbon emissions in the cement and concrete industry, outlines several approaches to lowering emissions, and describes the role her research plays in innovating solutions to this challenge.

Check out a preview from her episode.

> *"The way that we cast concrete and the way we have cast concrete forever is through the use of formwork. So first you construct the formwork, and then you cast or pour your concrete into that formwork. And then once your concrete has developed sufficient structure and strength, then you can strip the form work. … With 3D printing, you eliminate the need for formwork altogether. And so once you eliminate that big step of constructing and stripping formwork, it leads to significant increase in efficiency in terms of time, material, labor."*

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

AWARDS AND DEADLINES

Last call for 2024 award nominations

Nominations for several Division awards are due in January 2024. Nominations are encouraged for deserving candidates from groups that have been underrepresented in ACerS awards relative to their participation in the Society, including women, underrepresented minorities, industry scientists and engineers, and international members. For more information, visit www.ceramics.org/awards or contact Vicki Evans at vevans@ceramics.org. ■

Announcing: The David W. Richerson Educational Outreach Award

The American Ceramic Society has a new award to recognize undergraduate or graduate students in the ceramic and glass materials community who have made a significant impact in outreach to primary and secondary school students. The David W. Richerson Educational Outreach Award was established through a gift from David W. Richerson, Richerson & Associates. Richerson is an early pioneer in the development of high-strength silicon nitride, introducing grain boundary engineering and the use of fracture surface analysis to improve materials.

The award will be given annually at the ACerS Annual Meeting Awards Banquet to honor up to two ACerS student members who have demonstrated exceptional efforts in educational outreach. Recipients will receive a certificate, a $2,000 award honorarium, and a registration waiver to attend ACerS Annual Meeting. The nomination deadline is **March 1, 2024**.

For more information, visit www.ceramics.org/awards or contact Erica Zimmerman at ezimmerman@ceramics.org. ■

Nomination deadline: March 1, 2024

Society awards will be presented at the Annual Awards Banquet during ACerS Annual Meeting at MS&T in October 2024.

Society awards	Description
Distinguished Life Membership	ACerS' highest honor, given in recognition of a member's contributions to the ceramics profession. Nominees must be current members who have attained professional eminence because of their achievements in the ceramic arts or sciences, service to the Society, or productive scholarship.
Fellows	Recognizes individuals who have made outstanding contributions to the ceramic arts or sciences through broad and productive scholarship in ceramic science and technology, by conspicuous achievement in the ceramics industry, or by outstanding service to the Society. Nominees must be 35 years old or older.
W. David Kingery Award	Recognizes distinguished lifelong achievements involving multidisciplinary and global contributions to ceramic technology, science, education, and art.
John Jeppson Award	Recognizes distinguished scientific, technical, or engineering achievements in ceramics.
The European Ceramic Society-American Ceramic Society Joint Award	Recognizes individuals who foster international cooperation between The American Ceramic Society and the European Ceramic Society, in demonstration of both organizations' commitment to work together to better serve the international ceramics community.
The Rishi Raj Medal for Innovation and Commercialization Award	Recognizes one individual whose innovation lies at the cusp of commercialization in a field related, at least in part, to ceramics and glass.
Medal for Leadership in the Advancement of Ceramic Technology	Recognizes individuals who, through leadership and vision in an executive role, have made significant contributions to the success of their organization and in turn have significantly expanded the frontiers of the ceramics industry.
Corporate Environmental Achievement Award	Recognizes an outstanding environmental achievement made by an ACerS Corporate Partner in the field of ceramics.
Corporate Technical Achievement Award	Recognizes an outstanding technical achievement made by an ACerS Corporate Partner in the field of ceramics.
Richard M. Fulrath Awards	Promotes technical and personal friendships between Japanese and U.S. ceramic engineers and scientists. Recognizes individuals for excellence in research and development of ceramic sciences and materials. Nominees must be 45 years old or younger at the time of award presentation.

Society awards (cont.)	Description
Karl Schwartzwalder-Professional Achievement in Ceramic Engineering Award	Recognizes an outstanding young ceramic engineer whose achievements have been significant to the profession. A nominee must be between 21 and 40 years of age, and must be a member of EPDC and ACerS.
Robert L. Coble Award for Young Scholars	Recognizes an outstanding scientist who is conducting research in academia, industry, or at a government laboratory. Candidates must be an ACerS member and must be 35 years old or younger.
Du-Co Ceramics Young Professional Award	A young professional member of ACerS who demonstrates exceptional leadership and service to ACerS.
Frontiers of Science and Society – Rustum Roy Lecture	Given each year by a nationally or internationally recognized individual who is conducting research in academia, industry, or at a government laboratory. Generally, the committee selects the lecturer, but suggestions from membership are invited.
Edward Orton, Jr. Memorial Lecturer	Selection is based on scholarly attainments in ceramics or a related field. Generally, the committee selects the lecturer, but suggestions from membership are invited.
The Navrotsky Award for Experimental Thermodynamics of Solids	Awarded biennially to an author who made the most innovative contribution to experimental thermodynamics of solids technical literature during the two calendar years prior to selection. (Next awarded in 2025)
Ross Coffin Purdy Award	Recognizes the author(s) who made the most valuable contribution to ceramic technical literature during the calendar year two years prior to the year of selection. The 2024 Purdy award is for the best paper published in 2022.
Richard and Patricia Spriggs Phase Equilibria Award	Recognizes the author(s) who made the most valuable contribution to phase stability relationships in ceramic-based systems literature during the previous calendar year (2023).
Morgan Medal and Global Distinguished Doctoral Dissertation Award	Recognizes a distinguished doctoral dissertation in the ceramics and glass discipline.
David W. Richerson Educational Outreach Award	Recognizes undergraduate or graduate students in the ceramic and glass materials community who have made a significant impact in outreach to primary and secondary school students. ■

ICACC 2023 best poster winners announced

The Engineering Ceramics Division announced the winners for best posters at ICACC 2023, which was held last January in Daytona Beach, Florida. The awards will be presented during the plenary session at ICACC 2024. Congratulations to the authors of these award-winning posters!

First place

Magnetic field-assisted chemical vapor deposition of $MgFe_2O_4$ films for photoelectrochemical water splitting—by **Ziyaad Aytuna**, **H. Lee, A. Bhardwaj**, **M. Wilhelm**, **B. May, D. Müller, K. Lê,** and **S. Mathur**; University of Cologne, Germany

Second place

Ammonolysis and sintering of complex nitride compounds—by **Shannon Rose Rogers**, **G. Brennecka**, **E. Toberer,** and **R. Smaha**; Colorado School of Mines

Third place

Lead-free $(1–x)BaZr_{0.08}Ti_{0.92}O_3–(x)CoFe_2O_4$ nanocomposite obtained by SPS—by **Laís Pacheco Caminata**, **J. A. Eiras**, and **R. H. Kiminami**; Federal University of Sao Carlos, Brazil

Trustee awards

The effect of BN coating layer thickness for LSI processed SiC/SiC composites—by **Seyoung Kim**, **I. Han**, **H. Bang**, **S. Kim**, **Y. Seong**, **S. Lee**; Korea Institute of Energy Research, Republic of Korea

Chemical imaging of Li-rich disordered rocksalt-type vanadium oxide particles using hard X-ray spectroscopic ptychography—by **Hideshi Uematsu**, **N. Ishiguro**, **M. Abe**, **S. Takazawa**, **J. Kang**, **I. Konuma**, **N. Yabuuchi**, **Y. Takahashi**; Tohoku University, Japan

Influence of weathered polyethylene terephthalate on performance of cement–polymer composites—by **Rachel Elizabeth Cook**, **S. Jhang**, **A. Newman**, **L. Sung**; National Institute of Standards and Technology, Maryland ■

more AWARDS AND DEADLINES

Class and Division awards: Nominations due Jan. 15, 21, 31 or March 1, 2024
Contact: Vicki Evans, vevans@ceramics.org

Class	Award	Deadline	Description
EPDC	Greaves-Walker Lifetime Service Award	March 1, 2024	Recognizes an individual who has rendered outstanding service to the ceramic engineering profession and who has exemplified the aims, ideals, and purpose of EPDC.
EPDC	Outstanding Educator Award	March 1, 2024	Recognizes outstanding work and creativity in teaching, directing student research, or in the general educational process (e.g., lectures, publications) of ceramic educators.
EPDC	Arthur L. Friedberg Engineering Tutorial and Lecture	March 1, 2024	Recognizes an individual who has made outstanding contributions to ceramic engineering that relate to the processing or manufacturing of ceramic products. The awardee must be a member of both EPDC and ACerS.

Division	Award	Deadline	Description
AACS	Anna O. Shepard	Jan. 15, 2024	Recognizes an individual(s) who has made outstanding contributions to materials science applied to art, archaeology, architecture, or cultural heritage.
BSD	Early Discovery	Jan. 15, 2024	Recognizes an early career member of ACerS who has demonstrated a contribution to basic science in the field of glass and ceramics.
BSD	Robert B. Sosman Lecture	Jan. 15, 2024	Recognizes an outstanding achievement in basic science that results in a significant impact on the field of ceramics.
BIO	Young Scholar	Jan. 31, 2024	Recognizes excellence in research among current degree-seeking graduate students and postdoctoral research associates.
BIO	Global Young Bioceramicist	Jan. 31, 2024	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	Jan. 31, 2024	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 towardclinical use.
BIO	Tadashi Kokubo	Jan. 31, 2024	Recognizes an individual's outstanding achievements in the field of bioceramics research and development.
Cements	Early Career	Jan. 15, 2024	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. Kreidl	Jan. 21, 2024	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 twelve-month period of the annual GOMD meeting.
GOMD	George W. Morey	Jan. 21, 2024	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 Lifetime Achievement	Jan. 21, 2024	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	Jan. 21, 2024	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	Jan. 15, 2024	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. ■

2022–2023 Global Ambassador awardees

The Global Ambassador Program recognizes dedicated ACerS volunteers worldwide who demonstrate exceptional leadership and/or service that benefits the Society, its members, and the global ceramics and glass community.

ACerS past president Sanjay Mathur (2022–2023) selected the following volunteers for the Global Ambassador Award:

Krista Carlson; University of Reno, USA

Gustavo Costa; NASA Glenn Research Center, USA

Bai Cui; University of Nebraska-Lincoln, USA

Nobuhito Imanka; Osaka University, Japan

Emanuel Ionescu; Fraunhofer IWKS, Germany

Do-Heyoung Kim; Chonnam National University, Republic of Korea

Kwang Ho Kim; Pusan National University, Republic of Korea

Ravi Kumar; Max Planck Institute for Metals Research, Germany

C.D. Madhusoodana; Bharat Heavy Electricals Limited, India

Yogendra Kumar Mishra; Sonderborg University, Denmark

Ahsan Ul Haq Qurashi; Khalifa University of Science and Technology, UAE

Prabhakar Singh; Indian Institute of Technology Varanasi, India

Ender Suvaci; Eskisehir Technical University, Turkey

Jenny Wang; AdValue, USA

Gunnar Westin; Uppsala University, Sweden ■

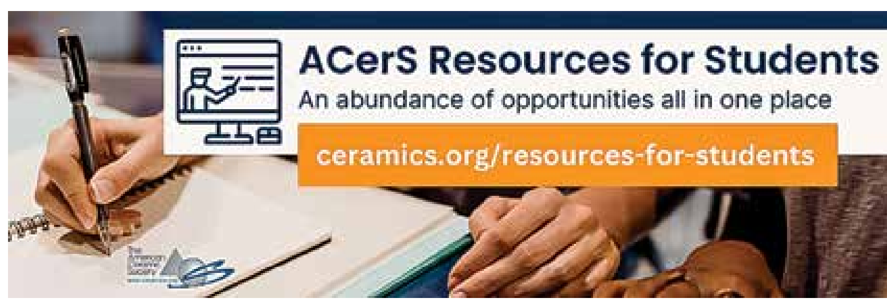
STUDENTS AND OUTREACH

Did you just graduate, or are you new to the materials science field? ACerS can help you succeed by offering you a FREE one-year Associate membership. Your second year of Associate membership is only $40. Associate membership is available to those who have not previously had ACerS Individual membership.

ACerS Associate members enjoy these benefits:

- Leadership opportunities for young professionals
- Networking events with future collaborators
- Access to ACerS Career Center

Visit www.ceramics.org/associate to learn more and to sign up for your free Associate membership. ■



CERAMIC AND GLASS INDUSTRY FOUNDATION

CGIF hosts Teacher Training Workshop as Colorado School of Mines launches new ceramic engineering degree

The teachers pause to don a pair of paper solar glasses and file outside just in time to see the 2023 annular solar eclipse, visible in parts of North America on Saturday, Oct. 14. Slices of the sun can be seen in the shadows as the teachers gaze up at the rare sighting. The event only added to the excitement of the Ceramic and Glass Industry Foundation's (CGIF) Teacher Training Workshop at Colorado School of Mines.

CGIF spent the day with local Colorado science teachers at this Teacher Training Workshop to equip them with the knowledge and tools to inspire the next generation of ceramic and glass professionals.

The day-long workshop, which took place on the Colorado School of Mines campus, allowed CGIF to train teachers from the Denver area using the nine hands-on lessons from the CGIF Materials Science Classroom Kit. The workshop was also generously sponsored by the Department of Materials Science and Engineering at Colorado School of Mines, Direxa Engineering, and Deltech Furnaces.

In addition to graduate students and professors from Colorado School of Mines, local ceramic and glass industry professionals from Ardagh Glass and Johns Manville attended the event to network with the teachers at an industry luncheon.

Teachers look up during an annular eclipse in between lessons during the CGIF Teacher Training Workshop at Colorado School of Mines.

Teachers, volunteers, and CGIF staff who participated in the Teacher Training Workshop at Colorado School of Mines.

The goal of the industry luncheon is for teachers to learn more about the diverse careers available in the ceramic and glass industries so that they can guide their students toward a career in materials science, or even guide them toward the new bachelor's in ceramic engineering that launched in fall 2023 at Colorado School of Mines.

"It was a fantastic day of materials science learning for the teachers," says Marcus Fish, director of development and industry relations at the CGIF. "It was so great to bring our teacher workshop to Mines with a new group of teachers to learn about materials science, especially with the new ceramic engineering undergraduate degree launching at Mines. This workshop will give teachers a firsthand view of an opportunity for their students to pursue a degree in ceramic engineering at one of the country's leading programs in materials science."

Throughout the day, the teachers followed a peer learning model, in which they first learned how to teach one of the lessons from the Materials Science Classroom Kit and then taught the lesson to their fellow teachers. Each teacher received a free kit to use in their own classroom.

The teachers also received a career packet that connects the CGIF Materials Science Classroom Kit lessons to real-life careers related to materials science and engineering, helping to further solidify the connection between materials science and the real world.

Assistant teaching professor Kim Scott, left, and professor Brian Gorman from the Colorado School of Mines Metallurgical and Materials Engineering Department with the refractory brick from the "Hot or Not?" lesson in the CGIF Materials Science Classroom Kit.

Want to see a Teacher Training Workshop near you? Visit ceramics.org/donate to help CGIF continue to bring this program nationwide. ■

research briefs

Mitigating crack formation—electron-rich metals increase the fracture resistance of ceramics

Researchers at the University of California, San Diego and Linköping University in Sweden published two open-access papers demonstrating the effect that electronic structure has on plastic deformation in high-entropy carbides.

High-entropy carbides are desired for ultrahigh-temperature applications due to their high melting temperatures and high-temperature mechanical stability, but they generally do not demonstrate the best fracture resistance.

In the first open-access paper, published in 2021, the researchers explain that previous papers showed the toughness of pseudobinary refractory nitrides could be enhanced by increasing valence electron concentration. This improvement was attributed to the fact that a high valence electron concentration allows electrons to fully occupy bonding shear-sensitive metallic states near the Fermi level, which facilitates dislocation movement due to lowered stacking fault energies.

The researchers used ab initio molecular dynamic simulations and nanoindentation testing to explore whether this approach to improving toughness would also work for high-entropy carbides, specifically (MoNbTaVW)C and (HfTaTiWZr)C. They found that the more electron-rich (MoNbTaVW)C exhibited a greater fracture resistance, which would appear to support the theory that increased valence electron concentration leads to improved toughness.

"Nonetheless, it remains debated whether the experimental observations were incidentally consistent with the theoretical predictions given that only two samples with markedly different VEC [valence electron concentrations] have been considered," the researchers write in the second open-access paper, published in September 2023.

In the second paper, they investigated six more high-entropy carbide compositions to further elucidate the correlation between valence electron concentration and resistance to brittle fracture. As with the previous study, they paired ab initio molecular dynamic simulations with nanoindentation testing.

The results from this study confirmed the relationship between valence electron concentration and fracture resistance, thus demonstrating "a reliable strategy for computationally guided and rule-based engineering" of high-entropy carbides, the researchers write.


Credit: Liezel Labios, UC San Diego Jacobs School of Engineering

Samples of high-entropy carbides that were engineered with electron-rich metals to withstand more force and stress before breaking.

The 2021 open-access paper, published in *Materials & Design*, is "Enhancing plasticity in high-entropy refractory ceramics via tailoring valence electron concentration" (DOI: 10.1016/j.matdes.2021.109932).

The 2023 open-access paper, published in *Science Advances*, is "Valence electron concentration as key parameter to control the fracture resistance of refractory high-entropy carbides" (DOI: 10.1126/sciadv.adi2960). ■

A new way to self-heal: Electron beam radiolysis drives crack repair in titanium dioxide

Researchers at the University of Minnesota Twin Cities described a counterintuitive discovery of a new way to self-heal cracks in ceramics—through electron beam radiolysis.

Radiolysis is the dissociation of molecules by ionizing radiation. One or several chemical bonds cleave under exposure to the high-energy flux.

Radiolytic bond breakage is well documented in many materials. So when chemical engineering and materials science Ph.D. student Silu Guo placed crystals of titanium dioxide under an electron microscope to study some naturally occurring narrow cracks, she expected the ceramic might experience some degradation.

Instead, much to her surprise, "these cracks kept filling in," she says in a University of Minnesota press release.

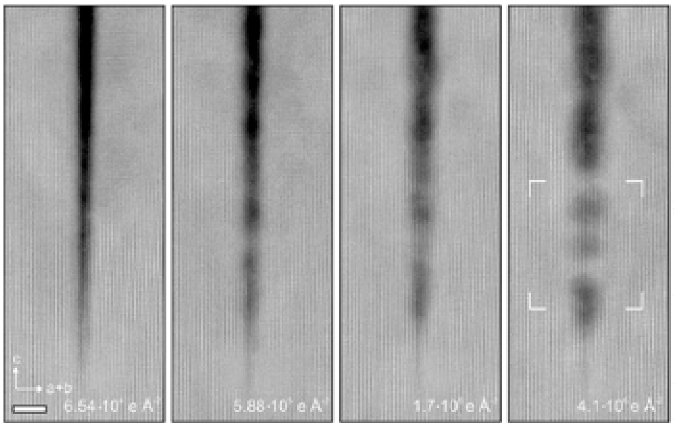
Research News

Mapping the impacts of the rare earths supply chain

A new map created by the Observatory on Debt in Globalization, in collaboration with the Environmental Justice Atlas at the Universitat Autònoma de Barcelona, the Institute for Policy Studies, and CRAAD-OI Madagascar, documents 28 social and environmental conflicts derived from the extraction, processing, and recycling of rare earth minerals. China, Chile, Brazil, Finland, Greenland, India, Kenya, Madagascar, Malaysia, Malawi, Myanmar, New Zealand, Norway, Spain, and Sweden are some of the scenes for these conflicts, which will be exacerbated as the demand for rare earth minerals increases. For more information, visit https://www.eurekalert.org/news-releases/1009215. ■

'Doughnut' beams help physicists see incredibly small objects

Researchers at the University of Colorado Boulder used doughnut-shaped beams of light to take detailed images of objects too tiny to view with traditional microscopes. The research is the latest advance in the field of ptychography, which measures how light scatters away from an object and then uses that data to image it. Until recently, ptychography has been unable to image samples with highly periodic structures. The new technique by UC Boulder researchers overcomes this limitation by relying on beams of extreme ultraviolet light in the shape of doughnuts, which can image structures only 10 to 100 nanometers in size. For more information, visit https://www.colorado.edu/today. ■



These scanning transmission electron microscope images show how the crack in a crystal of titanium dioxide begins to "heal" with increasing electron doses.

Guo immediately set to work with other University of Minnesota students and professors, including lead researcher and chemical engineering and materials science professor Andre Mkhoyan, to understand why the cracks were filling in. In the new paper, they detail the mechanism behind this unusual observation.

As expected, the electron beam irradiation caused extensive breaking of the titanium–oxygen bonds along the edge region of the crack. However, this release of the titanium and oxygen atoms enabled them to move into the crack and reform bonds. As the beam dose increased, the crack was gradually bridged via these "two-step" rolling movements.

Excitingly, the bridges within the crack had the same rutile structure as the bulk, meaning the material was restored to its original structure. The bulk region did not appear affected by the electron beam irradiation, except at very high doses.

The researchers predict that similar radiolysis-driven restructuring would be possible in other oxides as long as the oxides satisfy the requirements for significant radiolysis.

The open-access paper, published in *Nature Communications*, is "Mending cracks atom-by-atom in rutile TiO_2 with electron beam radiolysis" (DOI: 10.1038/s41467-023-41781-x). ■

Nanocoating offers new way to control 'runaway' thermal reactions

Researchers led by North Carolina State University developed a new nanocoating that provides even greater control over reaction rate and ignition propagation during combustion (burning).

Current methods for guiding or directing combustion reactions remain rather rudimentary. They allow for the reaction rate to be influenced but not the direction in which the flame spreads (ignition propagation) or different reaction rates based on location within the sample.

Nonflammable coatings, such as SiO_2, can provide location-based control over reaction rates during materials processing. Some previous studies that used nonflammable coatings to control the heat release during pyrolysis successfully achieved the transformation of organic fibers into carbon tubes.

In the new study, the researchers used an alkysilane-based coating that not only influenced location-based reaction rates but also the direction of ignition propagation within organic cellulose fibers. The coating achieved this "surface-then-core" ignition order because of a chemical transformation that takes place within the coating upon heating.

Initially, the alkysilane-based coating features flammable alkyl tails on the outer surface. When these tails combust upon heating, the inner surface of the coating transforms into a nonflammable silicate glass. This glass limits the amount of oxygen that can access the cellulose fibers, leading the cellulose to burn slowly from the inside out rather than bursting into flames.

The new coating allowed the researchers to synthesize carbon nano- and microtubes with tunable wall dimensions and lengths. They gained further control over the final tube structure by varying the size of the starting fiber, adjusting the amount of oxygen in the system, and introducing various salts into the fibers.

The paper, published in *Angewandte Chemie*, is "Spatially directed pyrolysis via thermally morphing surface adducts" (DOI: 10.1002/anie.202308822). ■

ceramics in energy

Black silicon wafers significantly improve efficiency of ultrathin solar cells

Researchers in Spain and Finland explored using black silicon to create ultrathin wafers for application in interdigitated back-contact (IBC) solar cells.

The transition to ultrathin silicon wafers for solar cells would allow for further cost savings in the solar industry because more wafers could be produced from a single silicon ingot. However, because silicon is a poor absorber of light in the long wavelength region, reducing the wafer thickness jeopardizes light absorption.

Black silicon offers a way to reduce thickness without jeopardizing performance. Black silicon refers to silicon that has been modified to have a needle-shaped surface structure. This textured surface reduces the inherent high reflectivity of silicon, making the material appear black when viewed, hence the name.

Black silicon was initially discovered as an undesirable side effect of reactive ion etching. But researchers now desire black silicon for its good light-trapping ability, which allows the material to absorb light across a broader range of wavelengths.

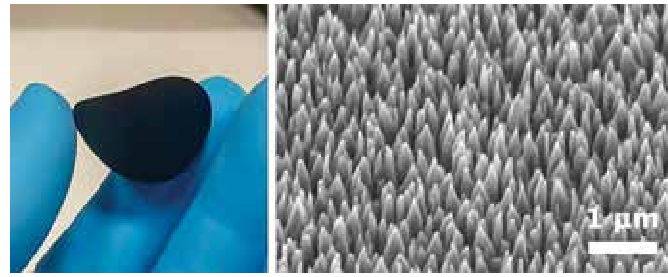
Several etching methods are used to make black silicon. However, for high-efficiency ultrathin solar cells, deep reactive ion etching (DRIE) at cryogenic temperatures appears to be the most promising method. That is because minimum surface damage occurs during this process, plus only a small amount of silicon is wasted to produce the textured surface.

In the recent study, the researchers used the DRIE process to produce wafers with three different thicknesses: 40, 20, and 10 µm. Compared to nontextured silicon wafers, all the black silicon wafers demonstrated improved absorption capabilities up to nearly 100% across the entire ultraviolet–visible spectrum and even extended toward the infrared spectrum.

After confirming the wafers' absorption capabilities, the researchers created a proof-of-concept IBC solar cell using the 40-µm black silicon wafers. It achieved a power conversion efficiency of 16.4%, an open-circuit voltage of 633 mV, a short-circuit current density of 35.4 mA cm^{-2}, and a fill factor of 73.4%. In contrast, a cell without black silicon achieved an efficiency of 11.5%, an open-circuit voltage of 600 mV, a short-circuit current density of 27.1 mA cm^{-2}, and a fill factor of 70.7%.

Based on the optical characterization of the wafer, the cell did not achieve the expected external quantum efficiency, i.e., the conversion efficiency of incident photons to electrical current. The researchers attribute this poorer-than-expected performance to several aspects of the device fabrication process, namely

- Successive cleaning steps caused additional etching of the substrate, changing the desired nanostructure.
- The multiple layers covering the textured substrate reduced the refractive index contrast and impedance mismatch, thus reducing the substrate's scattering effect.
- Thin film deposition of the layers filled in gaps between the silicon nanopillars, smoothing out the textured surface.



Credit: Garin et al., *Small* (CC BY 4.0)

A free-standing 10-µm-thick black silicon wafer (left) and a scanning electron microscope image of its nanotextured surface (right).

The researchers note that these negative effects could be minimized through further process optimization.

The open-access paper, published in *Small*, is "Black ultra-thin crystalline silicon wafers reach the $4n^2$ absorption limit–Application to IBC solar cells" (DOI: 10.1002/smll.202302250). ■

Build your literacy on energy topics with Stanford's new learning hub

Even though decisions regarding energy research and funding affect everyone, many people do not feel they can contribute knowledgeably to these discussions because energy is a complex topic. Fortunately, Stanford University's new Understand Energy Learning Hub can help anyone build their energy literacy at their own pace.

Open to the public, the new website shares content from Stanford's Understand Energy course, including recorded lectures and homework assignments that consist of "essential" and "optional and useful" videos and readings. These resources are categorized into six groups:

- **Introduction to Energy**, which helps users gain a big picture view of energy topics.
- **Why We Care About Energy**, which covers climate change, energy access, and environmental justice.
- **Energy Resources**, which provides a close look at fossil fuels, nuclear energy, and renewable energy.
- **Energy Currencies**, which considers secondary energy sources, such as electricity, natural gas, and hydrogen.
- **Energy Services**, which describes the use of energy in buildings and transportation.
- **Tools to Manage & Sustain Energy Systems,** which covers energy policy, energy storage, and carbon capture.

Explore the Understand Energy Learning Hub at https://understand-energy.stanford.edu. ■

Computer vision method demonstrates potential of rapid and automated quality control for cements

Two researchers at the University of Illinois Urbana-Champaign proposed a rapid characterization method for the sorptivity of cementitious pastes based on surface wettability.

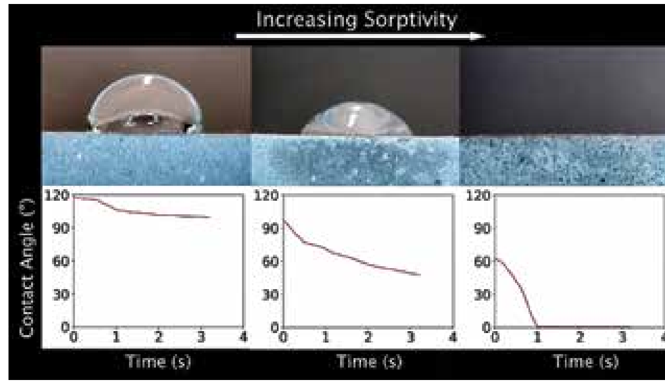
Sorptivity is a material's ability to absorb and transmit water through capillary suction. Gathering data on the sorptivity of cementitious systems can be a long process. While automated techniques have made experiments less laborious, these techniques still require several hours of operation.

The new method proposed by Nishant Garg, civil and environmental engineering professor, and his graduate student Hossein Kabir uses computer vision to see how quickly a single water droplet is absorbed into a sample's surface within the first few seconds or minutes. Crucially, their test accounts for the angle at which water droplets contact the surface.

"The dynamics of absorption change quickly while the water droplets change shape on the surface," says Garg in a press release.

Garg and Kabir created more than 60 unique cementitious paste samples using several different ASTM Type 1 cements. After gathering surface wettability data on these samples, they explored whether any meaningful correlation could be established between this data and the sorptivity of cementitious systems.

They determined a fairly good correlation exists between their results and the results from the conventional ASTM C1585 test method. However, they note that this correlation applies only to the initial sorptivity values and not the secondary sorptivity values (moisture diffusion through gel pores) of the system.



Credit: NewsAtIllinois, YouTube

Screenshot from a video showing how water droplet contact angle affects cement surface sorptivity.

Additionally, because the tests were conducted on cementitious pastes, the findings are limited to binders and paste systems. Garg and Kabir plan to explore whether this method can be extended to concrete samples.

The open-access paper, published in *npj Materials Degradation*, is "Rapid prediction of cementitious initial sorptivity via surface wettability" (DOI: 10.1038/s41529-023-00371-4). ■

Regression model predicts thermal properties of cemented carbides

Two researchers at Sweden-based tooling company Seco Tools AB formulated a regression model that offers fairly accurate predictions for thermal properties of cemented carbides using only reliable and readily measurable material characteristics.

Cemented carbides are the most common type of cutting tool materials. During metal cutting, temperatures up to 1,000°C can be generated at the interface between the cutting tool and the workpiece. So, the cutting tool must have good thermal conductivity to allow rapid heat transfer from the cutting zone.

Several previous studies investigated the thermal properties of cemented carbides, and they predicted thermal conductivity with varying degrees of success. The Steco researchers suggest there are likely several reasons for the lower success rates, but unreliable conductivity data and time-consuming grain size measurements are the main factors.

In this study, "the emphasis is put on predicting thermal conductivity from reliable, readily available, or easily measurable material characteristics, such as chemical composition, coercivity, density, etc.," the researchers write.

They selected 20 cemented carbide grades with a variety of tungsten carbide grain sizes and cobalt and cubic carbides content. Thermal properties were investigated by performing light (laser) flash analysis on flat circular samples using the Netzsch LFA 467 HT HyperFlash system.

For all investigated grades, thermal conductivity decreased with increased temperature, though the rate of decrease varied from grade to grade. Generally, conductivity of the samples with small tungsten carbide grain size and/or high cubic carbides content was less sensitive to the temperature.

Using this experimental data, the researchers formulated a set of regression equations based on the material's chemical composition and coercivity to predict thermal conductivity in the range of room temperature to 800°C. They achieved the most accurate predictions when the parameters fitted a linear equation, with an average 4% difference between calculated and measured values.

They caution that the predictions become less accurate for cemented carbides with cobalt content above 15 wt.% and completely inaccurate at low temperatures for grades with nanosized tungsten carbide grains.

Regardless, "Reasonable correlation between measured and calculated conductivity was observed for most materials and temperatures," they conclude.

The paper, published in *International Journal of Refractory Metals and Hard Materials*, is "Thermal properties of cemented carbides used for metal cutting" (DOI: 10.1016/j.ijrmhm.2022.106097). ■

To reduce the pileup of wind turbine blades after decommissioning (above), Carbon Rivers developed a glass-to-glass commercial technology for recovering the glass fibers (left).

Manufacturing the impossible: Supporting the development of a circular economy in the composites industry

By David Morgan

Glass fiber-reinforced composites are found in every industry, from marine and wind to automotive and construction. Carbon Rivers' recent glass-to-glass commercial technology for recovering glass fiber from end-of-life composites poses both advantages and challenges to the composites industry.

Glass fiber-reinforced composites (GFRCs) are ubiquitous in modern life. At any point, one is probably standing within 20 feet of a GFRC component, whether it be in an automobile, boat, wind turbine, or residential composite deck.

Despite their ubiquity, current methods for disposing of GFRCs at the end of their life are not ideal. These composites often end up in landfills, taking up significant amounts of space and wasting the potential to reuse these materials in new products.

Attention to this issue has grown significantly in recent years thanks to social media platforms. Viral photos of wind turbine blades sitting in landfills epitomize the seldom-seen trash created by renewable energy, as well as the frustration and innovation of industries that are attempting real solutions for real problems.

If we wish to continue using GFRCs, stopgap measures are necessary in the short term, such as dumping composites in landfills or using the waste as an alternative fuel for cement kilns. But these options do not provide ecological or even humanitarian responsible solutions to end-of-life composites in the long term.

In 2019, the U.S. Department of Energy provided a Small Business Innovation Research grant (SBIR) to Carbon Rivers (Knoxville, Tenn.) to explore solutions for a composite circular economy, with wind turbine blades being the chief focus. The company, which was founded in 2017 to take advantage of market opportunities in advanced materials, received additional SBIR grants to advance development of a new glass-to-glass (G2G) reclamation process.

Carbon Rivers partnered with LM Wind, Pacificorp, and GE to test the new G2G process. They recovered clean (removal of sizing) and mechanically intact (minimal degradation) glass fibers from end-of-life turbine blades on a pilot process line, while also producing renewable oil and syngas during the recycling process.[1]

Inside Carbon River's G2G reclamation process

Denver McGrady, product development director at Carbon Rivers, says Carbon Rivers' G2G reclamation process is "very rewarding" because it is, in many ways, an industry first.

"The G2G process has huge potential to be a sustainable solution for an age-old market," he says.

The G2G reclamation process begins with a mechanical downsizing (shredding) step. This step includes a mobile track system industrial grinder that can provide a throughput of at least 50 mT per day, which is equivalent to seven and a half GE 37 blades per day. The shredded material can then be screened to determine which will undergo further processing for glass fiber recovery and which will be pulverized as an alternative fuel for cement kilns, which has a comparable BTU to coal.[2]

The second step in the process is the actual glass fiber recovery from the low-heat thermal process, which cracks the polymer into light and heavy hydrocarbons. The light hydrocarbons recirculate into the system for net positive energy, displacing the need for natural gas, and the heavy hydrocarbons are condensed into a tank, which is captured as renewable polymer oil. The oil can be fractionated to certain points in the stack, including everything from a sulfur-free red diesel to a heavy bitumen.

The amount of polymer crude oil is a happy surprise, as the process initially focused on glass fiber recovery. Initial analysis demonstrated that the oil can be fractionated off the stack for next life cycle petrochemical production or aviation and marine fuel.

Figure 1. rGF layup for a prototype snowboard.

Credit: Carbon Rivers

The recovered glass fiber is then cleaned, strengthened, and prepared to be turned into new products, for example, processed into nonwoven mats or compounded with various polymers to form thermoplastic pellets. This aspect of the process requires careful oversight to ensure the recovered glass fiber (rGF) material is prepped and tested in accordance with customers' production part approval processes (PPAPs), which validate materials for use in commercial supply chains.

Each sector of the composite industry has its own product development and validation process. However, most of this testing is done at Carbon Rivers, and then the test data and materials are provided to the OEM / Tier suppliers for final testing and validation. The process is streamlined because Carbon Rivers receives the mechanical values that are necessary from the procurement officers and then sends off the rGF intermediates based on the product specifications.

The entire process encompassing mechanical, thermal, and chemical aspects is a carbon-negative process because the glass fiber, syngas, and oil all offset any embodied energy and greenhouse gas emissions used in the recovery process. These products go back downstream as materials for new components or applications, thus gaining a second life and providing the composites industry with a sustainable, circular economy.

Bowie Benson, co-founder and CEO of Carbon Rivers, has been involved in the process from the beginning. He says, "Doing the impossible, or just plain difficult, is just another day at Carbon Rivers, which is leading the industry in creating closed-loop, full-scope composite waste material solutions. Still, as great as

Credit: Carbon Rivers

Figure 2. rGF thermoplastic pellets in injection molded commercial sprayer head.

our technology is, it is still second to our most disruptive element: our team. There is a great deal of work to be done, and we are happy to take on the challenge."

The far-reaching opportunities for recycled glass fibers

The opportunities for repurposing glass fibers reclaimed from wind blades, marine vessels, automotive parts, and other GFRC products are far reaching. Many have seen the bike shelters and sea wall breaks made using rGF reinforcements, but more recreational applications are on the horizon, such as snowboards (Figure 1), pickleball racquets, and even recycled composite materials for water park designs.

Of course, there are a variety of sustainable avenues to repurpose end-of-life composites, but Carbon Rivers focuses on downstream applications that are both economical and practical. For example, rGF reclaimed from retired wind blades using Carbon River's G2G reclamation process has been used commercially in injection molded sprayer heads on multipurpose cleaners (Figure 2).

Furthermore, rGF can be compounded with various polymers to form thermoplastic pellets (Figure 3) or processed into nonwoven mats for sheet molding

Figure 3. rGF thermoplastic pellets.

Credit: Carbon Rivers

Figure 4. rGF nonwoven mats with various weights.

Credit: Carbon Rivers

and bulk molding compounds (Figure 4). These products have enormous potential for application in the automotive industry, as manufacturing mandates from the European Union have benchmarks of 25% recovered materials in vehicle production by 2030.[3] Carbon Rivers is collaborating with automotive suppliers to supply them with rGF from the G2G reclamation process.

Eva Li, chief engineering officer at Carbon Rivers, who played an instrumental role in designing the G2G reclamation process, says, "I find the most challenging part is also the most rewarding. We require our engineering team to be boldly creative yet brutally critical, which can be quite an interesting task to balance. There is a better way to treat composite waste than landfilling, and I'm proud to be part of the solution."

Planning for the future: Making recycled glass fibers economic for the bottom line

Although Carbon Rivers' G2G reclamation process was theoretically tenable from the beginning, the Carbon Rivers team spent the better part of three years refining the process to make it economically feasible for composite manufacturers to adopt.

"The glass fiber reclamation technology and process are quite developed from the initial DOE SBIR time," says Bailey French, chief operations officer at Carbon Rivers. "Multiple aspects have been put in place not only to provide a carbon negative technology but also to strengthen the rGF so it can go back into next-life cycle manufacturing without degraded or compromised mechanical properties."

Thanks to these developments, the rGF is price-competitive with virgin fiber and offers a real environmental, social, and governance (ESG) sustainable material for global markets. In addition, the rGF intermediates are in PPAP validation in multiple industries.

The implications of this technology for the composites industry is immediately evident, as it will allow for the industry to embrace circular economies at both the macro and micro levels and achieve an overall carbon-negative footprint.

But this impactful technology will have ripples in other industries, too. If metal, plastics, and now composites are genuinely recycled, then other material waste steam solutions are inevitable and even quite necessary to develop. Carbon Rivers has been approached by other industries to provide waste stream solutions and a circular economy that is ultimately materially responsible, economically valuable, and environmentally impactful.

As more regulations regarding sustainability start making their way into various industries, such as the automotive manufacturing mandates mentioned in the section above, businesses and manufacturing houses must be more innovative and forward thinking for how to adapt to these shifts. For example, it is not simply the capability of adopting a second-use material in manufacturing—the efficiencies and economics have to make sense for the bottom line.

Of course, credits and incentives help to move the needle on these initiatives. But it is necessary for these entities to manufacture in an ESG ecosystem without the aid of credits.

One might say that the current market is based on the mantra, "if it is sustainable, then it is profitable." But this is a reflection only of the current sentiment and credit-laden market. The mantra needs to be "if it is profitable, then it is sustainable." This mantra reflects a business environment that does not rely on incentives and credits but rather provides an intrinsic profit and impact from which naturally follows a circular economy.

About the author

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CARBON RIVERS G2G+

Reducing waste one sector at a time

Carbon Rivers was birthed in the basement of Bowie Benson in 2017 by a small group of engineers who previously worked at the U.S. Department of Energy. With expertise in a variety of engineering disciplines, including materials, nuclear, mechanical, chemical, and electrical, their aim was to commercialize a variety of disruptive technologies that would benefit humanitarian and environmental endeavors.

In addition to the G2G reclamation process described in this article, the Carbon Rivers team has also used graphene to enhance the mechanical, electrical, and thermal properties of elastomers, composites, coatings, concrete, and textiles.

These materials find application in the aerospace, manufacturing, automotive, defense, energy, and marine industries.

Carbon Rivers not only commercializes its own advanced material projects but also consults with other global companies for waste stream solutions, manufacturing efficiencies, and enhanced products. These engineering consulting projects typically lead to collaborative commercial applications.

In 2024, Carbon Rivers is working on desalination and microplastic/metallic filtration of ocean water, as well as using graphene-enhanced transmission lines to upgrade energy grids.

Additionally, as a fun side project, the Carbon Rivers engineering team converted a Mazda RX-8 into an electric vehicle. The team will race the electrified car against petrol vehicles in a Road Atlanta race in hopes to set a world record for an electric vehicle beating petrol vehicles in an endurance race. ■

Engineering a sustainable future: Summer Research Institute offers unique learning opportunities for Alfred University undergraduates

By Mark Whitehouse

In summer 2023, about 30 undergraduate engineering students at Alfred University in New York had the opportunity to participate in research settings normally reserved for graduate students thanks to the university's new Summer Research Institute program.

The Summer Research Institute, held from May 30 through July 28, was developed to give students the opportunity to discover, very early in their college careers, how materials can impact everyday life. Normally, it is difficult to involve undergraduate students in a laboratory setting. But at Alfred University, where class sizes are smaller, there are more opportunities for students just beginning their educational journey to interact with faculty in a research environment.

Wilkinson

"Alfred is one of a very few places in the country that has an emphasis on undergraduate research and hands-on experiences," says Collin Wilkinson, professor of glass science. He supervised eight undergraduates in their summer research work.

The students who participated in this first Summer Research Institute came from a wide variety of engineering majors, including glass science engineering, ceramic engineering, biomaterials engineering, and materials science and engineering. Their research projects, which were supervised by 11 faculty members in the Inamori School of Engineering, addressed several important sustainability challenges.

Sustainability projects at the Summer Research Institute

Decreasing carbon emissions in glass manufacturing

Vasilii Maksimov from Moscow, Russia, is a junior majoring in glass science engineering and physics, with minors in computer science and mathematics. His project involved investigating ways to decrease the amount of environmentally harmful carbon dioxide produced during the production of glass.

"That's a huge issue. We need to decarbonize the glass manufacturing process," Maksimov says.

Figure 1. Elene Taniashvili removes some melted glass from a furnace as part of her research on developing plant fertilizer using waste glass.

Credit: Alfred University

His research examined how melting glass with hydrogen combustion, which contains no greenhouse gases, affects the properties of glass, namely its durability and toughness.

"I'm simulating fractures in different types of glass and seeing how the concentration of hydrogen affects the toughness of the glass. It will contribute to a theoretical model that helps us understand hydrogen's impact on the behavior of glass," explains Maksimov, who is advised in his research by Wilkinson. "Theoretically, this could produce guidelines on whether to use hydrogen in the glass melting process."

Recycling and reuse of glass waste products

Elene Taniashvili from Tbilisi, Georgia, is a sophomore majoring in glass science engineering. She conducted research aimed at developing fertilizer made from waste glass products (Figure 1).

"We're trying to make a fertilizer that is more effective than traditional fertilizer and acts as a better silicon nutrient provider than rock dust," she says.

Taniashvili explained that glass contains some silicon-based materials that are beneficial to plant growth. Her research, advised by William LaCourse, emeritus professor of glass and current research faculty member, modifies glass waste from a powdered form into a foam material that can hold more water and come in contact with a greater soil surface area than powder. The foaming process is done using water glass—a compound containing sodium oxide and silica—which avoids carbon dioxide emissions.

A key to the development of an effective fertilizer made from waste glass is the removal of sodium, which is detrimental to plant growth. Taniashvili says removal can be achieved via a process called glass leaching, or ion exchange.

Alexander Johnsson from South Windsor, Connecticut, a junior majoring in ceramic engineering as well as art and design,

Figure 2. Jane Heffernan prepares a sample as part of her research studying ways to 3D print silicon carbide.

is also working on the project. He explains that the ion exchange process uses water to remove sodium, which is high in alkalinity, and replaces it with potassium, which is good for plant growth.

Improving mechanical properties of UHTCs

Jane Heffernan from Eden, New York, is a sophomore majoring in ceramic engineering. Her project explored whether silicon carbide, an ultrahigh-temperature ceramic (UHTC), printed using digital light processing was stronger than silicon carbide created using a traditional extrusion-based 3D printing technique (Figure 2).

They are most concerned with the process and results to determine properties and how the materials hold up under extreme conditions, she says.

"3D printing based on photopolymerization is a much higher resolution. Using photopolymerization is still pretty new. We want to know how you can take it from the lab and use in industry," she explains.

Her project is part of the master's thesis project of graduate student Anthony Brandl, whom Heffernan is assisting. Brandl is advised by Junjun Ding, professor of materials science and engineering. The research is being conducted as part of a partnership with the U.S. Army Research Laboratory, in which Alfred University received a $13.5 million five-year contract to research the forming and characterization of UHTCs.

Glass for solid-state electrochemical electrolytes

Wyatt Kiff from Sidney, New York, is a senior majoring in glass science engineering. His research, which is part of his senior thesis project, involved creating atomistic simulations to computationally analyze glass physics for applications in solid-state electrochemical electrolytes. Kiff, with Wilkinson as his advisor, worked on the project during his junior year and continued his research during the Summer Research Institute.

Recycling photovoltaic components

Beatrice Crespo from Tacoma Park, Maryland, is a sophomore majoring in glass science engineering as well as art and design. She researched the feasibility of recycling photovoltaic components in solar panels from both a technical and economic standpoint.

The recycling process, Crespo explains, involves delamination of the solar panels, which is required before the panels can be reused. Her project, under the advisement of Wilkinson and Gabrielle Gaustad, dean of the Inamori School of Engineering, investigated both thermal delamination—which uses heat to soften and remove the laminate—and chemical solvent delamination.

Ensuring a sustainable learning environment for students

The Summer Research Institute program provided more than just research opportunities—numerous professional development and socializing events took place as well.

"Research is difficult. You can't just put the student in the lab and say 'Go.' It's not sustainable; you have to have social activities," says Wilkinson, who hosted a group of undergraduates at his home to celebrate the Fourth of July.

Examples of non-research activities during the Summer Research Institute include field trips to plants and facilities, such as Guardian Glass and Owens-Illinois; a tour of the Corning Museum of Glass; and presentations given by faculty and administrators. Gaustad spoke about giving public talks while Scott Misture, Inamori Professor of Materials Science and Engineering, talked about the value of international travel and study abroad programs. The program culminated with a poster contest, where students presented their various research projects.

Feedback from the students confirmed the effectiveness of the Summer Research Institute.

"By summer's end, I will have written a paper, participated in a poster contest, and completed a research project, all before my sophomore year starts. That usually takes an entire undergraduate career," says Crespo, who studied the recycling of photovoltaic components. "This definitely gives me a leg up. I can't imagine a better experience to put me in a position to continue succeeding."

Gaustad hopes to see the program grow in future years to provide even more students the opportunity to pursue their research interests.

"The fields of ceramics, glass, and materials science are constantly changing how we interact with the world around us," she says. "It's my expectation that we'll see more students involved in this summer program in future years, pursuing research in topics that are not only important to them but to society as a whole."

This first Summer Research Institute was sponsored by the Center for Advanced Ceramic Technology (CACT) at Alfred University; the New York State Foundation for Science, Technology, and Innovation; Corning Inc.; Owens-Corning; and Washington Mills.

The Summer Research Institute will be offered again in summer 2024. It is open to all students at both Alfred and other institutions.

About the author

Mark Whitehouse is director of communications at Alfred University. Contact Whitehouse at whitehouse@alfred.edu. ■

Credit: Esther Dokyoung

Relief models based on images of Nok terracotta figures, created by inpatients with mood disorders at a Nigerian mental health facility.

Influence of ceramics on mood: Nok relief modeling exercise benefits Nigerian inpatients

By Esther Dokyoung

Ceramic-based arts are an effective tool for stimulating emotional development and self-reflection in people with mental disorders. A case study in Nigeria demonstrated its benefits through a relief modeling exercise held at three mental health facilities.

The global rise in people diagnosed with mental disorders has exposed the paucity of resources and strategies to treat these conditions.[1]

Mental disorders are clinically significant disturbances in an individual's cognition, emotional regulation, or behavior. Mood disorders, such as depression and bipolar disorder, are the most common type of mental disorder. People who suffer from mood disorders have a lower quality of life, reduced functioning, and significant levels of emotional and social distress.

While verbal communication plays a key role in many treatment strategies for mood disorders, the ability of arts-based activities to improve mental wellbeing is increasingly recognized by academics and health professionals.[2] Ceramic art specifically is an effective tool because, unlike the conventional art techniques of drawing and painting, clay-based art requires a person to touch the material with their hands. This unique sensory experience is more effective in terms of reducing depression levels, improving daily functioning, and maintaining holistic well-being.[3]

Considering these benefits—and the fact that clay is more affordable than other art materials—ceramics can serve as an accessible and effective treatment strategy for mood disorders in areas that lack access to cutting-edge treatments and technologies. For example, in Nigeria, communities have limited access to available and affordable mental health services.[4,5]

This article describes a study carried out at three mental health facilities in Jos, Nigeria. Inpatients at these facilities were given the opportunity to create relief models of Nok terracotta figures.

Nok terracotta: A window into ancient Nigerian art and culture

In 1928, archeologists uncovered unique terracotta figures in the southern Kaduna State of Nigeria. These figures, which are known for their distinctive human heads (Figure 1), belonged to a then-unknown culture now known as the Nok, in reference to the village where the figures were found.

Nok terracotta has since won appreciation on a global scale because it is the first known example of a West African culture to produce such art. Due to its importance within Nigeria's cultural history, Nok terracotta is perfectly positioned to serve as the basis for new ceramic-based art programs in Nigeria.

Nok relief modeling exercise

The Nok relief modeling exercise took place at Quintessential Healthcare Center, Jos University Teaching Hospital, and the Substance Abuse and Rehabilitation Center at Vom Christian Hospital. The study, which was carried out following approval from each facility's respective ethics committee, involved the participation of 31 male and nine female patients between the ages of 18 to 44, who were undergoing continuing care for diverse mood disorders. The exercise was offered as a recurring activity at each facility during several different periods between February 2020 and May 2021.

The first stage of the exercise involved teaching participants about the relief modeling process, which transforms images of Nok terracotta figures into relief models, or flat sculptures that project slightly from the background. The process begins by placing the images on gypsum plaster molds, where they are then traced with a pen, pencil, or dull anvil point onto the plaster. A reduction process etches away the excess plaster, leaving behind a mold to mass produce relief models from clay, which the participants can then paint.

During the learning stage, participants watched recorded and live demonstrations of the relief modeling process and handled some of the relief models. They then had the opportunity to perform the relief modeling process themselves, though not all took the opportunity. Upon conclusion of the study, participants were categorized into four groups based on their level of engagement with the exercise (Figure 2).

The Nok relief modeling exercise took place alongside other continuing care activities at the mental health facilities, such as music and sports. Participants also still received medication, pastoral counseling, and participated in a 12-step recovery program during the time of the study.

Influence of Nok relief modeling on mood

A written survey, face-to-face interviews, and analysis of participants' facial expressions and vocal tones were used to determine if the Nok relief modeling exercise helped participants experience a positive change in their moods.

Mood assessed from survey

Direct questioning of participants on their knowledge of Nok terracotta during the exercise indicated that 70% did not have any prior knowledge of Nok terracotta. Additionally, only one person reported having knowledge of relief modeling processes, which meant more than 95% of participants were learning about relief modeling for the first time.

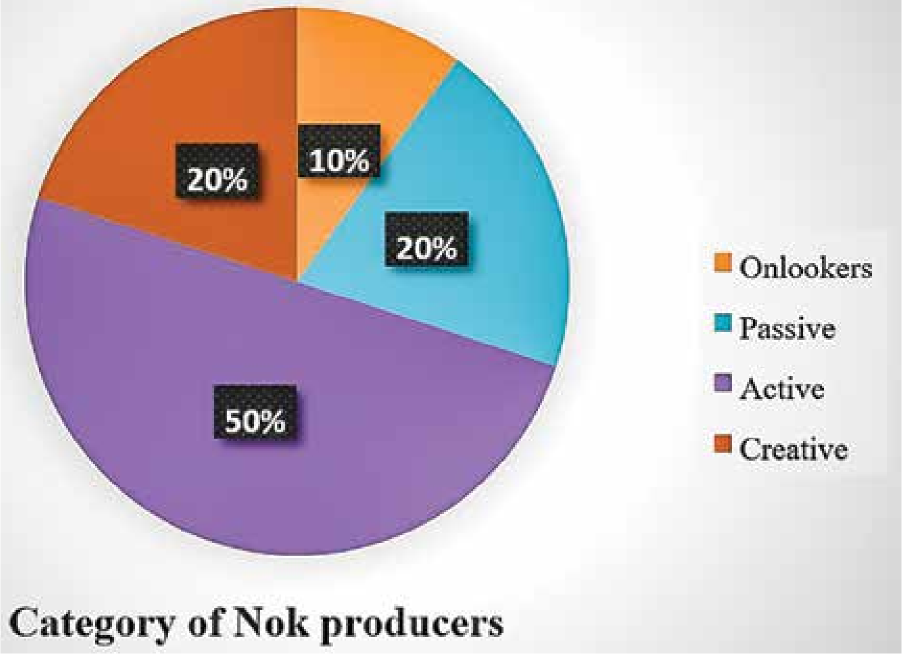
Participants initially found the Nok relief modeling exercise challenging, and 30% quit before the end of the study for this and other reasons. Those who attended at least four sessions, however, responded to the written survey (Table 1).

The participants reported that the exercise greatly increased their knowledge of Nok relief modeling, with 90% reporting "very influenced" or "extremely influenced" on Question 2.

Additionally, 90% of participants reported that the ability to produce a ceramic piece influenced their mood "very" or "extremely" positively on Question 4. This effect on the participant's self-efficacy was confirmed through a Pearson product moment correlation performed on the survey data.[6]

Credit: Sailko, Wikimedia (CC BY 3.0)

Figure 1. Example of a Nok terracotta figure, displayed in the Cleveland Museum of Art.



Credit: Esther Dokyoung

Figure 2. Breakdown of how participants engaged in the Nok terracotta relief modeling exercise. Onlookers were regular attendees in class but did not create relief models themselves. Passive producers did not initially make relief models but decided to try after watching others. Active producers eagerly participated in the making of relief models. Creative producers went beyond the basic models that were demonstrated during the learning stage.

The overwhelmingly positive reception to the exercise is likely due in part to the fact that all learning styles were accounted for during the exercise: visual and auditory learning through the recorded and live demonstrations, plus tactile exposure by making relief models themselves.

Mood expressed from the narratives

Participants expressed a positive view of themselves in conversations held during the Nok relief modeling exercise and afterward. Some said the exercise helped them to find "hope" and "self-worth" by being aware of their abilities, and many said they wished the study could continue after its conclusion.

On the other hand, some participants said the exercise required a time commitment that was challenging. For example, one participant said he missed his wife and wanted to return home, but he stayed to finish the exercise.

By week four of the study, some participants expressed boredom from only producing Nok relief models; they wanted other motifs to use as models. They were content to continue, though, after it was explained to them that only Nok terracotta figures could be used because of the study's experimental design. However, images of additional Nok terracotta figures were introduced as options for relief models.

Mood identified through facial expressions and vocal tones

Analysis of the facial expressions and vocal tones of participants in the Nok relief modeling exercise pointed toward the exercise having positive effects on participants' moods, with surprise, satisfaction, and anticipation being some of the expressions identified. Even some who appeared bored or tired during the learning stage were later seen producing a model and showing interest.

In the cases where a participant did not appear to be enjoying the exercise, it was typically caused by events outside the exercise and not due to the exercise itself. For example, some participants said they wanted to be discharged from the hospital and go home.

Color and creativity as expressions of mood

The color and creativity of the Nok relief models also served as an indicator of the participants' moods. For example, participants with bipolar disorder chose colors toward the brighter side, while participants with depression chose very dark colors, such as black-on-purple or plain dark brown. Strange color combinations that resulted from repeatedly layering several colors over each other suggested a state of mental confusion. These observations align with Friedmann's findings that the choice of color can reveal personality and mood.[7]

Conclusions

Results from the survey, interviews, and facial and tonal evaluations indicate the Nok relief modeling exercise had an overall positive influence on the participants' moods. These benefits were due not only to the materials used and the cultural significance of the figures, but also because the exercise took place within a supportive, communal environment. Thus, this study supports the notion that ceramic-based arts should be adopted more widely as a strategy for continuing care treatment of mood disorders.

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Table 1. Results from the mood survey. Percentages are based on a total of 40 responses.

Question	Slightly influenced	Moderately influenced	Influenced	Very influenced	Extremely influenced	Mean	Standard deviation
1. How influential was the relief modeling activity to your ability to perform ceramics task solely by observation?	0.0%	0.0%	17.5%	45%	27.5%	3.9	0.92
2. To what extent was the activity influential to your knowledge of Nok relief modeling?	0.0%	2.5%	7.5%	20%	70%	4.5	0.79
3. To what extent has your artistic skill been exposed or enhanced by working on this project?	0.0%	5%	15%	25%	55%	4.3	0.91
4. How did your ability to produce a ceramic piece influence your mood positively?	0.0%	5%	5%	42.5%	47.5%	4.3	0.79
5. To what extent did the learning activity increase feelings of negative mood, sadness, pain, or difficulty to perform task?	0.0%	62.5%	35%	2.5%	0%	1.4	0.54


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GLASSWeek 2023

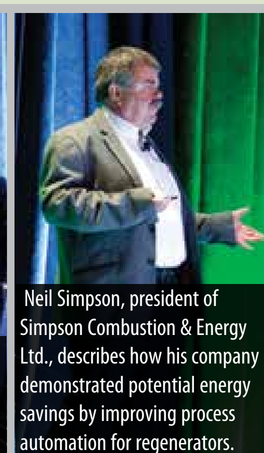
CONFERENCE ON GLASS PROBLEMS

All photos (Credit: ACerS)

Expanding possibilities in materials and processing at 84th Conference on Glass Problems

Opportunities for expanding possibilities in the glass manufacturing industry served as the unifying theme for talks presented at the 84th Conference on Glass Problems (GPC), which took place in Columbus, Ohio, from Nov. 6–8, 2023.

Jeff Smith, at the podium, expresses his gratitude for receiving the 2023 Glass Manufacturing Excellence Award while GMIC president Scott Cooper looks on.



Neil Simpson, president of Simpson Combustion & Energy Ltd., describes how his company demonstrated potential energy savings by improving process automation for regenerators.

GPC is the largest glass manufacturing conference in North America. It is co-organized by The Glass Manufacturing Industry Council (GMIC) in partnership with Alfred University. The annual conference aims to provide a platform for leading experts and manufacturers to share information on new innovations and methods to deal with challenges the industry faces with manufacturing glass.

This year, almost 400 attendees converged on the Greater Columbus Convention Center to participate in the conference. Student attendance was funded in part by a $15,000 donation from the Air Products Foundation given to GMIC and the Ceramic and Glass Industry Foundation.

The talks on Tuesday and Wednesday were arranged into several tracks that helped pinpoint critical areas throughout the glass production process that are especially ripe for innovation. While some of these areas were predictable, such as replacing fossils fuels with hydrogen during firing, others were surprising reminders not to take any aspect of the process for granted.

For instance, during the Combustion track on Tuesday morning, Neil Simpson of Simpson Combustion & Energy Ltd. described how his company demonstrated potential energy savings by improving process automation for regenerators. Traditionally, end-fired furnaces run on 20-minute reversals regardless of pull rates or glass type. His company instead used a simple control algorithm to modify reversal times based on these factors, allowing for extended firing periods and reduced off-cycles.

It will be the summation of small modifications such as these that ultimately lead to the necessary gains in efficiency, according to Xavier d'Hubert of XDH-energy. During his talk on Tuesday, he argued that focusing only on the maturation of carbon capture and storage technologies will not achieve the emission reductions that are required to ensure long-term sustainability of the industry.

The talks this year also benefited from including academic and government perspectives alongside the industry presentations. S. K. Sundaram and W. C. LaCourse, both of Alfred University, gave the first presentation of the conference, describing a potential multi-forehearth approach to glass manufacturing. Hope Wikoff of the National Renewable Energy Laboratory gave the last presentation of the conference, on the use of glass in the solar energy industry.

In addition to the talks, the 84th GPC provided an opportunity for GMIC executive director Kerry Ward to announce some exciting updates and initiatives taking place at GMIC, including a new website, new logo, and new strategic plan.

GMIC also launched a new awards program to celebrate both individual and organizational achievements in the glass industry. The first two recipients were recognized during the opening session on Tuesday morning: Jeff Smith, senior glass engineering technician at Johns Manville, received the 2023 Glass Manufacturing Excellence Award, while Rod Gravley, president of Precision Partners LLC, received the 2023 Certificate of Appreciation.

This year is Ward's first as GMIC executive director, and he says he was excited to manage his first GPC and GMIC/GlassTrend Symposium, which bookended the conference on Thursday.

Next year, GPC and GMIC/GlassTrend Symposium will move from its traditional home in Columbus to the so-called "Glass City" of Toledo, Ohio. It will also take place earlier than usual, in September 2024.

View more photos from GPC 2023 on ACerS Flickr page at https://bit.ly/84th-GPC. ■

UPCOMING DATES

HILTON PANAMA, PANAMA CITY, PANAMA

In 2022, the first PACC conference was held jointly with the Ferroelectric Meeting of Americas (FMAs) to facilitate interactions in and among the countries of the Americas and to provide an insight into the work being done in these countries for others around the world. The 2024 PACC will also be jointly held with the FMAs.

GOLDEN NUGGET LAS VEGAS HOTEL & CASINO, LAS VEGAS, NEV.

Join ACerS Glass & Optical Materials Division for a program featuring six symposia involving glass. The conference will provide an open forum for glass scientists and engineers from around the world to present and exchange findings on recent advances related to glass science and technology.

HOTEL BONAVENTURE, MONTREAL, QC, CANADA

The theme for the 10th International Congress on Ceramics will be “Enabling a better world through ceramic and glass materials.” Abstracts for this meeting are due Jan. 15, 2024.

HYATT REGENCY VANCOUVER, VANCOUVER, BRITISH COLUMBIA, CANADA

Join us in Vancouver, British Columbia, Canada, May 4–9, 2025, for the 16th Pacific Rim Conference on Ceramic and Glass Technology and the Glass & Optical Materials Division Meeting (GOMD 2025).

resources

Calendar of events

January 2024

28–Feb 2 48th International Conference and Expo on Advanced Ceramics and Composites (ICACC 2024) – Hilton Daytona Beach Oceanfront Resort, Daytona Beach, Fla; https://ceramics.org/icacc2024

February 2024

13–16 Electronic Materials and Applications (EMA 2024): Basic Science and Electronic Materials Meeting – Hilton City Center, Denver, Colo.; https://ceramics.org/ema2024

March 2024

13–14 XII European Congress of Refractory Raw Materials, Machinery & Installation – Meliá Lebreros, Seville, Spain; https://imformed.com/get-imformed/forums/xii-european-congress-on-refractory-raw-materials

26–28 59th Annual St. Louis Section/Refractory Ceramics Division Symposium on Refractories – Hilton St. Louis Airport Hotel, St. Louis, Mo.; https://ceramics.org/event/59th-annual-st-louis-section-refractory-ceramics-division-symposium-on-refractories

April 2024

7–11 Pan American Ceramics Congress and Ferroelectrics Meeting of Americas – Hilton Panama, Panama City, Panama; https://ceramics.org/PACCFMAs-2024

9–12 ceramitec 2024 – Munich, Germany; https://ceramitec.com/de/muenchen

10–12 ➡ Smart Additive Manufacturing, Design & Evaluation (Smart MADE 2024) – Osaka University Nakanoshima Center, Japan; https://sites.google.com/view/smart-made-2024

22–24 Mineral Recycling Forum 2024 – Hilton Imperial Hotel, Dubrovnik, Croatia; http://imformed.com/get-imformed/forums/mineral-recycling-forum-2024

30–May 1 ➡ Ceramics Expo 2024 – Suburban Collection Showplace, Novi, Mich.; https://ceramics.org/event/ceramics-expo-2024

May 2024

19–23 2024 Glass & Optical Materials Division Annual Meeting – Golden Nugget Las Vegas Hotel & Casino, Las Vegas, Nev.; https://ceramics.org/gomd2024

June 2024

16–19 ➡ The 5th International Symposium on New Frontier of Advanced Silicon-Based Ceramics and Composites (ISASC-2024) – Seogwipo KAL Hotel, Jeju, Korea; https://www.isasc2024.org

17–19 ACerS 2024 Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Sheraton Oklahoma City Downtown Hotel, Oklahoma City, Okla.; https://ceramics.org/clay2024

19–21 14th Advances in Cement-Based Materials – Missouri University of Science and Technology, Rolla, Mo.; https://ceramics.org/event/14th-advances-in-cement-based-materials

23–27 ➡ American Conference on Neutron Scattering (ACNS 2024) – Crowne Plaza Knoxville Downtown University, Knoxville, Tenn.; https://ceramics.org/event/american-conference-on-neutron-scattering-acns-2024

July 2024

14–18 International Congress on Ceramics – Hotel Bonaventure, Montreal, Canada; https://ceramics.org/ICC10

August 2024

18–22 ➡ 14th International Conference on Ceramic Materials and Components for Energy and Environmental Systems – Budapest Congress Center, Budapest, Hungary; https://akcongress.com/cmcee14

October 2024

6–10 ACerS 126th Annual Meeting with Materials Science and Technology 2024 – David L. Lawrence Convention Center, Pittsburgh, Pa.; https://ceramics.org/event/acers-126th-annual-meeting-with-materials-science-and-technology-2024

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.

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Niusha Heshmati
Guest columnist

Sustainable solvent engineering for perovskite solar cells—one step closer to commercialization

The need to reduce carbon emissions has catalyzed intensive research into novel photovoltaic technologies aimed at achieving high power conversion efficiencies (PCEs) at reduced manufacturing costs.

Perovskite solar cells have gained attention as a promising alternative to traditional silicon solar cells. They offer several advantages, including cost-effective fabrication, flexible and light weight panels, and a broader absorption spectrum. These properties allow them to be integrated into the built environment in various ways, including as windows, structural materials, and even clothing!

Perovskite solar cells have achieved impressive results on the laboratory scale, with PCEs of up to 26.1% for single-junction cells and 33.9% for tandem solar cells (TSCs) when combined with crystalline silicon.[1] However, challenges such as stability and material toxicity require ongoing research to enable scaling to industrial production and commercial implementation.

The current highest-performing perovskite solar cells rely on the dissolution of precursor materials, namely organic/inorganic cations and metal halides, in toxic solvents. A typical solvent system has a 4:1 vol.% ratio of N,N-dimethylformamide (DMF) to dimethyl sulfoxide (DMSO). DMF serves as the host solvent due to its excellent dissolving capabilities, while DMSO acts as a coordinating solvent owing to its strong coordination properties.

To induce nucleation and crystallization of the precursor materials in the DMF/DMSO solvent system, an antisolvent is added to the solution during the film deposition process. Chlorobenzene (CB), another toxic chemical, is commonly employed as an antisolvent due to its limited solubility with the precursor materials and its compatibility with both DMF and DMSO.

Despite the proven effectiveness of using these chemicals for perovskite film production, handling these chemicals in the quantities required for industrial use raises significant environmental and health concerns. For instance, to create a blade-coated perovskite module capable of producing 1 GW of solar power, it would take about 3,500 liters of solvent.[2]

Researchers have explored ecofriendly antisolvents such as ethyl acetate, anisole, and ethanol as replacements for CB. However, there is limited research on developing environmentally friendly primary solvents to replace hazardous DMF.

This scarcity of research is primarily due to the low solubility of perovskite precursors in common green solvents. Issues such as weak intermediate phases and poorly controlled nucleation processes are frequently encountered, which negatively impact the crystalline quality of perovskite thin films.

For optimal results, the ideal solvent should possess polar aprotic qualities with a high donor number, strong coordination abilities, and a low boiling point. Having a firm grasp of solvent parameters associated with polarity can prove to be a highly effective method for predicting whether a liquid can effectively serve as a suitable solvent for a particular solute.

Perovskite solar cells could be a key piece in the puzzle to realizing a sustainable energy future if several challenges, such as stability and material toxicity, are addressed.

Credit: Niusha Heshmati

For example, the employment of volatile solvents, such as ethanol or tetrahydrofuran, can reduce the necessary heating temperature for the crystallization process. But it may also result in uncontrolled nucleation and growth. Thus, fine-tuning of the solvent–antisolvent system becomes essential to ensure the successful formation of high-quality perovskite films.[3]

In my ongoing research, we are working to achieve three key objectives:

1. Developing a more stable perovskite composition that allows for film fabrication outside of controlled glovebox conditions.
2. Replacing toxic solvents with ecofriendly alternatives to minimize environmental impact.
3. Scaling up module production using blade coating techniques.

It is our hope that by 2030, perovskite solar cells will play a vital role in mitigating greenhouse gas emissions.

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Niusha Heshmati is a third-year Ph.D. candidate in materials and nanochemistry at the University of Cologne, Germany. Her research revolves around the synthesis, characterization, and performance enhancement of lead halide perovskite materials for solar cell applications. She has a profound appreciation for various forms of art, and she plays the violin as a hobby. ■

Center for Advanced Ceramic Technology

Happy New Year from Alfred University & CACT

It's been an eventful 2023 at Alfred University and the CACT. We were joined by new faculty including Dr. Myungkoo Kang and Dr. Benjamin Moulton in the Glass Science Department. We're excited to be adding three additional faculty to the Ceramics Department in 2024.

Federally funded projects in ultrahigh temperature materials, additive manufacturing of ceramics and glass, and sustainability are driving investments in new equipment and supporting undergraduate and graduate research.

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