AMERICAN CERAMIC SOCIETY

bulletin

emerging ceramics & glass technology

SEPTEMBER 2023

Propelling GaN electronics adoption:

An interview with QROMIS

New issue inside:

ACerS Awards of 2023 | 5G technologies and markets

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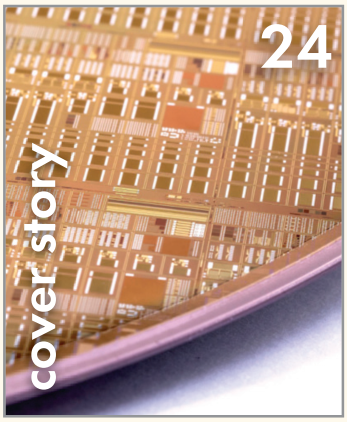

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Cover image

Closeup of a 200-mm 650 V, E-Mode GaN-on-QST monolithic power IC device wafer. Credit: QROMIS

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As seen on *Ceramic Tech Today*...

Credit: PxHere

Retiring the Kauzmann paradox—a call to focus future glass research elsewhere

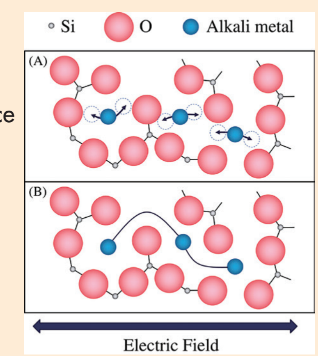
Initially proposed as a simple pondering by a U.S. chemist in the 1940s, the controversial Kauzmann paradox has inspired hundreds of follow-up papers in a variety of scientific disciplines. Now, researchers in the U.S. and Brazil led by ACerS Fellows Edgar D. Zanotto and John C. Mauro argue it may be best to focus future glass research elsewhere.

Read more at www.ceramics.org/Kauzmann

Also see our ACerS journals...

Sodium molybdate-hexagonal boron nitride composites enabled by cold sintering for microwave dielectric substrates
By J. Mena-Garcia, A. Ndayishimiye, Z. Fan, et al.
Journal of the American Ceramic Society

Dielectric response and polarization mechanism of alkali silicate glasses in gigahertz to terahertz frequency range
By K. Kanehara, S. Urata, S. Yasuhara, et al.
Journal of the American Ceramic Society



Trace additive enhances microwave dielectric performance significantly to facilitate 5G communications
By Z. Huang, L. Li, and J. Qiao
Journal of the American Ceramic Society

Enhanced high dielectric characteristics tri-layered structural ceramics for 5G/6G communications
By Z. Huang, J. Qiao, N. Sun, et al.
Journal of the American Ceramic Society

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ACSBA7, Vol. 102, No. 7, pp. 1–56. All feature articles are covered in Current Contents.

letter to the editor

Evidence-based sustainable development and circularity of materials

To the editor:

In a recent letter,[1] TU Darmstadt professor Jürgen Rödel stated, "Scientists need to move society onto a straight—but rocky and long—path to sustainability." We firmly resonate with his view.

Materials scientists design materials based on the requirements of the intended application. These materials may contribute to a more sustainable world—for example, when used to create clean energy technologies, such as fuel cells—but how often do we acknowledge, evaluate, and rationalize the environmental impacts (EIs) linked to producing a material? In the instances when it is addressed, it is often considered at a late developmental stage where, due to economic reasons, a process modification is unfeasible, regardless of the EI results.

Transitioning to a sustainable circular economy will inevitably require us to pay more attention to recycling. For example, the European Commission's Circular Economy Action Plan calls for products to be reusable, easier to recycle, and incorporate as much recycled materials as possible without affecting performance.[2]

However, recycling may not always be the most sustainable pathway to minimizing EIs because recycling is not entirely impact free. Consequently, the sustainability assessment of a specific recycling process needs to be quantifiably demonstrated.

Unfortunately, many reported recycling processes lack scientifically verified sustainability claims. Thus, without solid substantiation, these approaches are simply environmental marketing rather than enacting true sustainable change.

For these reasons, we strongly recommend integrating well-established scientific methods for environmental assessment, such as life cycle assessments (LCAs),[3] into early-stage material processes and recycling developments to favor evidence-driven sustainability. Doing so will have the following concrete benefits.

- Significant contributors or "hotspots" to the EIs of a material's process and recycling can be identified and addressed at a relatively early stage.
- Quantified environmental assessment data for the primary development of a material will be available and will allow for a direct comparison with the EIs of simultaneously developed recycling routes.

Our research group and collaborators have already started coupling LCAs with the development of new materials and recycling routes.[4–5] In a recent work,[5] we identified EI hotspots during the primary synthesis of a recently proposed and promising ceramic oxygen transport membrane material. To tackle one of the hotspots, a new recycling route was developed. Another LCA was performed on this recycling route, which allowed us to scientifically claim that the developed recycling route not only tackled the hotspot but reduced the EI in twelve out of fourteen categories.

However, as mentioned, recycling is not entirely impact free. Compared to the primary process, our recycling process consumes more energy and releases more process emissions. We are working to modify our methodology to resolve the remaining hotspots and report a process with the highest environmental performance.

Just as we cannot report functional advances in materials without supporting data, sustainability claims should only be made based on hard facts and unambiguous evidence. Our recommendation to perform a sustainability assessment during the early stages of materials/product development will help alleviate burden shifting and the need for difficult process modifications during later developmental stages. Additionally, higher technology readiness levels may be concomitant with complex resource flows—the Circular Footprint Formula offers valuable guidance in this area.[6]

By adopting these recommendations, we can move one step closer to attaining true sustainable development and recycling of materials.

Sincerely,

Rishabh Kundu,[a] Marc Widenmeyer,[a] Vanessa Zeller,[b] Emanuel Ionescu,[a, c] and Anke Weidenkaff[a,c]

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Direct correspondence to Marc Widenmeyer (marc.widenmeyer@mr.tu-darmstadt.de) and Rishabh Kundu (kundurishabh@gmail.com)

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[1]Rödel, J. "On sustainability … A grain of humility," *ACerS Bulletin* 2022, **101**(7): 3.

[2]"Circular economy action plan," European Commission, March 2020. Accessed 13 July 2023. Available at https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en.

[3]Klöpffer, W. and Grahl, B., 2014. *Life cycle assessment (LCA): a guide to best practice*. John Wiley & Sons.

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[5]Johanning, M., Widenmeyer, M., Cano, G.E., et al. "Recycling process development with integrated life cycle assessment: A case study on oxygen transport membrane material," Green Chemistry 2023, 25: 4735–4749.

[6]Zampori, L, and Pant, R. "Suggestions for updating the Product Environmental Footprint (PEF) method," Joint Research Center of the European Union, 2019. Accessed 13 July 2023. Available at https://eplca.jrc.ec.europa.eu/permalink/PEF_method.pdf. ■

news & trends

Proposed ban threatens budding agrivoltaic industry in the Netherlands

Despite the recorded benefits of agrivoltaics, or the practice of co-locating photovoltaic infrastructure and agriculture, an either/or mentality toward solar panels and crops remains a common perspective in governing bodies around the world. As such, numerous countries have proposed limitations or bans on solar deployments on agricultural land, which prevents the mutually beneficial practice of agrivoltaics from taking place.

Two recent media announcements out of the Netherlands reveal how this approach to solar regulation could severely hamper the country's budding agrivoltaic industry.

Raspberry orchard set to host one of Europe's largest agrivoltaic plants

On June 12, 2023, German renewable energy company BayWa r.e. and its Dutch subsidiary GroenLeven announced plans to construct an 8.7 MW agrivoltaic plant in the Netherlands.

The plant will consist of 24,206 solar panels installed on the Piet Albers raspberry farm in Babberich, which is owned by local farmer Maarten van Hoof. A 2020 pilot project on the same site set the background for this full-scale expansion. After successful results, van Hoof decided that BayWa r.e. should outfit his entire raspberry crops with solar panels.

When completed, BayWa r.e. says the plant will be Europe's biggest renewable energy project using photovoltaic modules above fruits. It will protect the raspberries from bad weather while also producing enough energy for more than 2,800 households.

Funding for the project came from government subsidies as well as van Hoof. BayWa r.e. expects to complete installation by the first quarter of 2024.

On a webpage describing the upcoming plant, BayWa r.e. notes that the company recently partnered with Wageningen University & Research (the Netherlands) to investigate the combination of agrivoltaics with other berry crops, including redcurrant, blueberries, blackberries, and strawberries.

Credit: BayWa r.e.

A pilot agrivoltaic plant installed by German renewable energy company BayWa r.e. on a raspberry farm in the Netherlands.

Dutch parliament considers banning solar parks on agricultural land

On July 6, 2023, Dutch Minister of Economic Affairs and Climate Policy Micky Adriaansens sent a letter (in Dutch) to the Dutch parliament proposing a nationwide ban on solar deployments on agricultural land.

The letter is not without precedent. In 2019, the Dutch parliament authorized initial soft restrictions for solar parks on agricultural land. These regulations stipulated that large-scale solar projects had to adhere to the informal "Zonneladder" preference scheme, which prioritizes solar rooftop locations over ground-mounted projects.

If this ban is implemented—which could be as soon as July 2024—local farmers will no longer have the authority to install agrivoltaic systems on their fields, similar to raspberry farmer van Hoof in the section above.

Dutch photovoltaic association Holland Solar released a response letter (in Dutch) on July 7 that stresses a nationally imposed ban does not work in the best interests of either farmers or net-zero targets.

Instead, the decision should be left to local authorities who "can properly assess the local situation, with national support for solar energy, protection of existing natural values on agricultural land, and frameworks for the nature-inclusive development of sustainable energy and for combinations of sun and agriculture," the translated letter states. ■

Perovskite solar cells charge ahead to record-breaking efficiencies

Oxford PV set a new world record for the efficiency of a commercial-sized perovskite tandem solar cell in May 2023.

Credit: Oxford PV

The market for solar energy is growing quickly, with installed power capacity exceeding 1,000 TWh in 2021. Though prices have dropped significantly in recent years, power conversion efficiency remains a limitation due to continued reliance on silicon, the traditional photovoltaic material.

The average power conversion efficiency for current silicon-based solar panels is about 22%. Though a record efficiency of 26.81% was achieved by Chinese photovoltaics company LONGi in November 2022, the maximum theoretical efficiency for silicon-only solar cells is just 29%.

To increase efficiency beyond 29%, other materials besides silicon will be needed. Perovskites, a class of materials with the same crystal structure as calcium titanate ($CaTiO_3$), are attracting attention because of their high light absorption efficiency and ease of fabrication. They also can be made from inexpensive raw materials.

In December 2020, researchers at Technical University Berlin demonstrated the power of perovskites when they overcame the silicon-only efficiency limit. They achieved a record 29.15% efficiency with a perovskite–silicon tandem solar cell.

The potential of perovskites, both in combination with silicon and alone, is gaining steam. Below is a snapshot of some of the biggest advancements in this field in recent months.

A year of records for perovskite–silicon tandem solar cells

In the past year, several groups have set new efficiency records for perovskite–silicon tandem solar cells.

In October 2022, a team of researchers from the Netherlands achieved 30% efficiency for the first time with a four-terminal device. Two months later, German researchers at Helmholtz-Zentrum Berlin achieved 32.5%, an efficiency that was officially confirmed by the European Solar Test Installation (ESTI) and the National Renewable Energy Laboratory.

In April 2023, scientists led by King Abdullah University of Science and Technology achieved 33.2% efficiency. They almost immediately surpassed this record in May with an ESTI-certified efficiency of 33.7%.

In June 2023, LONGi announced it had achieved a close second-highest efficiency with an ESTI-certified 33.5%.

In May 2023, Oxford PV, a spinoff company from Oxford University, announced it achieved a record 28.6% efficiency for a commercial-sized tandem solar cell. This record, which was independently certified by Fraunhofer ISE, is more than 1.5% above Oxford PV's previous record for a device produced on their world-first volume manufacturing line for perovskite-on-silicon tandem solar cells.

According to a *Reuters* article, Oxford PV plans to commercially launch a tandem solar cell later this year, with a predicted conversion efficiency of 27% and energy yield of 24%.

There still is much room for growth with perovskite–silicon tandem solar cells. According to that same *Reuters* article, the maximum theoretical efficiency for these cells is 43%.

Developments in all-perovskite solar cells

In addition to perovskite–silicon tandem solar cells, there is also research taking place on all-perovskite solar cells. These cells are expected to provide more flexibility, be lighter weight, and have a lower environmental impact than cells that rely on silicon wafers.

In December 2022, researchers led by East China Normal University reported an inverted perovskite solar cell with the highest efficiency (22.15%) and highest fill factor (83.92%) to date. Key to their success was using the molecule daminozide as an interlayer and additive, which passivated defects at the interface as well as in the perovskite bulk.

In May 2023, researchers at the University of Tabriz in Iran and Bilkent University in Turkey used numerical simulations to show how an inverted perovskite solar cell could achieve an efficiency of 24.83% efficiency (with fill factor of 79.4%) depending on the bilayer configuration.

In June 2023, Nanjing Tech University researchers nearly achieved such a high efficiency in real life by fabricating a perovskite solar cell with a unique "Mortise-Tenon" structure. Their cell, which was created via a joining method typically used in woodworking, demonstrated a 24.55% efficiency.

Just a few days later in June, a different study by Nanjing University researchers reported a record-high efficiency notably surpassing these other studies with a certified 28.0% efficiency (with fill factor of 82.6%.). The cells, which were based on a 3D/3D bilayer perovskite heterojunction, retained more than 90% of their initial performance after 600 hours of continuous operation under simulated one-sun illumination. ■

Caltech announces first-ever wireless power transfer of space-based solar energy back to Earth

Even as investment in clean energy technologies reaches new heights, the intermittent nature of solar and wind power remains a perennial challenge. The ability of atmospheric conditions to impede access to these energy sources means new storage technologies must be developed to store the energy when it is available.

What if there was a way to ensure predictable and constant access to these sources? Though the idea may sound like science fiction, space-based solar power systems could turn this possibility into reality.

The space-based solar power concept posits that high intensity, uninterrupted solar radiation can be collected in space using satellite-based solar panels. Because these panels would be outside Earth's atmosphere, they would not be affected by clouds or nighttime. The collected energy could then be transmitted back to Earth in the form of lasers or microwaves.

On June 1, 2023, researchers at the California Institute of Technology (Caltech) reported that their space-based solar power prototype, which launched into orbit in January 2023, demonstrated the ability to beam detectable power back to Earth for the first time.

The experiment is part of Caltech's ongoing Space Solar Power Project (SSPP). SSPP owes its existence to the generosity of philanthropist Donald Bren, chairman of Irvine Company and a lifetime member of the Caltech Board of Trustees.

Bren first learned about the potential for space-based solar power through a *Popular Science* magazine article. In 2011, he approached Caltech's then-president Jean-Lou Chameau to discuss the creation of a space-based solar power research project. In 2013, Bren and his wife, Brigitte, also a Caltech trustee, made the first of their donations—which now exceed $100 million—through the Donald Bren Foundation to fund the project.

The project also received financial support from Northrop Grumman, which provided Caltech $12.5 million between 2014–2017 through a sponsored research agreement.

The recent milestone experiment was achieved during testing of three key technologies on Caltech's ongoing Space Solar Power Demonstrator (SSPD) mission.

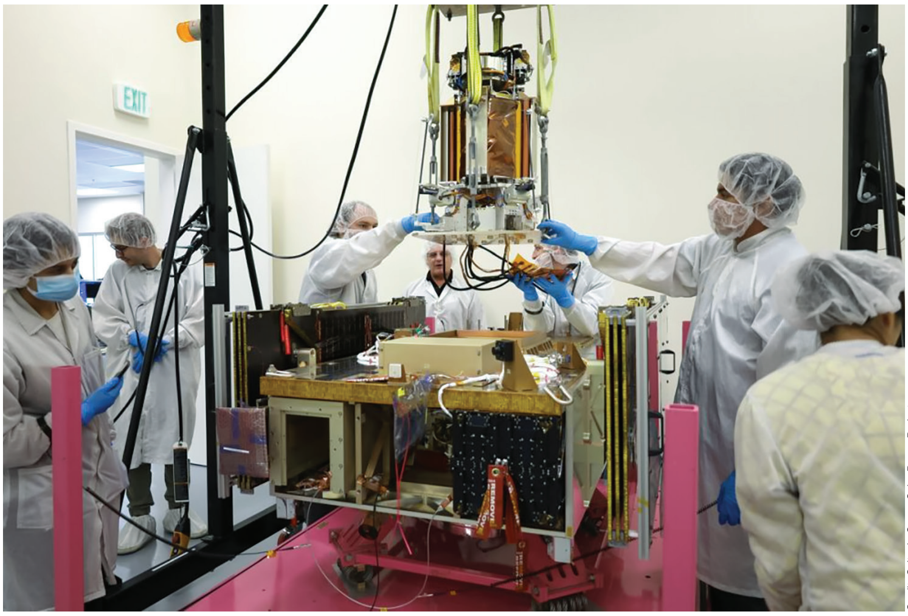
- **MAPLE** (Microwave Array for Power-transfer Low-orbit Experiment). This array of flexible lightweight microwave power transmitters is the device that successfully beamed energy back to Earth. It uses constructive and destructive interference between individual transmitters to shift the focus and direction of the energy it beams out—without any moving parts.
- **DOLCE** (Deployable on-Orbit ultraLight Composite Experiment). A structure measuring 6 feet by 6 feet that demonstrates the architecture, packaging scheme, and deployment mechanisms of the modular spacecraft,

which would eventually comprise a kilometer-scale constellation forming a power station.

- **Alba.** A collection of 32 different types of photovoltaic cells to enable an assessment of the types of cells that are the most effective in the punishing environment of space.

An additional fourth component of SSPD is a box of electronics that interfaces with the Momentus Vigoride spacecraft computer and controls the three experiments.

According to the Caltech press release on this mission, the Alba tests of solar cells are ongoing; the team has not yet attempted to deploy DOLCE. Results from these experiments are expected in the coming months. ■



Credit: Caltech, Space Solar Power Project

Engineers carefully lower the DOLCE portion of the Space Solar Power Demonstrator onto the Momentus Vigoride spacecraft before the mission's launch in January 2023.

Global markets for 5G technologies

By BCC Publishing Staff

The global market for 5G technologies was valued at $18.8 billion in 2021 and is anticipated to grow at a compound annual growth rate (CAGR) of 64.9% to reach $228.6 billion by 2026.

The journey to full scale implementation of 5G, which is expected to take at least 10 years, is fraught with challenges. Standards within each technology area of 5G are awaiting agreement, as well as technical feasibility demonstrated by mobile operators, software, and hardware suppliers. Nevertheless, the mobile industry is forging ahead with investments and marketing declarations.

5G will require changes in all aspects of the mobile network. For example,

- **New air interface standard**. The air interface will use a new standard called orthogonal frequency-division multiplexing (OFDM), which encodes data on multiple carrier frequencies. OFDM will allow 5G radios to operate at lower latency and provide greater flexibility by working with low frequencies as well as high frequencies.
- **Changes to site location and dimensions**. 5G standards call for less than 1 millisecond latency and 20-gigabits-per-second transmission speeds. To accomplish these standards, operators will locate 5G sites closer to the user while also reducing their dimensions.
- **Software-defined mobile core networks**. Software-defined networks promise increased cost savings and flexibility by replacing manual provisioning, controlling, and servicing of communications infrastructure with automation.
- **Enhanced network processors**. The complexity and performance demands of data traffic in 5G environments require high-performance network processors, particularly for forwarding functions and related services.

Table 1. Global market for 5G technologies, by application, through 2026 ($ millions)

Application	2021	2022	2026	CAGR% (2021–2026)
Automation	6,559.8	10,700.3	83,243.1	66.2
Smart surveillance	4,264.2	6,854.9	50,299.1	63.8
Connected vehicle	3,164.1	5,122.2	38,679.2	65.0
VR & AR	1,851.5	3,063.8	25,166.3	68.5
Enhanced video services	1,377.2	2,189.5	15,304.6	61.9
Others (e.g., entertainment, multimedia, satellite internet)	1,537.6	2,413.9	15,945.7	59.6
Total	18,754.5	30,344.6	228,638.0	64.9

- **New security schemes**. With 5G, there are more network elements and endpoints to be considered as well as more sites, so the attack footprint for security becomes larger. As such, new kinds of network security schemes are required.

According to the February 2022 report from the U.S. Patent and Trademark Office that focuses on each company's 5G-related patenting over the past decade, six companies are the most active in terms of essential 5G patenting: Huawei, LG, Qualcomm, Samsung, Ericsson, and Nokia.

From a spending perspective, Asia-Pacific is leading the global 5G market with advanced research and development dating back as much as 10 years. This trend is in harmony with traditional planning for technology innovation, particularly in China and Japan, where a 10-year planning cycle is the norm. In contrast, markets in the Middle East, Africa, and Latin America will likely be triggered by multinational mobile network operators and enterprises seeking to spread the technology to regional subsidiaries.

About the author

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

Resource

BCC Publishing Staff, "Global markets for 5G technologies" BCC Research Report IFT147B, May 2022. www.bccresearch.com. ■

Table 2. 5G communication network providers, by country

Country	Network providers
U.S.	AT&T Sprint T-Mobile Verizon
Canada	Rogers Wireless Bell Mobility, Telus Mobility Videotron
Mexico	Altan Redes AT&T/Unefon Movistar, Telcel
China	China Mobile China Telecom China Unicom
India	Reliance JIO Infocomm Ltd. Bharti Airtel Limited Bharat Sanchar Nigam Ltd. Vodafone Idea Ltd.
Germany	Deutsche Telekom Telefonica Vodafone
U.K.	EE 02 Vodafone Three
Spain	Telefonica Movistar Vodafone Orange Yoigo

SOCIETY DIVISION SECTION CHAPTER NEWS

Welcome new ACerS Corporate Partner

ACerS is pleased to welcome its newest Corporate Partner:

SK FINE

SK Fine Co.

To learn about the benefits of ACerS Corporate Partnership, contact Marcus Fish, industry relations director, at (614) 794-5894 or mfish@ceramics.org.

Bioceramics Division leaders help co-chair Indo-German Workshop

ACerS Bioceramics Division chair Bikramjit Basu (Indian Institute of Science, Bangalore) and Aldo R. Boccaccini (Friedrich-Alexander-Universität Erlangen-Nürnberg) helped co-chair an Indo-German Workshop (BIODENT) on "Design and manufacturing of biomaterials and implants for dental, cranio-maxillofacial reconstruction and bone regeneration" in February 2023. The workshop took place at the University of Erlangen-Nuremberg, Germany. Basu (front row, fourth from right) and Boccaccini (front row, third from right) are pictured with workshop attendees.

Attend your Division business meeting at MS&T23

Six ACerS Divisions will hold executive and general business meetings at ACerS Annual Meeting at MS&T23 in Columbus, Ohio. General business meetings will be held Monday or Tuesday in the Greater Columbus Convention Center. Plan to attend to get the latest updates and to share your ideas with Division officers.

Monday, Oct. 2

Glass & Optical Materials Division: 11 a.m.–12 p.m.
Electronics Division: Noon–1 p.m.
Engineering Ceramics Division: Noon–1 p.m.
Bioceramics Division: 2–2:30 p.m.
Energy Materials and Systems Division: 5:30–6:30 p.m.

Tuesday, Oct. 3

Basic Science Division: Noon–1 p.m.

FOR MORE INFORMATION:

ceramics.org

Volunteer spotlight

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

Jacob Jones is Kobe Steel Distinguished Professor of Materials Science and Engineering at North Carolina State University. He also serves as director of the Science and Technologies for Phosphorus Sustainability Center and director of the Research Triangle Nanotechnology Network. Since 2012, he has been a senior visiting fellow in the School of Materials Science and Engineering at the University of New South Wales in Sydney, Australia.

Jones received his B.S. and M.S. degrees in mechanical engineering from Purdue University in 1999 and 2001, respectively, and then a Ph.D. in materials engineering from Purdue in 2004. His research involves developing structure–property–processing relationships in emerging functional materials, including dielectric, ferroelectric, and functional nanomaterials, primarily using advanced X-ray and neutron scattering tools.

Jones has been a member of ACerS since 2002 and was elevated to ACerS Fellow in 2015. He participates in the Basic Science and Electronics Divisions, and he helped found and served as chair of the Carolinas Section from 2020 to early 2023. He is senior author on two manuscripts awarded the Edward C. Henry "Best Paper" awards from the Electronics Division.

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

IN MEMORIAM

Allen Apblett

Rolf Janssen

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

more SOCIETY DIVISION SECTION CHAPTER NEWS

ACerS@ECerS Get Together during ECerS biennial conference

ACerS members from the United States and Europe celebrated the U.S. 4th of July holiday at an "ACerS@ECerS Get Together" event during ECerS biennial conference in Lyon, France, July 2–6, 2023.

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.

Alexander Michaelis was honored with the Rieke Ring of the Deutsche Keramische Gesellschaft e. V. (German Ceramic Society) for his many years of commitment to the DKG. The award ceremony took place on March 29, 2023, at the 98th DKG Annual Conference in Jena, Germany. ■

Ceramic Tech Chat: Rita Baranwal

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 June 2023 episode of Ceramic Tech Chat, Rita Baranwal, senior vice president for energy systems at Westinghouse Electric Company, provides an overview of the nuclear power industry today, talks about the emerging focus on small modular reactors as well as full-size plants, and describes the new technologies that Westinghouse is developing to support the future of low-carbon energy.

Check out a preview from her episode, which features Baranwal talking about how important nuclear power generation is to today's energy portfolio.

> *"Nuclear power is very important to the energy portfolio of the United States. It is responsible for 50 percent of our country's carbon-free electricity. ... If we talk about how important nuclear power is in the world, there are over 430 operable reactors around the world. There are almost 60 reactors under construction worldwide. And all the operating reactors are the world's second-largest source of low-carbon power. And that's 26 percent of the total, using 2020 data."*

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

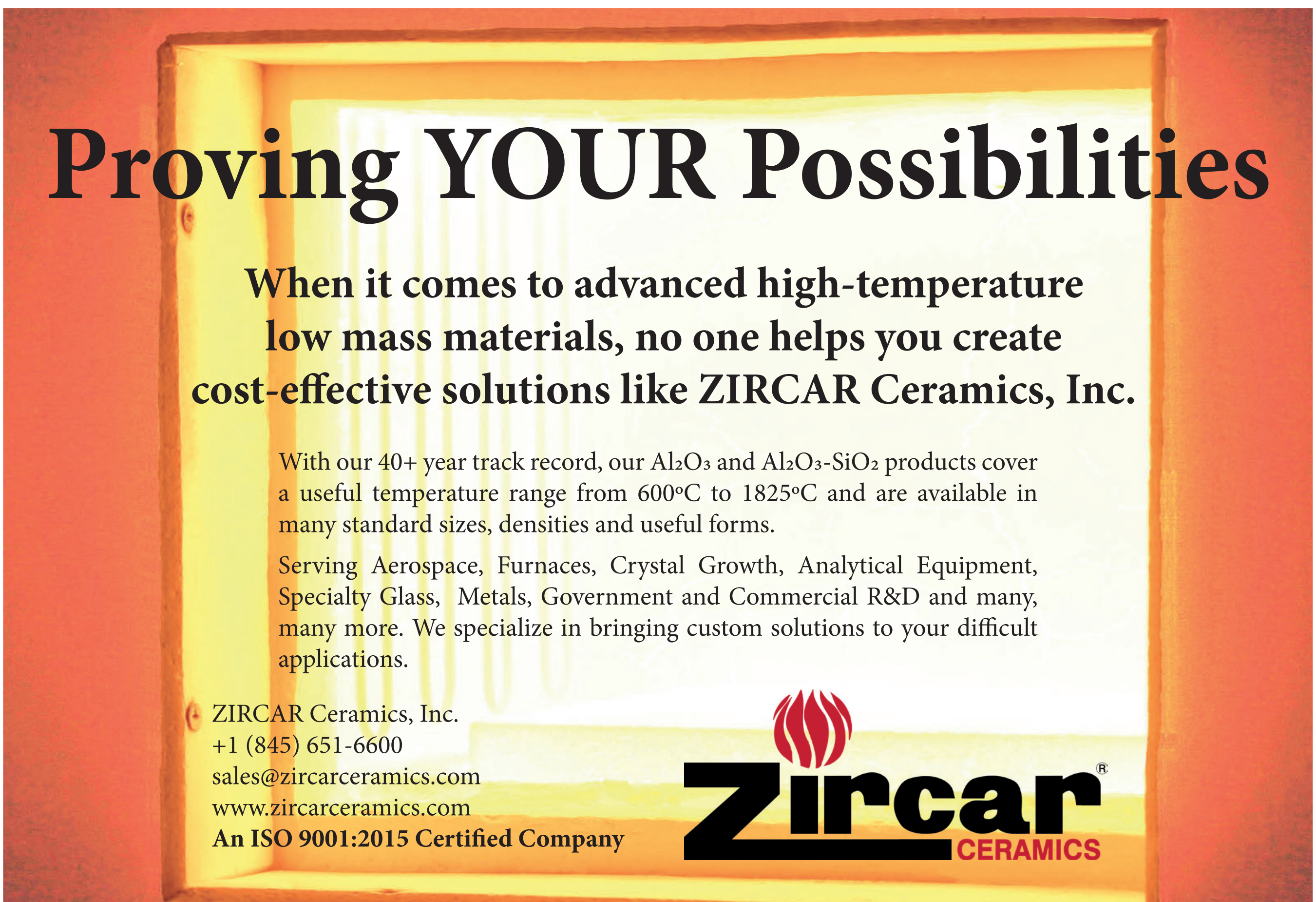
AWARDS AND DEADLINES

2024 Class of Fellows: Nominations deadline is Jan. 15, 2024

The ACerS Fellow designation recognizes members who have made outstanding contributions to the ceramic arts or sciences through productive scholarship or conspicuous achievement in the industry or by outstanding service to the Society. Nominees shall be persons of good reputation who have reached their 35th birthday and who have been members of the Society at least five years continuously. Questions may be directed to Erica Zimmerman at ezimmerman@ceramics.org. ■

Do you qualify for Emeritus membership?

If you will be 65 years old (or older) by **Dec. 31, 2023**, and will have 35 years of continuous membership in ACerS, you are eligible for Emeritus status. Note that both criteria must be met. Emeritus members enjoy waived membership dues and reduced meeting registration rates. To verify your eligibility, contact Erica Zimmerman at ezimmerman@ceramics.org. ■



STUDENTS AND OUTREACH

FOR MORE INFORMATION:

ceramics.org/resources-for-students

ACerS Ceramographic exhibit and competition

The Roland B. Snow Award is presented to the Best of Show winner of the 2023 Ceramographic Exhibit & Competition organized by the Basic Science Division.

This unique competition, held at ACerS Annual Meeting at MS&T, which this year takes place Oct. 1–4, 2023, in Columbus, Ohio, is an annual poster exhibit that promotes the use of microscopy and microanalysis in the scientific investigation of ceramic materials. Winning entries are featured on the back covers of *Journal of the American Ceramic Society*.

Poster entries are due **Sept. 30, 2023**. Learn more and apply at ceramics.org/awards/ceramographic-competition-and-roland-b-snow-award. ■

Ceramic Mug Drop Contest

The Ceramic Mug Drop contest at ACerS Annual Meeting at MS&T provides students the opportunity to demonstrate their prowess in designing and manufacturing a ceramic mug possessing high strength, mechanical reliability, and/or aesthetics. Mugs fabricated by students from ceramic raw materials are judged (separately) on aesthetics and then by dropping them from ever-increasing heights. The mug with the highest successful drop height will win. The Ceramic Mug Drop Contest is sponsored by Keramos. Visit www.matscitech.org/MST23 for more information. ■

Ceramic Disc Golf Contest

The Ceramic Disc Golf contest at MS&T always draws a crowd! Students create discs from ceramic or glass materials to meet certain specifications, and the discs are thrown into a regulation disc golf basket. Each disc will be judged in the categories of farthest distance achieved and aesthetics. The disc that is successfully thrown into the disc golf basket from the farthest distance in the fewest number of shots will be named winner of the Ceramic Disc Golf Contest, and the most aesthetically pleasing/creative disc will be recorded as "Best Looking" disc. The Ceramic Disc Golf Contest is sponsored by Keramos. Visit, www.matscitech.org/MST23 for more information. ■

Give GGRN a 'like' on Facebook!

Whether you are an ACerS Global Graduate Researcher Network (GGRN) member or not, we invite you to join us on Facebook at www.facebook.com/acersgrads to stay up to date with ACerS news, opportunities, competitions, career development tips & tricks, and more.

If you are not a current GGRN member but are a graduate student or working towards your Ph.D. and your work includes ceramics or glass, be sure to stop by www.ceramics.org/ggrn to join GGRN today. ■

GLOBAL GRADUATE RESEARCHER NETWORK
THE AMERICAN CERAMIC SOCIETY
CERAMICS.ORG/GGRN

CERAMICANDGLASSINDUSTRY FOUNDATION

Introducing 'Outreach in a Box': Bring materials science education into your local community

The Ceramic and Glass Industry Foundation (CGIF) is thrilled to announce the launch of its newest program, Outreach in a Box!

This initiative is designed to bring materials science education directly to your local community with the help of dedicated volunteers like you. With Outreach in a Box, CGIF provides resources and guidance for hosting engaging outreach events, conveniently packaged in one comprehensive toolkit.

WHAT IS IN THE TOOLKIT?

Each toolkit contains a wealth of valuable resources, including

• **Suggested planning timeline**. The CGIF has outlined a step-by-step timeline to help you organize and execute your outreach event. From initial preparations to post-event follow-ups, the timeline helps you sort through crucial details.

• **Approximate budgets**. The CGIF has included approximate budgets for each outreach event, giving you a clear idea of the financial requirements involved. These budgets are flexible and can be adjusted based on your specific circumstances.

• **Connection to materials science curriculum**. It is important to align outreach activities with educational goals. The CGIF included free lessons that connect to materials science curriculum, thus enhancing the learning experience and providing a strong foundation for students to explore the world of materials science.

• **Tips and tricks for hosting a successful event**. The toolkit is packed with valuable tips and tricks gathered from experienced event organizers. Whether it is managing logistics, engaging with attendees, or ensuring safety, these resources provide valuable insights to make your event a resounding success.

GET STARTED TODAY WITH GLOW!

The CGIF is excited to announce that its first Outreach in a Box toolkit, **GLOW: Glass Learning Opportunity Workshop**, is now available for free download at bit.ly/CGIF-GLOW.

GLOW introduces middle and high school students to a hot glass demonstration plus a career panel. The workshop's primary objective is to provide students an immersive experience where they not only witness the art of glass blowing but also learn the underlying science.

The career panel consists of local industry professionals from the ceramics and glass industry. These professionals share their personal journeys, experiences, and expertise with the students, offering valuable insights into potential career paths within this field. By connecting students with industry experts, GLOW aims to ignite their passion for the ceramics and glass industry, encouraging future exploration of educational and career opportunities.

The combination of hot glass demonstrations, scientific learning, and career exploration makes GLOW a comprehensive and enriching experience for students. It not only exposes them to the beauty and complexity of glass blowing, but it also broadens their horizons by showcasing the practical applications and exciting career prospects within the ceramics and glass industry.

Join us in bringing the excitement of materials science education to communities worldwide with Outreach in a Box. Download the toolkit, explore the possibilities, and get ready to make a lasting impact in your community by visiting https://foundation.ceramics.org/outreach-in-a-box. ■

Volunteers at CGIF's inaugural GLOW event, which took place during ACerS Annual Meeting at MS&T22 in Pittsburgh, Pa. From left: Alfred University graduate students Elizabeth Tsekrekas, Jacob Kaspryk, and Lucas Greiner; The Pennsylvania State University graduate student Nathan McIlwaine; and CGIF program manager Amanda Engen.

Unveiling the hidden role of intermediate oxides in glass

In a recent study, researchers from Brazil and China, led by ACerS Fellow Edgar D. Zanotto, senior professor at Federal University of São Carlos and director of the Center for Research, Technology, and Education in Vitreous Materials (CeRTEV), and Hellmut Eckert, professor at the University of São Paulo and vice-director of CeRTEV, looked to elucidate the structural role of niobium oxide (Nb_2O_5) in glass.

In glass science, oxides are considered to fulfill one of three roles within the atomic structure: network former, network modifier, or intermediate oxide. While the first two roles are rather self-explanatory, "intermediate oxide" describes oxides that

1. Do not form a glass by themselves under standard laboratory cooling methods unless combined with certain other non-glass formers, and
2. Easily vitrify in the presence of good glass-formers or other intermediates, where they contribute by forming bridging oxygens.

The effect that intermediate oxides have on glass formation and the resulting properties is often significant. So, understanding their structural role and their effect on glass properties is essential for developing effective material models.

Recently identified intermediate oxide Nb_2O_5 has garnered significant attention in various fields due to its impact on glass properties. It influences a glass's refractive index and nonlinear optical properties, making niobium-containing glasses desirable for electro-optical applications. Moreover, Nb_2O_5 shows promise in enhancing the mechanical properties of bioactive glasses while retaining their bioactivity.

Despite this knowledge about the macroscopic properties of niobium-containing glasses, the structural role of Nb_2O_5 remains elusive, primarily due to the limited amount of spectroscopic characterization data.

The authors of the recent study gathered data about the niobium-containing silicate glasses at CeRTEV using nuclear magnetic resonance (NMR) and Raman spectroscopy. They then used computational modeling—specifically comparative molecular dynamics and Monte Carlo simulations—to interpret the results.

Niobium-containing glasses exhibit enhanced optical properties, and so the glasses are being used in next-generation technologies like the smart windows above. However, there is still much to learn about the specific structural role of niobium oxide in glass.

Credit: CBMM, YouTube

The researchers drew several important conclusions about the structural role of Nb_2O_5 in silicate glasses. Specifically,

- The addition of niobium oxide to silicate glasses leads to a higher degree of polymerization of the siliceous network, which increases bond density and network connectivity. As a result, the glasses' thermal and chemical stability improves.
- A higher niobium content in the glass induces clustering of the niobium oxide component, which enhances the electronic polarizability of the glass. This effect has a key impact on the glasses' optical properties.

In the discussion section of the paper, the researchers highlighted the need for further experimental work to enhance the modeling of the NMR data.

Research News

Electrified cement could turn houses and roads into nearly limitless batteries

In recent years, several groups have made structural supercapacitors by spiking cement with highly conductive forms of carbon, such as graphene or carbon nanotubes. Although these perform well, the ingredients are expensive and hard to produce in the massive volumes used in the cement industry. Recently, in search of a cheaper alternative, Massachusetts Institute of Technology researchers mixed a small percent of carbon black with cement powder and added water. They then cut this wired cement into small plates, creating supercapacitors about the size of a button that lit up a series of LED lights. For more information, visit https://www.science.org. ■

Engineering team uses diamond microparticles to create high security anti-counterfeit labels

Researchers led by the University of Hong Kong, together with Sun Yat-sen University and Peking University, created diamond-based anti-counterfeiting labels. They made these labels by depositing artificial diamond microparticles of all different shapes and sizes on a silicon plate.

The diamonds form a unique pattern that scatters light in a unique way, and this "fingerprint" scattering can be scanned using a phone. Additionally, the diamonds have defects known as silicon-vacancy centers, which cause them to emit near-infrared photoluminescence when under green light. For more information, visit https://www.hku.hk/press/press-releases. ■

"Owing to the intrinsic nature of the glassy state, the NMR parameters are not uniquely defined by singular values as they are in crystals but are subject to distribution functions that greatly impact the NMR spectra," they explain.

Nevertheless, "Our strategy, combining NMR and Raman spectroscopy with computational modeling, holds promise for studying many other functional elements in many other glass types, including optical materials, bioactive glasses, and glassy fast ion conductors, containing suitable NMR-active nuclear probes," they explain in an email.

The paper, published in *Acta Materialia*, is "Structural impact of niobium oxide on lithium silicate glasses: Results from advanced interaction-selective solid-state nuclear magnetic resonance and Raman spectroscopy" (DOI: 10.1016/j.actamat.2023.119061). ■

Threading dislocation lines' effect on conductivity in gallium nitride versus indium nitride

Two researchers at the University of British Columbia recently detailed the striking contrast between the effects of threading dislocation lines on the electrical properties in gallium nitride versus indium nitride.

During fabrication, dislocations tend to form in group-III-nitride semiconductors, such as gallium nitride and indium nitride, because they are grown on substrates without a suitably matching lattice. This mismatch leads to high mechanical stress at the semiconductor–substrate interface, and the stress is accommodated by the formation of misfit dislocations in the semiconductor. These dislocations can trigger further defects called threading dislocation lines, which extend from the underlying substrate up through the grown crystal.

Gallium nitride and indium nitride have very different electronic band structures, with gallium nitride having a wide bandgap (~3.4 eV) and indium nitride having a small bandgap (~0.65 eV).

"Owing to this critical difference, threading dislocation line charge occupancy considerations are expected to be quite different for the two materials," the researchers write.

First 'ghost particle' image of Milky Way

From visible starlight to radio waves, the Milky Way galaxy has long been observed through the various frequencies of electromagnetic radiation it emits. Now, researchers have obtained the first-ever neutrino-based image of the Milky Way using the U.S. National Science Foundation-supported IceCube Neutrino Observatory in Antarctica. Drexel University physicist Naoko Kurahashi Neilson proposed the innovative computational analysis used to generate the image and received funding to pursue her idea through a grant from NSF's Faculty Early Career Development program. For more information, visit https://new.nsf.gov/news. ■

Various theoretical and experimental studies have confirmed this expectation. In gallium nitride, threading dislocation lines *trap* electrons, thereby reducing the free electron concentration. In indium nitride, threading dislocation lines *donate* electrons, thereby increasing the free electron concentration.

For *n*-type semiconductors, in which current travels mainly through the movement of electrons, the number of free electrons affects the semiconductor's conductivity. As such, understanding the implications of the two different charge mechanisms on a semiconductor's conductivity is an intriguing prospect to explore.

The researchers used two concentric cylinders to model the behavior of the threading dislocation lines: the inner cylinder represented the dislocation's core charge, while the outer cylinder represented the surrounding space charge layer.

To simplify the model, they assumed two things about their *n*-type and wurtzite structured semiconductors:

1. Each threading dislocation line introduces only one energy level into the energy band structure of the semiconductors.
2. Only one orbital within this single energy level governs the threading dislocation line occupation statistics.

Their simulations using this model showed that, for indium nitride, the concentration of free electrons does not really drop below 10^{16} cm^{-3} if there are threading dislocation lines present. In contrast, for gallium nitride, very low free electron concentrations can be achieved by tuning the density of threading dislocation lines.

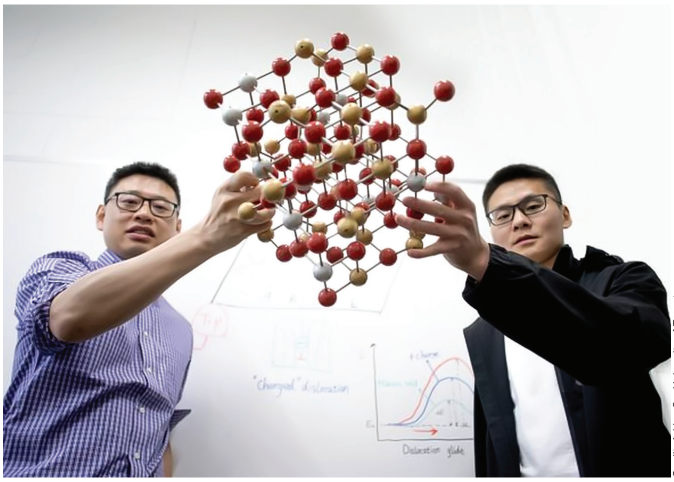
In other words, tuning the electrical conductivity is easier to do in gallium nitride than indium nitride. The "donating" nature of the indium nitride defects makes it difficult to reduce the free electron concentration if any threading dislocation lines are present. In contrast, careful growth parameters can help reduce the number of threading dislocation lines in gallium nitride, and thereby modulate the strength of the defect's "trapping" effect.

The paper, published in *Solid State Communications*, is "Threading dislocation lines within indium nitride versus gallium nitride: The implications of different dominant dislocation line charge screening mechanisms" (DOI: 10.1016/j.ssc.2022.114833). ■

Electric fields control motion of ceramic dislocations without need for mechanical loading

In a recent paper, an international group of researchers presented real-time observations of dislocation motion in a single-crystalline zinc sulfide that was controlled using only an external electric field.

Engineering dislocations into ceramics is a nascent method for unlocking versatile and unexpected functional and



Credit: Adrian So, University of Toronto

University of Toronto professor Yu Zou, left, and Ph.D. candidate Mingqiang Li hold an atomic structure model of a zinc sulfide crystal, which was used in their new study on controlling dislocation motion via electric fields.

mechanical properties in ceramics. Due to the brittleness of most ceramics, engineering dislocations into ceramics without crack formation is a challenge. Thus, to date, researchers have engineered dislocations in ceramics mainly through interface design, processing, and mechanical deformation. Among these approaches, mechanical deformation offers the best opportunity for aligning dislocations along specific slip planes.

While some studies have demonstrated that electric fields and light exposure can affect the motion of dislocations in ceramics, the principal driving force of motion in these cases was still mechanical stress. Proof that dislocation motion can be controlled solely by a nonmechanical stimulus remained elusive—until now.

The researchers of the recent study explained that recent advances in in-situ transmission electron microscopy (TEM) are what allowed them to observe the motion of dislocations in zinc sulfide. They used atomic-scale characterization of the dislocation cores and density functional theory calculations of the dislocation glide barriers to explain how the electric field caused the dislocations to move.

They also ruled out the possibility of other effects influencing the dislocation motion by pointing out some key parts in the in-situ TEM footage. Specifically,

- The observation of dislocations moving back and forth eliminates the **Joule heating mechanism** because "the thermal stress arising from Joule heating is independent of the direction of the applied electric field."
- The possibility that **electron wind force** plays a dominant role in the motion was ruled out because "the different types of dislocations move in opposite directions under the same voltage."
- Though **electron beam irradiation** is reported to possibly enhance dislocation mobility, in this study, "even when the electron beam is off, we still observe that the positions of the 30° dislocations are changed under an electric field."

A University of Toronto press release reports that the researchers plan to explore the possibility of using this technique to engineer dislocations in other types of crystals.

The paper, published in *Nature Materials*, is "Harnessing dislocation motion using an electric field" (DOI: 10.1038/s41563-023-01572-7). ■

High-throughput automated testing platform places dozens of samples on same substrate

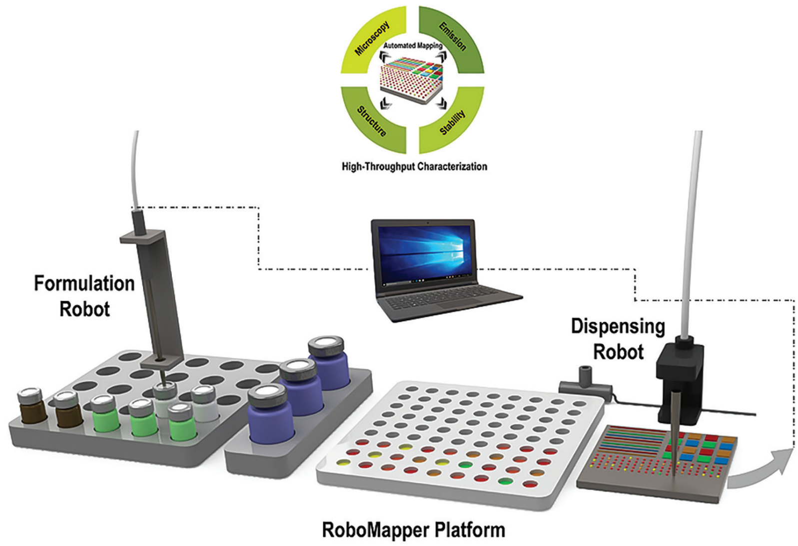
Researchers led by North Carolina State University developed a new multisample, high-throughput automated testing system called the RoboMapper.

Computer simulations have allowed promising material compositions and structures to be determined more quickly than testing every option through conventional trial-and-error experiments. Once promising materials are identified, however, conventional trial-and-error experiments are needed on the different compositions to verify the predictions. These tests can be repetitive and labor intensive, and thus limit the speed of the development process.

In recent years, researchers have started using advanced computing techniques and robotic systems to automate the experimental steps of the development process. To date, these efforts have relied largely on automating the existing assembly line structure, i.e., samples are sent one by one through the entire data collection process.

Advances in capillary printing and liquid handling means researchers can now design systems that robotically deposit multiple samples on a single substrate. This format allows data collection to take place on multiple materials in parallel, thus saving time and energy.

The new RoboMapper platform is a compact, benchtop system that consists of an ink formulation bot that works in tandem with a dispensing bot, which



Credit: Wang et al., *Matter*

Schematic of the RoboMapper platform that enabled automated ink formulation and microprinting of a wide variety of solution-processable materials from a library of precursors onto a common substrate. The materials array is then subjected to multimodal characterization and mapping using a wide range of laboratory- and synchrotron-based microprobes. Photo courtesy Aram Amassian.

allows microprinting and microcoating with volumes ranging from 0.6 pL to 0.5 nL. In contrast to other automated systems, the RoboMapper platform deposits samples using a gantry-based hollow capillary approach rather than spin-coating or drop-casting. This approach allows for the creation of smaller sample areas, which leads to lower costs.

To test the utility of the RoboMapper platform, the researchers used it to search for perovskite compositions that can best withstand degradation when exposed to sunlight.

With each composition taking about 8 minutes to make, they ultimately deposited 150 different metal halide perovskite samples on one substrate using the RoboMapper system. They then evaluated these samples using optical spectroscopy and X-ray structural assessments. Results from the RoboMapper process were validated using conventional testing techniques.

In the paper, the researchers describe the significant time, cost, and energy savings that came with using the RoboMapper platform instead of serial (one-by-one) automation or a manual approach, as well as the reduced environmental impact.

Time savings. Thanks to the reduced number of operational steps associated with sample loading, alignment, and calibration, it can take as little as 6 days for 500 compositions to be palletized and fully screened through the RoboMapper platform. In contrast, the same task requires at least 54 days via serial automation (9-fold increase) and upward of 84 days for a manual workflow based on full-time labor (14-fold increase).

Cost and energy savings. The researchers estimate that a sample dataset generated through the RoboMapper workflow will only cost \$0.34 and 0.344 kWh, in contrast to \$2.82 and 6.284 kWh for existing serial automation workflows and \$17.61 and 8.936 kWh for manual workflows.

Environmental impact. Due to the streamlined data collection that comes from the RoboMapper system placing dozens of samples on the same substrate, the researchers determined this approach has a significantly lower environmental impact than serial automation or a manual approach. They provide estimates for reduced waste generation and greenhouse gas emissions as examples.

In a press release, Aram Amassian, professor of materials science and engineering at North Carolina State University, says the group plans to use the RoboMapper platform to expedite research on other solution-processable materials, such as organic semiconductors, quantum dots, and nanoparticles.

"We're open to working with industry partners to identify new materials for photovoltaics or other applications. And with support from the Office of Naval Research, we are already using RoboMapper to advance our understanding of materials for both organic solar cells and printed electronics," he says.

The paper, published in *Matter*, is "Sustainable materials acceleration platform reveals stable and efficient wide-bandgap metal halide perovskite alloys" (DOI: 10.1016/j.matt.2023.06.040). ■

Molten salt electrochemical synthesis could improve sustainability of white phosphorus production

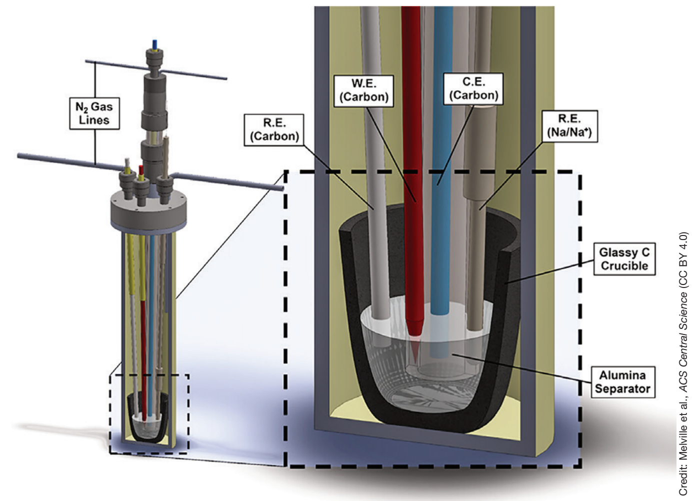
Massachusetts Institute of Technology researchers developed a molten salt synthesis process for white phosphorus production.

White phosphorus is a synthetic form of phosphorus that is produced by breaking phosphate-containing rocks down into the elementary form, which is then converted into phosphoric acid or other phosphorus compounds (a small amount is used directly as a reactant).

This roundabout reduction–reoxidation sequence to create phosphorus-based products is necessary to overcome the incredible stability of the phosphorus–oxygen bond in natural phosphate. This strong bond hinders the direct conversion of phosphate-containing rocks into valuable phosphites or phosphonates.

However, the conventional carbothermal reduction process for producing white phosphorus has a high carbon footprint. This process involves heating carbon coke and phosphate up to 1,500°C in an arc furnace to break the strong phosphorus–oxygen bonds. The reaction generates carbon dioxide as a major byproduct. It also produces a calcium metasilicate slag because the coke does not completely oxidize, which wastes about 30% of the energy input.

Molten salt electrochemical synthesis is one option being explored to lower carbon emissions. In this relatively low-temperature process, molten salts serve as the solvent and facilitate an enhanced reaction rate by increasing the mobility of reactants and the contact area between them.



Cutaway schematic of the MIT molten salt electrochemical cell. The system features separated anodic and cathodic chambers with independent nitrogen flow streams, a Na/Na+ electrode for use as a fixed-potential reference, and a cold trap for product characterization and quantification. W.E. = working electrode; R.E. = reference electrode; C.E. = counter electrode.

The new process developed by MIT researchers uses a dehydrated form of phosphoric acid, which contains long chains of phosphate salts held together by bonds called phosphoryl anhydrides. The phosphoryl anhydride bonds dramatically lower the fusion temperature of the salt melts, from 1,583°C for sodium orthophosphate (Na_3PO_4) to only 628°C for sodium metaphosphate, ($[NaPO_3]_n$).

Experiments on this molten salt system demonstrated its ability to achieve highly efficient and sustained production of white phosphorus. Specifically, they recorded a 95% Faradaic efficiency, which indicates the amount of collected product relative to the amount produced from the total charge transferred.

Other advantages of the system include

- **Reduction in carbon emissions**. The system reduced the overall carbon footprint of the synthesis process by about 50% compared to the conventional approach. Carbon emissions may be brought down to almost zero by using renewable energy to provide the required electricity.
- **Potential for on-site production**. The researchers predict that if they can scale up the process, it would allow industrial users to generate white phosphorus on site instead of having it shipped to them, which would cut down on the risks of transporting this explosive material.

The open-access paper, published in *ACS Central Science*, is "Electrolytic synthesis of white phosphorus is promoted in oxide-deficient molten salts" (DOI: 10.1021/acscentsci.2c01336). ■

New analytical protocol offers affordable purity analysis of silicon carbide

In an open-access paper, researchers in Italy and Norway developed a new analytical protocol to determine the purity of silicon carbide.

Currently, the most common approach for determining silicon carbide purity involves dissolving the sample and then analyzing it through inductively coupled plasma mass spectrometry or inductively coupled optical emission spectrometry. There are two drawbacks to this approach:

1. Silicon carbide is extremely inert, so dissolving it requires harsh conditions, such as microwave acid digestion or alkaline melting.
2. The dissolution of silicon carbide through these methods can lead to high background or blank signals.

Thus, determination of trace elements is difficult, with detection limits generally greater than mg/kg levels.

Analytical techniques that work directly on the sample without pretreatment are another option for trace element analysis. For example, glow discharge mass spectrometry (GD-MS) can yield highly sensitive measurements in the order of tens or hundreds of μg/kg. But this technique can be very costly, which inhibits its adoption in industry.

Laser ablation paired with inductively coupled plasma mass spectrometry (LA-ICP-MS) has been proposed as a simpler and more affordable direct analytical method. The instrumental cost of LA-ICP-MS is at least four times less than that of double-focusing GD-MS. Plus, it can provide reliable quantitative information down to mg/kg and sub-mg/kg levels.

To date, few studies have reported on the use of LA-ICP-MS to analyze silicon carbide purity. So, the researchers of the new study looked to develop an optimized protocol for using LA-ICP-MS in this way.

The first step was preparing the sample for analysis. For good quantitative analysis with laser ablation, a fundamental requirement is that the sample be as compact and planar as possible. This structure allows for the laser beam to hit perpendicularly, an angle which favors a better and more reproducible ablation of the material.

The researchers compacted silicon carbide powder using two different strategies:

1. The fabrication of binder-free silicon carbide tablets, as proposed by Zhou et al. (2013)
2. The embedding of silicon carbide powder in epoxy resin (newly developed strategy).

The first strategy, which involved finely grinding silicon carbide powder in an agate mortar, was not able to obtain a sufficient degree of compactness for LA-ICP-MS analysis. An additional thermal treatment was needed to induce partial sintering of the pressed powders.

Even then, analysis revealed that the process of grinding the silicon carbide in an agate mortar contaminated the sample, "a bulk contamination that cannot be lowered by preventive ablation cleanings," the researchers write.

This result led them to develop the second strategy mentioned above. In this case, both grains and fine powders of silicon carbide were embedded in epoxy resin. The samples were then cut, polished, and externally cleaned using hydrochloric acid 0.1 M.

Compared to the binder-free tablets, the embedded epoxy samples were highly compact and could be handled without special precautions. Additionally, during optimization of the laser ablation parameters, the researchers immediately observed the total absence of unwanted powder lifting, which ensured much more stable and less noisy signals.

Using GD-MS as a reference technique, the researchers optimized sample preparation and ablation protocols and ultimately achieved highly precise results with LA-ICP-MS for sub-ppm concentrations.

Next steps include further optimizing sample preparation and introducing a multipoint calibration technique, which would allow for more elements to be quantified.

The open-access paper, published in *Molecules*, is "Tackling the challenging determination of trace elements in ultrapure silicon carbide by LA-ICP-MS" (DOI: 10.3390/molecules28062845). ■

Propelling GaN electronics adoption: An interview with QROMIS

Closeup of a 200-mm 650 V, E-Mode GaN-on-QST monolithic power IC device wafer.

By Eileen De Guire

Cem Basceri, QROMIS president and CEO, displays a 200-mm-diameter 650 V, E-mode gallium nitride discrete power device wafer on a QROMIS Substrate Technology (QST®) substrate.

Silicon, a semiconductor material with a bandgap of 1.12 eV, has to date served as the backbone of the electronics industry.

However, as society comes to rely more and more on high-power electronic systems, the shortcomings of silicon become more apparent, leading researchers to investigate alternative semiconductor materials that could better serve the needs of today's power conversion systems.

Gallium nitride (GaN) is a wide bandgap semiconductor material with a bandgap of 3.4 eV. This wide bandgap gives GaN unique physical properties, including higher breakdown strength, faster switching speed, and lower on-resistance than silicon. These properties allow GaN-based devices to convert power far more efficiently than silicon-based devices, and thus enable smaller, faster, lighter, and low-cost power conversion systems.

Additionally, industry analysts have estimated that the CO_2 footprint of manufacturing and shipping GaN-based power devices is up to 10x less than for silicon-based semiconducting chips, and it can reduce the end-application footprint by up to 30%. In total, each GaN-based power device could save an estimated 4 kg of CO_2, and it is expected these savings will achieve a 2.6 Gton/yr reduction in CO_2 emissions by 2050.

For these reasons, the demand for GaN has grown considerably in recent years as companies work to develop next-generation, energy-efficient power electronics.

In 2009, Micron Technology, Inc. and the U.S. Naval Research Laboratory combined their fundamental materials and process technologies to develop a unique and scalable complementary metal-oxide semiconductor (CMOS) fabrication-friendly substrate technology, which was targeted at unlocking the full potential of GaN. In 2016, the thermally matched substrate technology, which was validated in Micron's memory fab, and its intellectual property were transferred to fabless technology innovator QROMIS, Inc. (Santa Clara, Calif.). QROMIS combined the substrate with its technologies and intellectual properties, which allowed the company to develop commercial products with its manufacturing partners.

Bulletin editor Eileen De Guire talked with Cem Basceri, co-founder, president, and CEO of QROMIS, about the current state of the GaN-based device market and the work that QROMIS is doing to solve the remaining challenges limiting widespread GaN adoption.

Q. *What are the current applications of GaN?*

A. GaN is most commonly encountered in the commercial marketplace through LED lighting. GaN-based LED lighting fixtures exhibit energy efficiency improvements of more than 85% compared to similar incandescent fixtures.

GaN is also used in power conversion applications, such as mobile chargers, consumer power supplies, data centers, solar inverters, and electric vehicle power. In these applications, GaN-based devices can help to reduce power losses by up to 10x. GaN is used in wireless communication applications as well, such as 5G and beyond. In these applications, GaN-based devices can help to improve the efficiency and range of wireless signals. This improvement is due to the ability of GaN-based devices to switch currents at much higher frequencies than silicon-based devices.

Finally, GaN is used in display technologies, such as microLEDs. MicroLEDs are a new type of display that is being developed to replace LCDs and OLEDs. GaN-based microLEDs can be used to create high-resolution displays with low power consumption.

Q. *Do you expect GaN to replace silicon, or will the future be a portfolio of semiconductor materials for engineers and designers to select from?*

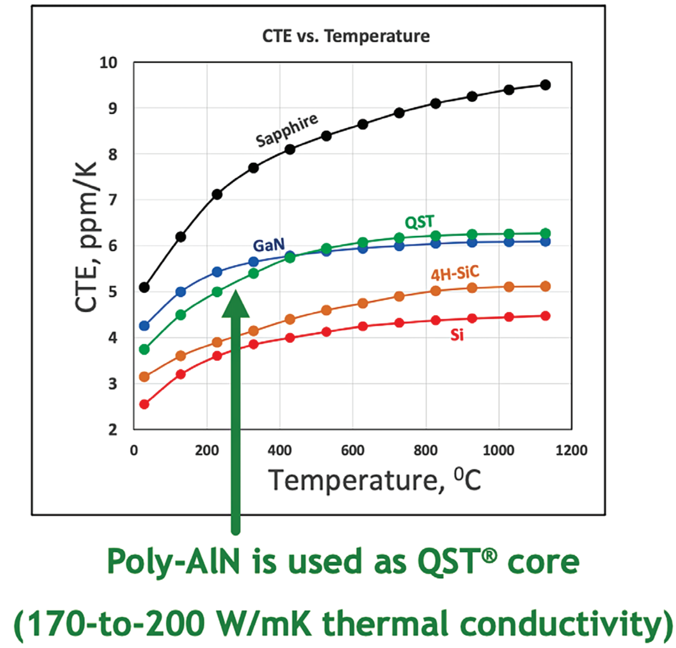
A. Compared to conventional silicon-based devices, GaN-based power devices have demonstrated higher switching frequencies and power densities, as well as greater power conversion efficiency with simplified topologies. Because of these benefits, consumer applications for GaN, such as power adapters, have already seen widespread adoption and are growing exponentially. Industrial applications, such as electric vehicles and power supplies for data centers and solar inverters, are expected to follow by 2030.

It is expected that both GaN- and silicon carbide (SiC)-based power devices will co-exist with silicon-based devices for a while; however, a complete switch over to these alternative semiconductor materials is expected in a few decades.

Q. *What challenges must be overcome to further expand the use of GaN in commercial applications? How is QROMIS approaching these challenges, and what progress has been made?*

A. There are no fundamental material barriers to scale-up and mass production of GaN. Instead, the main barrier to widespread GaN adoption is the lack of both a scalable and low-cost substrate technology for GaN electronics.

To date, commercial products containing GaN have relied on substrates with low performance and high mismatch in the thermal expansion (e.g., silicon, sapphire, silicon-on-insulator). To achieve widespread GaN adoption, it will require the development of a substrate with a more closely matched thermal expansion that is scalable, high-yielding, wafer breakage-free, CMOS compatible, and SEMI standard thickness. Such a substrate will enable economies of scale and a full spectrum of low-cost, reliable products, such as lateral and vertical power switches extending from 100 V to 1,800 V and beyond, in discreet and monolithic integrated circuit (IC) forms.



Credit: QROMIS

Coefficient of thermal expansion (CTE) versus temperature for GaN and different substrates.

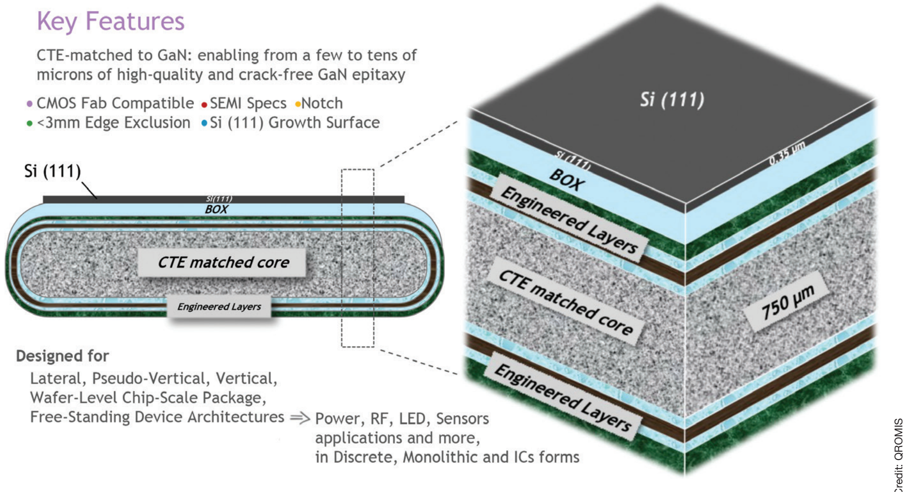
QROMIS' disruptive commercial solution—which enables high volume, wafer breakage-free, low cost, and scalable GaN power device manufacturing—is the CMOS fab-friendly and SEMI standard thickness engineered substrate called QST®. This substrate has a core based on polycrystalline aluminum nitride (AlN) with a thermal expansion that very closely matches the thermal expansion of the GaN/AlGaN epitaxial layers. This groundbreaking solution allows for GaN epi thickness scaling as well as enables a confident roadmap to 300-mm-diameter GaN production.

Proprietary engineered layers wrapped around the AlN ceramic core, followed by a buried oxide and thin top silicon (111) nucleation surface, result in a wafer that meets CMOS fab compatibility at standard SEMI specifications and with less than 3-mm edge exclusion.

The AlN ceramic core of the QST is also electrically insulating and compatible with the manufacture of radio frequency devices due to low absorption loss, unlike silicon. It has a thermal conductivity of 170–220 W/mK, which is higher than that of silicon.

These unique features enable not only mainstream lateral GaN power devices but also the long-awaited commercial and low-cost vertical GaN power switches and rectifiers suitable for high voltage aand high current applications presently dominated by limited-performance silicon insulated-gate bipolar transistors and high-cost SiC power field-effect transistors and diodes.

Currently, both QROMIS and its licensee Shin-Etsu Chemical Co., Ltd. (SEC) offer commercial 150-mm and 200-mm QST substrates and GaN-on-QST epitaxy wafers for worldwide GaN device manufacturers. 300-mm-diameter commercial products are targeted to be offered in the 2024–2025 timeframe.



The CMOS fab-friendly, SEMI Spec QST substrate structure.

Q. *In November 2022, Vanguard International Semiconductor (VIS) in Taiwan started mass production of the first 200-mm, 650 V GaN power chip using the QST substrate technology under license from QROMIS. How significant was this breakthrough? What would be the next scale-up milestone?*

A. VIS' 200-mm GaN-on-QST processing technology is remarkable for two reasons. One, it is the first time that a company has offered 200-mm GaN device foundry services on a scalable and CMOS fab friendly QST platform for all GaN industry players. Two, this breakthrough was achieved in only five years, from ground-zero in 2018 to the release of products in 2023. Most other GaN device manufacturers spent 10+ years to achieve commercialization with very limited performance on non-QST substrates.

In 2018, VIS adopted QROMIS' QST technology for a processing development of 0.35-μm 650 V GaN-on-QST on 200-mm substrates. The processing technology was completed in Q1 2022, and it successfully entered the mass production phase in Q4 2022. VIS simultaneously launched several collaborations with domestic and overseas integrated design manufacturing vendors and IC design companies.

VIS' 0.35-μm 650 V GaN-on-QST processing technology is compatible with the development and production of the company's existing 200-mm silicon wafer equipment, thus allowing it to achieve optimal production efficiency and product yield performance. Moreover, with the superior thermal property of QST substrates, GaN wafers produced by VIS achieve better overall heat dissipation performance for fast-charging solutions. In fact, based on the results of system verification at the customer end, products using the GaN wafers provided by VIS that address the fast-charging market for greater than 65 W have achieved world-leading performance.

In addition to the option of 650 V components, VIS' GaN-on-QST processing technology also offers customers with add-on and robust electrostatic discharge as a flexible design option. Not only does VIS GaN technology platform offer greater device reliability, but VIS also launched cooperation with multiple customers for development of scalable device technologies for higher voltage applications (greater than 1 kV) to satisfy their product needs.

Additional reading

J. Raynel Koch, "GaN wide bandgap semiconductor enabling 1200 V and beyond power switches, now commercially available for 200-mm large-scale manufacturing," U.S. Naval Research Laboratory. Published 7 June 2021. Accessed 24 July 2023. https://www.nrl.navy.mil/Media/News/Article/2648514/gan-wide-bandgap-semiconductor-enabling-1200v-and-beyond-power-switches-now-com

"VIS 0.35 μm 650 V GaN process enters mass production," VIS. Published 22 Nov. 2022. Accessed 24 July 2023. https://www.vis.com.tw/en/press_detail?itemid=18308 ■

QROMIS—Gallium nitride technology innovator

QROMIS, founded by Cem Basceri and Vladimir Odnoblyudov in 2015, is a privately held fabless technology innovator headquartered in Santa Clara, Calif. The company, with its global partners Micron Technology Inc., Vanguard International Semiconductor Corp. (VIS), Shin-Etsu Chemical Co., Ltd. (SEC), SPARX Group Co., Ltd, and Tokyo Electron Ltd. Venture Capital, is a premier player in the rapidly growing, multibillion dollar energy efficient GaN electronics industry. Its disruptive and patented engineered substrate technology innovation (more than 200 worldwide patents) enables an unmatched cost, performance, and application scale for GaN power electronics.

As a rapidly growing Silicon Valley-based fabless company, QROMIS is driving the commercialization of its groundbreaking and patented engineered substrate innovation by leveraging the manufacturing platforms of its worldwide industrial partners and customers through close collaborations, up and down the supply chain. Commercial QST® substrates are available from QROMIS and SEC in 150-mm and 200-mm diameters (300-mm diameter coming in 2024–2025) for 100 V to 1,800 V and beyond high-performance GaN discreet and wafer-level monolithic IC power devices. In parallel, VIS, as a pure-play foundry, offers 200-mm GaN-on-QST power device foundry services for all industry players.

GaN-based devices built on the new and disruptive QST substrate technology will dramatically reduce global energy use and consumption. Markets served include power electronics, light emitting diodes, advanced displays, and RF electronics, and other emerging high-performance and energy-efficient applications. ■

Honoring the ACerS

Over its long history, The American Ceramic Society has established a tradition of awards to recognize its members' outstanding contributions and accomplishments and to create career benchmarks for aspiring young scientists, engineers, and business leaders.

The most prestigious of ACerS awards is Distinguished Life Member designation, a recognition bestowed upon only two or three members each year. In 2023, two individuals will receive DLM honors: Edwin R. Fuller and Curtis A. Johnson.

The Society will elevate 20 members to Fellow and recognize many more outstanding members with various Society, Division, and Class awards during the ACerS Annual Honor and Awards Banquet Reception on Oct. 2, 2023.

2023 DISTINGUISHED LIFE MEMBERS

Edwin R. Fuller

Sometimes it takes looking back to realize your dream career was staring you in the face all along, even if you did not realize it at the time.

"I went to graduate school at the University of Illinois Urbana-Champaign, and I used to study a lot over in the ceramics library, which was across the street from the building where I was, the Physics Building. And so I would go over there to study because the library was so quiet. But I didn't think anything at all about ceramics. I would have never dreamt at that time that I would have ended up in ceramics; that it would be my home society," says Edwin "Ed" Fuller.

Fuller's path to materials research—and ceramics specifically—began after graduate school, when he joined the National Bureau of Standards, now the National Institute of Standards and Technology (NIST), as a National Research Council Postdoctoral Fellow. He initially planned to conduct research on traditional physics topics, in line with his education. But he became fascinated with the field of fracture mechanics after sharing an office with ACerS DLM Anthony "Tony" Evans.

Just into his second year as a postdoc, Fuller attended ACerS Annual Meeting to present his work with Evans on the fracture mechanics of ceramic and glass materials. That year, John B. Wachtman, Jr. gave the Sosman Award Lecture on the topic of fracture mechanics, which solidified Fuller's interest in the field.

With the advances of computers in the 1980s, Fuller became immersed in developing computer simulations to model micromechanical behavior of heterogeneous, stochastic microstructures. His seminal contributions to this field include leading development of the computer software program Object-Oriented Finite Elements, or OOF, which was one of the earliest computational tools developed to predict material behavior by inputting either experimental and/or fundamental data.

Fuller's research on simulations has been widely recognized. He is a recipient of the ACerS Ross Coffin Purdy Award (1987), the NIST Jacob Rabinow Applied Research Award (2000), and the Basic Science Division Robert B. Sosman Award (2004). In 1999, he along with along with S. A. Langer, W. C. Carter, and A. R. Roosen were awarded one of *Industry Week's* Technology of the Year awards for developing OOF.

In addition to his involvement with ACerS Basic Science Division, Fuller gained many friends in the Refractory and Cements Divisions when he conducted research in those areas during the 1970s energy crisis. In the 2010s, he became involved in the Art, Archaeology & Conservation Science Division as a result of previously inviting a Smithsonian researcher to join his processing group and use some of their equipment.

Besides his expansive engagement across multiple ACerS Divisions, Fuller also was involved in the Baltimore–Washington Section (now the Washington DC/Maryland/Northern Virginia Section), where he served in all leadership positions. Today he is active in the recently formed Carolinas Section. He also served ACerS as chair of various committees, on the Board of Directors (2007–2011), and as ACerS president (2009–2010).

Fuller says he is honored to be recognized as a DLM in a society that, over the course of his career, became a "natural home" full of supportive mentors who aided his growth as a young professional. He specifically wants to acknowledge the mentorship of Shelly Wiederhorn, also a DLM, who became a mentor, then a colleague, and then a friend.

"I wouldn't be where I am today without the mentors that I've had," he says.

Awards Class of 2023

Curtis A. Johnson

A small town about 10 miles outside of Johnstown, Pa., with a population of roughly 600 people may have the largest number of ceramic engineers per-capita in the United States. Certainly, the town can boast the largest number of ACerS Distinguished Life Members per capita with the elevation of Curtis A. Johnson, whose brother David is also a DLM. Johnson and his brother have the added distinction of being the Society's first sibling DLMs.

Johnson points to several factors that led him to his career in ceramic engineering.

"My father worked for Bethlehem Steel. It was a metals town. There were always metals and metallurgy around," he says. Additionally, "We grew up in a household that always challenged us to understand why things work."

Johnson found himself drawn to applied sciences more than the pure sciences, leading him to study metallurgy at The Pennsylvania State University, where he earned B.S. and Ph.D. degrees. His five-years-older brother David had studied ceramic science at Penn State, so metallurgy seemed like a good way to avoid "following his brother."

Fate had other plans. Just down the hall from the metallurgy program, Johnson got to know the students and professors working on ceramic engineering research projects. He came to the (natural) conclusion that "ceramics were more interesting than metals."

Johnson conducted his Ph.D. work under the guidance of DLM Richard Bradt on a project using metallurgical principles to understand creep in a ceramic material. He contemplated a career in academia, but he found himself drawn to a career in industrial research and its connection to products.

Upon completion of his Ph.D., Johnson joined General Electric's Corporate Research and Development Center (now called General Electric Global Research), where he rose through the technical ranks to the role of principal scientist, the highest position afforded a bench scientist at GE.

"What really attracted me to GE were opportunities for diverse problems to get involved with," he says.

Johnson is widely recognized for his contributions in the areas of mechanics of materials, thermal barrier coatings, and environmental barrier coatings, all of which have played a critical role in aerospace and land-based turbine engines. His understanding of mechanics coupled with his expertise in ceramics provided important insight into the failure of brittle materials. Today, all major jet engine aircraft manufacturers apply TBCs to their engine components, which allows engines to run at temperatures near 2,400°F.

"Ultimately, when these coatings fail or a CMC fails, there is a mechanical aspect to it. My involvement generally gets back to that core: What is the final threat that it's going to fracture, delaminate, or spall?" he says.

His work on the development and deployment of a CMC shroud in GE's LEAP engine was a fulfilling highlight of his career.

"Composites were thought of at the time of my Ph.D., but it seemed overwhelming to make something structural out of ceramics. It's been very satisfying to see it go from something that people said would never happen to where we've had 25 million hours—not passenger hours—but aircraft hours," he says.

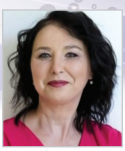
Johnson joined the Society as a graduate student, and he has found ACerS meetings to be invaluable sources of interaction, networking, and exchange of ideas. Being named a DLM was unexpected.

"It's overwhelming. I've been involved in a lot of ceramic things that are important to me, the company, and maybe to society. I was really, really surprised when I got the call," he says.

Of course, the most burning question is—do the Johnson brothers "talk shop" at Thanksgiving dinner? With a chuckle, Johnson admits, "We're allowed to talk about it on the side, but the rest of the table doesn't care!" ■

The 2023 Class of Fellows

Jake Amoroso is Fellow Engineer at Savannah River National Laboratory. Amoroso received a B.S. in glass engineering science and a Ph.D. in materials science and engineering from Alfred University. He has been an ACerS member since 2007 and is affiliated with the Energy Materials and Systems Division. He served as chair of the previous Nuclear and Environmental Technology Division and helped merge this Division into the newly formed EMSD. He has co-organized symposia at ICACC, PACRIM, MCARE, and MS&T, and he has served on the ACerS Book Publishing Committee for four years.



Katalin Balázsi is head of the Thin Film Physics Department at the Institute for Technical Physics and Materials Science in the Hungarian Academy of Sciences Center for Energy Research. Balázsi received a Ph.D. at Slovak University of Technology. She is a member of the Engineering Ceramics Division. She is a member of the John Jeppson Award Subcommittee (2019–2024) and has been a speaker, session chair, and co-organizer of some ACerS symposia. She received the Jubilee Global Diversity Award (2019) and was designated a Global Ambassador (2020).

Sung Choi is science and technology lead of materials engineering in the Naval Air Warfare Center-Aircraft Division at the Naval Air Systems Command. Choi received a B.E., M.S., and Ph.D. in mechanical engineering from Yonsei University (Republic of Korea), the University of Washington, and the University of Massachusetts-Amherst, respectively. He has been an ACerS member for 34 years and is affiliated with the Engineering Ceramics Division. He has served as session chair and invited speaker at numerous ACerS meetings, and he has served as a co-organizer of the International Symposium on Ceramic Matrix Composites at ACerS Annual Meeting for the past 15 years.

Keith DeCarlo is vice president of technology at Blasch Precision Ceramics. DeCarlo received a B.S., M.S., and Ph.D. in ceramic engineering from Alfred University and an M.B.A. from SUNY Albany Finance. He is a member of the Manufacturing Division and Western New York Section. He currently volunteers on the Publications Committee, the Corporate Environmental Achievement Award Subcommittee, and the Manufacturing Division Executive Committee in an advisory role.

Mari-Ann Einarsrud is professor of materials science and engineering at Norwegian University of Science and Technology. Einarsrud received a Ph.D. from Norwegian Institute of Technology. She is a member of the Basic Science and Energy Materials and Systems Divisions, and she has been an organizer of several ACerS symposia.

Manabu Fukushima is group leader in the Multi-Materials Research Institute at the National Institute of Advanced Industrial Science and Technology, Japan. Fukushima received a Ph.D. degree from Tokyo Institute of Technology. Fukushima is a member of the Engineering Ceramics Division. He has served as chair (2018–2019) and parliamentarian (2020–2023) of ECD, as member (2017–2019) and chair (2018–2019) of the Award Committee, as member of the Strategic Planning for Emerging Opportunities Committee (2019–22), as member of the Nominating Committee (2020–2023), and as associate editor for *International Journal of Applied Ceramic Technology* (2020–present).

R. Edwin García is professor of materials engineering at Purdue University. García received an undergraduate degree in physics from the Universidad Nacional Autónoma de México, and both an M.S. in materials science and Ph.D. in materials science and engineering from Massachusetts Institute of Technology. He has been an ACerS member since 2000 and is the current vice-chair of the Basic Science Division.

Venkatraman Gopalan is professor of materials science and engineering at The Pennsylvania State University. Gopalan received a bachelor's of technology from the Indian Institute of Technology and a Ph.D in materials science and engineering at Cornell University. He has been an ACerS member since 1995 and is a member of the Basic Science Division. He has organized or co-organized numerous ACerS meetings and has received the Robert R. Coble (2002) and Richard M. Fulrath (2009) awards.

Surojit Gupta is associate professor of mechanical engineering at the University of North Dakota. Gupta received a Ph.D. at Drexel University and received an MBA from the University of Massachusetts-Amherst. He has been an ACerS member since 2003. He has been active in numerous ACerS committees, including the Coble Awards Committee, ACerS Member Services Committee, Meetings Committee, Du Co Awards Committee, and Nominating Committee. He was chair of the Engineering Ceramics Division and was program chair for the ICACC conference.

Michael D. Hill works as a researcher on acoustic wave filters for Skyworks Solutions, focusing on materials selection and on developing new materials to support new acoustic filter products. Hill received a B.S. in materials engineering and an M.S. in materials science and engineering from Virginia Tech and a Ph.D. in materials science and engineering from the University of Maryland. Hill has been an ACerS member since 1990 and is a member of the Electronics and Art, Archaeology & Conservation Science Divisions. He is currently an associate editor for the ACerS–NIST Phase Equilibrium Diagram database.

The 2023 Class of Fellows (continued)

Dachamir Hotza is full professor in the Department of Chemical and Food Engineering and supervisor of the Laboratory of Ceramics Processing and the Laboratory for the Development of Nanostructures at Federal University of Santa Catarina, Brazil. Hotza received a bachelor's in chemical engineering and M.Sc. in mechanical engineering from Federal University of Santa Catarina and a Ph.D. in materials engineering from Hamburg University of Technology, Germany. He has been an ACerS member since 2002 and is affiliated with the Basic Science and Manufacturing Divisions. He is an associate editor of *International Journal of Ceramic Engineering & Science* and is a co-organizer of symposia at the Pan-American Ceramics Congress.

Stephen Houseman is president of Harrop Industries, Inc. Houseman received a B.S. in business administration from The Ohio State University. Houseman has been an ACerS member since 1991 and is affiliated with the Structural Clay Products and Manufacturing Divisions. He served as part of the executive leadership of the Central Ohio Section (1997–2002) and participated in the ACerS Environmental Achievement Award and Finance Committees for three years. Houseman served two terms as treasurer of both ACerS and CGIF from 2018–2022. He was also awarded an ACerS Global Ambassador Award in 2021.

Bryan Douglas Huey is professor and department head for materials science and engineering at the University of Connecticut. Huey received a B.S. in materials from Stanford University and an M.S. and Ph.D. in materials from the University of Pennsylvania. He is co-chair for PacRim 2025, chair of the Basic Science Division, and co-organizer for EMA.

Leena Hupa is professor of inorganic chemistry and leader of the High-Temperature Processes and Materials research group at Åbo Akademi University, Finland. She is a member of the Glass & Optical Materials and Bioceramics Divisions. She has been an organizer and presenter at several ACerS meetings, including GOMD and ICACC.

Jon Ihlefeld holds a dual appointment as professor of materials science and engineering and professor of electrical and computer engineering at the University of Virginia. Ihlefeld received a B.S. in materials engineering from Iowa State University and M.M.S.E. and Ph.D. from North Carolina State University. He is past chair of the Electronics Division and is a member of the Electronics, Basic Science, and Glass & Optical Materials Divisions. He has served as a general chair for the Electronic Materials and Applications meeting.

Pierre Lucas is professor of materials science and engineering and professor of optical engineering at the University of Arizona. Lucas received a B.S. in chemistry from the University of Rennes (France) and a Ph.D. in physical chemistry from Arizona State University. He is an associate editor for *Journal of American Ceramic Society* and previously served as GOMD chair (2017–2018). He has chaired two international conferences on glass and optical materials: the Joint ICG-GOMD conference at PACRIM in Vancouver, B.C., in 2009, and the GOMD conference at MS&T in Columbus, Ohio, in 2011.

Rodrigo Moreno is research professor at the Institute of Ceramics and Glass of the Spanish National Research Council. Moreno received a B.S. and Ph.D. in chemistry from the Autonomous University of Madrid, Spain. He has been an ACerS member from 1991–2004 and 2014–present. He previously was an associate editor of *Journal of the American Ceramic Society* (2009–2011).

Nathan Newman is president of Paramagnetix Inc. and Emeritus Professor in materials at Arizona State University. Newman received a B.S. in biomedical and electrical engineering from the University of Southern California and a M.S. and Ph.D. in electrical engineering from Stanford University. He has been an ACerS member since 2013. He has been presented many invited talks at the Electronic Materials and Applications meeting.

Ian M. Reaney is European site director for the U.S. National Science Foundation Center for Dielectrics and Piezoelectrics. Reaney received a Ph.D. from the University of Manchester, U.K. He is a member of the Electronics Division and has served as chair of the U.K. Chapter since 2021. He was awarded the Edward C. Henry Award for Best Paper in *JACerS* in 2002.

Hui (Claire) Xiong is professor in the Micron School of Materials Science and Engineering at Boise State University. Xiong received a B.E. in applied chemistry and M.S. in inorganic chemistry from East China University of Science and Technology and a Ph.D. in electroanalytical chemistry from the University of Pittsburgh. She is a member of the Electronics and Basic Science Divisions. She is past chair of the Electronics Division.

Visit https://ceramics.org/awards/society-fellows to learn more about the 2023 Fellows.

Society Awards

W. DAVID KINGERY AWARD recognizes distinguished lifelong achievements involving multidisciplinary and global contributions to ceramic technology, science, education, and art.

Vincent Harris is University Distinguished Professor and William Lincoln Smith Chair Professor at Northeastern University in Boston, Mass.

His research encompasses materials design and the study of processing, structure, and magnetism in a wide range of ceramic materials used principally in high-frequency devices, systems, and platforms.

JOHN JEPPSON AWARD recognizes distinguished scientific, technical, or engineering achievements.

Ruyan Guo, FACerS, is Robert E. Clarke Endowed Professor of Electrical Engineering at the University of Texas, San Antonio. Guo earned a B.S. and M.S. in electrical engineering from Xi'an Jiaotong University (China) and a Ph.D. in solid-state science from The Pennsylvania State University.

Guo specializes in interdisciplinary materials research and electronic device engineering. She served as chair of the ACerS Electronics Division (2002–2003) and was honored in 2020 with the Global Ambassador Award.

ROBERT L. COBLE AWARD FOR YOUNG SCHOLARS recognizes an outstanding scientist conducting research in academia, industry, or at a government-funded laboratory.

Mattia Biesuz is assistant professor of materials science and technology at the University of Trento, Italy. He received a Ph.D. there in materials, mechatronics, and systems engineering.

His interests embrace understanding the sintering process under nonconventional heating conditions and the nanostructure of polymer-derived ceramics.

ROSS COFFIN PURDY AWARD recognizes authors who made the most valuable contribution to ceramic technical literature in 2021.

The structure of sodium silicate glass from neutron diffraction and modeling of oxygen–oxygen correlations

Published in *Journal of the American Ceramic Society* 2021, **104**(12): 6155–6171.

Alex C. Hannon, Rutherford Appleton Laboratory, U.K.

Shuchi Vaishnav, Sheffield Hallam University, U.K.

Oliver L. G. Alderman, Rutherford Appleton Laboratory, U.K.

Paul A. Bingham, Sheffield Hallam University, U.K.

RICHARD AND PATRICIA SPRIGGS PHASE EQUILIBRIA AWARD honors authors who made the most valuable contribution to phase stability relationships in ceramic-based systems literature in 2022.

Phase equilibria of $MgO–Al_2O_3–TiO_2$ system at 1,600°C in air: Emphasis on pseudobrookite and spinel solid solution phases

Published in *Journal of the American Ceramic Society* 2022, **105**(11): 1–12.

Yuchao Qiu, Northeastern University, China

Junjie Shi, Northeastern University, China

Bin Yu, Panzhihua Steel Group Research Institute Co. LTD, China

Changle Hou, Northeastern University, China

Jingjing Dong, Northeastern University, China

Song Li, Liupanshui Normal University, China

Yumo Zhai, Northeastern University, China

Jianzhong Li, Northeastern University, China

Changsheng Liu, Northeastern University, China

THE AMERICAN CERAMIC SOCIETY

2023 ANNUAL HONORS AND AWARDS BANQUET

125 YEARS OF ADVANCING THE CERAMICS AND GLASS COMMUNITY

Join us to honor the Society's 2023 award winners at ACerS Annual Honors and Awards Banquet

Monday, Oct. 2 at MS&T23

6–6:30 p.m. Reception

6:30–9 p.m. Dinner and awards

9–11 p.m. ACerS 125th Anniversary Afterglow

Regency Ballroom,
Hyatt Regency

Please note: This year we are providing open seating.
You are free to select your table when the doors open at 6 p.m.

Purchase banquet tickets with your conference registration or contact Erica Zimmerman at ezimmerman@ceramics.org.

Tickets must be purchased by noon on Sept. 15, 2023.

Society Awards (continued)

MORGAN MEDAL AND GLOBAL DISTINGUISHED DOCTORAL AWARD recognizes a distinguished doctoral dissertation in the ceramics and glass discipline.

Mao-Hua Zhang is a postdoctoral researcher at The Pennsylvania State University. He received a bachelor's and master's degrees in materials science and engineering from Tsinghua University (China) and a Ph.D. in materials and geosciences from Technical University of Darmstadt (Germany).

His dissertation focused on the development of new lead-free antiferroelectric materials with reversible field-induced phase transitions and the exploration of the underlying mechanisms and potential applications. He succeeded in reversing the previously irreversible antiferroelectric–ferroelectric phase transition in $NaNbO_3$-based materials.

MEDAL FOR LEADERSHIP IN THE ADVANCEMENT OF CERAMIC TECHNOLOGY recognizes individuals who have made substantial contributions to the success of their organization and expanded the frontiers of the ceramics industry through leadership.

Jacques Rennotte is general manager of the Belgian Ceramic Research Centre in Mons, Belgium. He initially studied chemical engineering at the University of Liege and then pursued a Ph.D. in process engineering, focusing on the development of liquid–vapor equilibrium thermodynamic models for electrolyte solutions and process engineering.

He joined the Belgian Ceramic Research Centre to give a boost to industrial activities in the field of ceramics. Today he is involved in the deployment of ceramic technologies for the benefit of industry and its entrepreneurs.

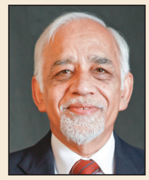
DU-CO CERAMICS YOUNG PROFESSIONAL AWARD recognizes a young professional member of ACerS who demonstrates exceptional leadership and service to ACerS.

Lisa M. Rueschhoff is materials research engineer in the Ceramics Branch of the Materials and Manufacturing Directorate at the Air Force Research Laboratory. She received a B.S. in materials engineering from Iowa State University and a Ph.D. in materials engineering from Purdue University.

Rueschhoff's current research focuses on advanced processing methods for high-temperature structural ceramics and composites as well as materials and structures development for morphing aerospace concepts.

RISHI RAJ MEDAL FOR INNOVATION AND COMMERCIALIZATION recognizes an individual whose innovation lies at the cusp of commercialization in a field related, at least in part, to ceramics and glass.

Raj N. Singh is Regents Professor at the Oklahoma State University and is the founding head of the School of Materials Science and Engineering. He obtained a Sc.D. degree in ceramics from Massachusetts Institute of Technology.



He is a world expert on ceramic matrix composites and has demonstrated an innate ability to invent new materials and novel processing methods. Singh's current research interests are in processing and properties of nanomaterials for quantum devices, fuel cells, batteries, supercapacitors, medicine, and smart systems.

NAVROTSKY AWARD FOR EXPERIMENTAL THERMODYNAMICS OF SOLIDS recognizes an author who made the most innovative contribution to experimental thermodynamics of solids technical literature during the two calendar years prior to selection.

Radiation damage and thermal annealing in tunnel structured hollandite materials

Published in *Acta Materialia* 2021, 206: 116598.

Kyle Brinkman is chair of the Department of Materials Science and Engineering at Clemson University. Brinkman received a B.S. in chemical engineering and an M.S. in materials science and engineering, both from Clemson. He graduated from the Swiss Federal Institute of Technology in Lausanne, Switzerland, with a Ph.D. in materials science and engineering.

KARL SCHWARTZWALDER–PROFESSIONAL ACHIEVEMENT IN CERAMIC ENGINEERING (PACE) AWARD honors the past president of the National Institute of Ceramic Engineers, focusing on public attention on outstanding achievements of young persons in ceramic engineering and illustrates opportunities available in the ceramic engineering profession.

Scott Cooper is technical director at Celsian Glass. Cooper received a B.S. in materials science from the University of Arizona and a Ph.D. from the University of Florida. A vocal advocate for the glass industry's transformation to a sustainable future, Cooper believes that a vibrant glass industry is vital to a well-functioning society. ■

ECerS-ACerS 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.

Francis J Cambier, retired, is an advisor to his successor at the Belgian Ceramic Research Centre. He received an M.Sc. and Ph.D. in industrial chemistry.

Cambier is a member of various scientific advisory boards, including serving on the JECS Trust. He also serves as a reviewer for several scientific journals. ■

Richard M. Fulrath Symposium and Awards

Promote technical and personal friendships between Japanese and American ceramic engineers and scientists.

Amjad S. Almansour, materials research engineer, Ceramic and Polymer Composites Branch, Materials and Structures Division, NASA John H. Glenn Research Center, USA

Sanshiro Aman, section manager, Materials Research Center, Technology HQ, TDK Corporation, Japan

Fuminori Mizuno, project general manager, Advanced Battery Development Division, Toyota Motor Corporation, Japan

Nicola Perry, associate professor of materials science and engineering, University of Illinois Urbana-Champaign, and affiliate of the Materials Research Laboratory, USA

Yukio Sato, professor, Research and Education Institute for Semiconductors and Informatics, Kumamoto University, Japan ■

Check matscitech.org for latest updates.

Corporate Environmental Achievement Award

The Corporate Environmental Achievement award recognizes a single outstanding environmental achievement made by an ACerS Corporate Partner in the field of ceramics.

RHI MAGNESITA

RHI Magnesita is a global leader in refractories headquartered in Vienna, Austria. The company has one of the world's most vertically integrated refractory supply chains, with its raw materials coming from its own mines.

The company's sustainability strategy is integral to and supports its overarching strategy. The topics identified by internal and external stakeholders to be most important to the company's sustainability mission are climate and energy, health and safety, diversity, recycling, and reducing NO_x and SO_x emissions. For each of these topics, RHI Magnesita has set targets and regularly reports progress toward achieving them. The company also sets targets for additional topics such as water usage, forest management, and supply chain sustainability, among others. ■

Class Awards

EPDC OUTSTANDING EDUCATOR AWARD

recognizes outstanding work and creativity in teaching, directing student research, or the general educational process.

Brian P. Gorman is professor in the George Ansell Department of Metallurgical and Materials Engineering at Colorado School of Mines. He completed B.S., M.S., and Ph.D. degrees in ceramic engineering from the University of Missouri-Rolla.

Over the past two decades, Gorman routinely taught undergraduate atomic structures and diffraction as well as particulate materials and ceramic forming. Most recently, he has focused on giving ceramic engineering students hands-on experiences with sintering and glass science that incorporate design of experiments.

EDUCATION & PROFESSIONAL DEVELOPMENT COUNCIL: GREAVES-WALKER LIFETIME SERVICE AWARD

The Greaves-Walker Lifetime Service Award is presented to an individual who has rendered outstanding service to the ceramic engineering profession and who, by life and career, has exemplified the aims, ideals and purpose of EPDC.

Kevin M. Fox retired as Fellow Engineer from the Savannah River National Laboratory in 2020, where he researched glass and ceramic materials for the safe disposition of nuclear waste. An ACerS Fellow and a past member of the ACerS Board of Directors, his service includes helping to develop and launch the Education and Professional Development Committee in 2017 and the Energy Materials and Systems Division in 2019.

ENERGY MATERIALS AND SYSTEMS DIVISION D.T. RANKIN AWARD, in memory of Tom Rankin, recognizes a member of the former Nuclear & Environmental Technology Division who has demonstrated exemplary service to the Division.

Jake Amoroso is principal engineer at Savannah River National Laboratory. He received a Ph.D. in materials science and engineering from New York State College of Ceramics at Alfred University. ■

ACerS Award Lectures

ACerS/EPDC ARTHUR L. FRIEDBERG CERAMIC ENGINEERING TUTORIAL AND LECTURE

Kathy Lu, FACerS, professor, Virginia Tech

Polymer derived ceramics—a new class of materials unrivaled by others

Lu's research focuses on polymer-derived ceramics and composites; materials degradation in harsh environments; materials synthesis, processing, characterization, and fundamental studies; and coatings for harsh environments and long-term uses.

EDWARD ORTON JR. MEMORIAL LECTURE

Sergei Kalinin, Weston Fulton Chair Professor, University of Tennessee, Knoxville

Microscopy is all you need: The rise of autonomous science

For the last 15 years, Kalinin's research has focused on the applications of machine learning and artificial intelligence in nanotechnology, direct electron beam atomic fabrication, and materials discovery via scanning transmission electron microscopy, as well as mesoscopic studies of electrochemical, ferroelectric, and transport phenomena via scanning probe microscopy.

ACerS FRONTIERS OF SCIENCE AND SOCIETY RUSTUM ROY LECTURE

Mrityunjay Singh, DLM, FACerS, chief scientist, Ohio Aerospace Institute

Strategically aligned additive manufacturing: Disruptor to global supply chains and enabler of sustainable societal development

Singh's research has addressed both basic and applied questions and has been instrumental in establishing design, integration, and performance limits for single and multimaterials used in a wide variety of aerospace and ground-based applications.

BASIC SCIENCE DIVISION ROBERT B. SOSMAN AWARD AND LECTURE

Elizabeth Dickey, FACerS, Teddy & Wilton Hawkins Distinguished Professor, Carnegie Mellon University

Defect disorder in electronic ceramics: Designing functionality

Dickey's research focuses on the application of electron microscopy and spectroscopy techniques to understanding the role of material defects on electrical and chemical transport in dielectric materials.

GLASS & OPTICAL MATERIALS DIVISION ALFRED R. COOPER AWARD SESSION

COOPER DISTINGUISHED LECTURE PRESENTATION

Lothar Wondraczek, chair, Glass Chemistry II, Otto Schott Institute of Materials and Research, Germany

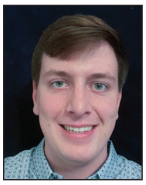
Glassy disorder and macroscopic properties

Wondraczek's research activities span all areas of experimental glass science with particular focus on the exploration and development of new glass and glass-ceramic compositions and surface modification techniques.

2023 ALFRED R. COOPER YOUNG SCHOLAR AWARD

Cooper Scholar:
John Bussey, Washington State University

Salt formation and detection in nuclear waste glasses

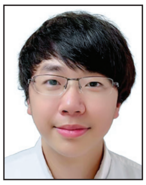


Cooper runner up:
Stuart Leland, Iowa State University

Developing a method to characterize the crystallization and viscosity behaviors of glassy solid-state electrolytes

Cooper runner up:
Vaibhav Bihani, Indian Institute of Technology Delhi, India

StriderNET: A graph reinforcement learning approach to optimize glassy structures on rough energy landscapes



Cooper runner up:
Yi Wei, Coe College, Iowa

Extending the glass formation of alkali tellurites

Check www.matscitech.org for latest updates.

UPCOMING DATES

OCT. 1–4, 2023
Register now!

ACerS 125TH ANNUAL MEETING with

Technical Meeting and Exhibition

MS&T23

MATERIALS SCIENCE & TECHNOLOGY

https://matscitech. org/MST23

Organizers: The American Ceramic Society, AIST Association for Iron & Steel Technology, TMS The Minerals, Metals & Materials Society

Co-sponsor: Society For Biomaterials

Co-locating with THE Advanced Materials SHOW USA

GREATER COLUMBUS CONVENTION CENTER, COLUMBUS, OHIO

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

JAN. 28–FEB. 2, 2024
Call for papers!

48TH INTERNATIONAL CONFERENCE AND EXPO ON ADVANCED CERAMICS AND COMPOSITES (ICACC2024)

ceramics.org/icacc2024

HILTON DAYTONA BEACH RESORT/OCEAN WALK VILLAGE, DAYTONA BEACH, FLA.

This conference has a strong history of being one of the best international meetings on advanced structural and functional ceramics, composites, and other emerging ceramic materials and technologies.

FEB. 13–16, 2024
Call for papers!

ELECTRONIC MATERIALS AND APPLICATIONS (EMA 2024)

ceramics.org/ema24

HILTON CITY CENTER, DENVER, COLO.

Jointly programmed by the Electronics Division and Basic Science Division, this conference is designed for those interested in electroceramic materials and their applications.

APRIL 7–11, 2024
Call for papers!

2024 PAN AMERICAN CERAMICS CONGRESS and FERROELECTRICS MEETING OF AMERICAS (PACC-FMAs)

PAN AMERICAN CERAMICS CONGRESS AND FERROELECTRICS MEETING OF AMERICAS (PACC-FMAS)

ceramics.org/PACCFMAs

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.

MAY 19–23, 2024
Save the date!

WELCOME TO Fabulous LAS VEGAS NEVADA

2024 GLASS & OPTICAL MATERIALS DIVISION ANNUAL MEETING

ceramics.org/gomd24

Calendar of events

September 2023

25–28 ➡ 12th International Conference on Microwave Materials and Applications – Mainz, Germany; https://converia.uni-mainz.de/frontend/index.php?folder_id=786&page_id=

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

October 2023

1–4 ACerS 125th Annual Meeting with Materials Science & Technology 2023 – Columbus Convention Center, Columbus, Ohio; https://matscitech.org/MST23

4–6 8th Ceramics Japan Expo Tokyo – Makuhari Messe, Chiba, Japan; https://www.ceramics-japan.jp/en-gb.html

November 2023

5–10 ➡ 15th Pacific Rim Conference on Ceramic and Glass Technology – Shenzhen World Exhibition & Convention Center, Shenzhen, China; https://ceramics.org/event/15th-pacific-rim-conference-on-ceramic-and-glass-technology

6–9 ➡ Glass Week 2023 (Conference on Glass Problems and GMIC Symposium) – Columbus Convention Center, Columbus, Ohio; glassproblemsconference.org

27–Dec. 1 SIPS 2023 (Sustainability through Science and Technology) – Hyatt Dreams Playa Bonita, Panama; https://www.flogen.org/sips2023/?p=186#toop

28–Dec. 1 ➡ International Conference on Ceramics and Geomaterials in Central Africa – University of Yaoundé, Yaoundé, Cameroon; https://www.cacers.org/?lang=en

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

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

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

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

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.

SEPTEMBER 2023 • VOLUME 4 • ISSUE 3

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www.ceramics.org/ceramicandglassmanufacturing

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INDUSTRY NEWS

LG ELECTRONICS GROWS ITS ADVANCED MATERIALS BUSINESS

LG Electronics' advanced materials business is now using an in-house developed antimicrobial glass powder and marine glass, which the company says will help grow its new advanced materials business. The company's antimicrobial glass powder is made at LG Smart Park in Changwon, Republic of Korea, which produces 4,500 tons of the material annually.


The antimicrobial glass powder was initially applied to LG ovens launched in North America in 2013.

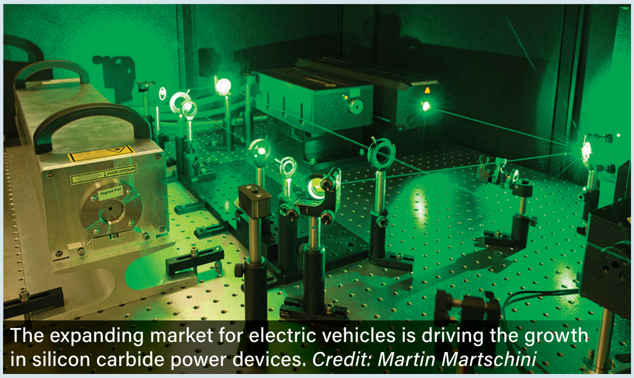

Manufacturing of Velocity Vials at SGD Pharma's facility in Vemula, India, is expected to begin in 2024.

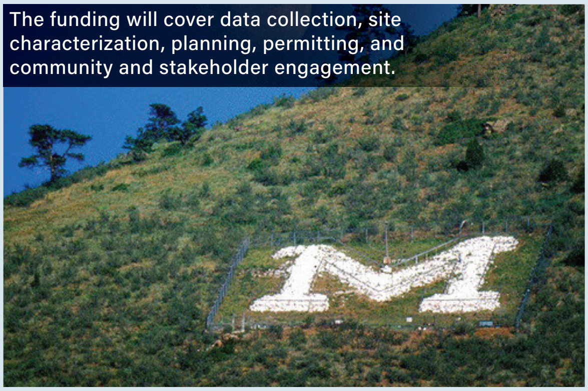
CORNING CREATES JOINT VENTURE IN INDIA

Corning and SGD Pharma announced a joint venture to open a glass tubing facility in Telangana, India, to expand access to Corning's Velocity Vial technology in India. The agreement combines SGD Pharma's vial-converting expertise with Corning's proprietary glass-coating technology. "The joint venture supports our continued global expansion as we localize manufacturing for our customers," says Ron Verkleeren, senior vice president and general manager of Corning's Life Sciences Market Access Platform.

COHERENT CORP. TO DEVELOP SIC DEVICES FOR MITSUBISHI ELECTRIC

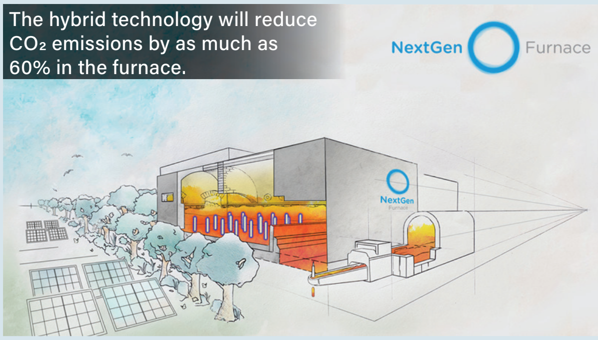
Pittsburgh-based Coherent Corp. signed a memorandum of understanding with Mitsubishi Electric to collaborate on a program to scale manufacturing of silicon carbide power electronics. Mitsubishi Electric announced an investment of 260 billion yen in the five-year period ending March 2026, with about 100 billion yen for the construction of a new plant for SiC power devices. Under the MOU, Coherent will develop a supply of 200-mm *n*-type 4H SiC substrates for Mitsubishi's future SiC power devices manufactured at the new facility.


The expanding market for electric vehicles is driving the growth in silicon carbide power devices. *Credit: Martin Martschini*


The funding will cover data collection, site characterization, planning, permitting, and community and stakeholder engagement.

MINES CARBON STORAGE PROJECT AWARDED DOE FUNDING

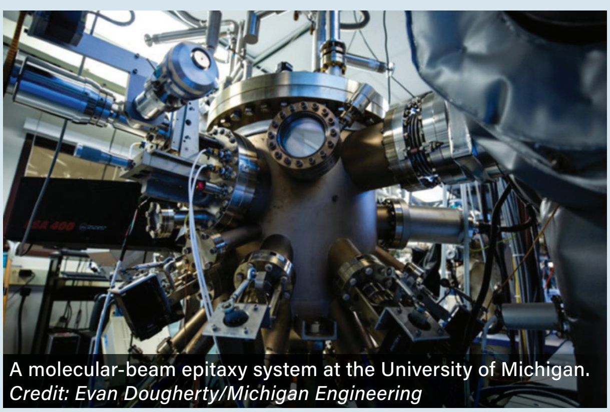
Colorado School of Mines, Carbon America, and Los Alamos National Laboratory were awarded $32.6 million from the U.S. Department of Energy's Carbon Storage Assurance Facility Enterprise initiative to advance the development of a carbon storage hub for the Pueblo, Colo., area. It was one of nine projects selected by DOE as part of a $242-million nationwide investment to accelerate the development of large-scale, commercial carbon storage projects with capacities to securely store carbon dioxide deep underground.



The hybrid technology will reduce CO_2 emissions by as much as 60% in the furnace.

ARDAGH GLASS BUILDS LARGE-SCALE HYBRID FURNACE

Ardagh Glass GmbH is constructing a hybrid furnace to enable a switch to renewable electricity at its glass production facility in Obernkirchen, Germany. The large-scale hybrid electric furnace will run predominantly on renewable electricity and a small amount of gas. It will use high levels of recycled glass cullet to produce up to 350 tonnes of glass bottles per day.


A molecular-beam epitaxy system at the University of Michigan. *Credit: Evan Dougherty/Michigan Engineering*

NSF INVESTS IN NINE MATERIALS RESEARCH CENTERS

The U.S. National Science Foundation will invest $162 million in nine Materials Research Science and Engineering Centers to transform scientific breakthroughs into benefits for multiple sectors of the U.S. economy. The centers are Illinois Materials Research Science and Engineering Center at the University of Illinois at Urbana-Champaign; Center for Dynamics and Control of Materials at the University of Texas; University of Washington Molecular Engineering Materials Center; Northwestern University Materials Research Science and Engineering Center; Laboratory for Research on the Structure of Matter at the University of Pennsylvania; Materials Research Laboratory at the University of California, Santa Barbara; Wisconsin Materials Research Science and Engineering Center at the University of Wisconsin; Center for Advanced Materials & Manufacturing at the University of Tennessee; and Center for Materials Innovations at the University of Michigan. Each center will receive $18 million over six years.

HYDRO AND SAINT-GOBAIN GLASS PARTNER TO DECARBONIZE BUILDING FACADES

Hydro Building Systems entered into an agreement with Saint-Gobain Glass to reduce the carbon footprint of building facades in half by integrating the low-carbon solutions offered by both companies. Hydro Building Systems uses a high percentage of recycled post-consumer scrap in its aluminum facades, while Saint-Gobain Glass produces low-carbon glass products using renewable electricity and recycled content.


Bruno Mauvernay, left, managing director of the glass facades unit at Saint-Gobain, and Henri Gomez, vice president at Hydro Building Systems.

RESEARCH PARTNERSHIP EXAMINES HYDROGEN FUEL FOR REFRACTORIES

The U.K.-based Materials Processing Institute announced a research partnership with Trent Refractories and Swedish industrial heating technology company Kanthal to examine the impact on industrial processes of using hydrogen as an alternative fuel source. The three-year agreement will focus on the effect of hydrogen on refractories and will also test a range of electrical elements for use in high-temperature applications in a hydrogen environment.


The research will examine the effect of hydrogen on heat-resistant materials that form the linings of furnaces, crucibles, kilns, and ladles.

CERAMIC MATRIX COMPOSITES: IS THE FUTURE HERE YET?

By David Holthaus

Ceramic matrix composite (CMC) technology has long held the promise of solving some of the most fundamental yet perplexing challenges in the materials industries.

CMCs are created by embedding coated fibers about the width of a human hair into a ceramic matrix. Coating the fibers alters the bond between fiber and matrix, permitting the material to be more durable. Cracks from the surrounding material do not propagate into the fibers, so the material holds together in service environments and avoids catastrophic failures.

CMC technology has been the subject of decades of research and testing at leading manufacturers, national laboratories, and universities. The sustained interest in CMCs stems from the fact they are typically one-third the density of metal alloys and one-third the weight. They are also more heat resistant than metals and can be very durable in extreme environments.

The decades of CMC research have led to application of the technology in aerospace, power generation, transportation, and defense—and subsequent gains in competitiveness, efficiency, and

GE's LEAP engine at the assembly plant in Durham, N.C. *Credit: GE Aerospace*

Global market for CMCs

The lighter weight, durability, and heat resistance of CMCs has made this technology a subject of investment, research, and application in the aerospace, automotive, and energy industries. Unsurprisingly, all this investment is causing the global market for CMCs to expand.

An informal survey of market forecasts showed global market growth of CMCs is estimated to range from a 9.6% consolidated annual growth rate to 11% over the next five to seven years. Estimates vary, but three market research firms forecast the global market will grow to at least $21.5 billion in five years.

Driving that growth will be increases in demand in the automotive sector, which is seeing a surge in demand for lightweight and electrified automobiles, and the aerospace sector, where the airlines and engine makers are searching for more powerful yet lighter weight engines and aircraft.

sustainability in these industries. But though CMC technology has been tested, adopted, and put into commercial use in many areas, the technology is still considered to be in an early stage of development. Promising research is underway that is expected to lead to broader application in a range of industries.

THE EARLY DAYS OF CMCS

Research into CMCs goes back at least three decades, but it was advanced in the early 1990s when the Department of Energy funded its Continuous Fiber Ceramic Composite (CFCC) program, which supported research and development that was going on at private corporations, including Dow Chemical, Dow Corning, DuPont, and GE. The program funded companies to make composites, which were then characterized at national labs and universities. The researchers were working toward a common goal of getting CMCs into industrial applications, including high-pressure heat exchangers, land-based turbines, heat-treating furnaces, and radiant burners.

The efforts at that time were coordinated and funded through Oak Ridge National Laboratory (ORNL), where researchers studied different fibers, coatings, and matrices, as well as how the materials degraded and performed, and cost-effective techniques for preparing them.

GE researchers have worked with CMCs since the ’70s. They initially studied the technology’s application in gas turbines, which then found its way into industrial power plants. Researchers at the industrial conglomerate then turned their attention to the company’s jet engine manufacturing and the possibility of using CMC technology in flight.

They were undeterred by a 2001 study done by the Institute of Defense Analyses for the Defense Advanced Research Projects Agency. The study assessed the potential use of CMCs in the development of military supersonic aircraft, which would require a lightweight, efficient engine that could operate at high pressure. The study, titled “Will pigs fly before ceramics do?,” ultimately concluded that “What is needed is a more radical, unconventional approach toward designing turbine engines that will take better advantage of ceramic materials properties … if the present mindset in technology development continues, there may be more pigs flying than ceramics in the future.”

Two decades later, GE has invested more than $1.5 billion in CMC research and development. The company’s CMC technology has found its way into the LEAP engine, the first widely deployed CMC-containing product. CMCs are used in the hottest section of the LEAP engine, which is made by CFM International, a joint venture between GE and Paris-based Safran Aircraft Engines.

CMC DEVELOPMENT AT GE: LEAPING INTO COMMERCIAL DEPLOYMENT

Jon Blank, an engineer and manager at GE Aerospace who has worked with CMCs for years, explained the technology’s evolution at the jet engine maker.

Components of the ceramic matrix composite turbine shroud in the LEAP engine. *Credit: GE Aerospace*

"We know temperatures are always going to go up, and engine pressures are going to go up," he says, describing the competitive drive to make more powerful yet efficient engines. "On the material side, we said we need the next-generation material."

Nickel-based superalloys were running out of the capability to achieve higher operating temperatures, he says.

"We needed that next step. And that's where ceramic matrix composites came in."

GE researchers began developing the material and testing it on a small scale. Fast forward to today, and ceramics are not only flying but have been successfully put into the field in one of the best-selling engines for single-aisle aircraft in the world.

The LEAP engine features a CMC turbine shroud, i.e., the component which directs airflow into the hottest part of the engine. The component is much lighter than its metal counterpart and can withstand hotter temperatures, increasing the potential for greater thrust and better efficiency.

"If you need more thrust, more power, this allows you to get that," Blank says. "It also is an environmental play, a sustainability play, because now you can change how you run the engine … you can change the amount of emissions that come off. It's a real game changer from a materials standpoint in our end product."

The LEAP engine has been embraced by the world's airlines. At the Paris Air Show in June 2023, GE announced orders for 70 LEAP-1A engines and for 80 LEAP-1B engines to power Boeing and Airbus aircraft.

Following the success of LEAP, GE has incorporated CMCs into its GE9X engine. This engine, which GE says is the largest and most powerful aircraft engine ever built, is designed to power the next-generation Boeing 777X aircraft. In contrast to the single CMC component in LEAP engine, the GE9x features five CMC components: two combustor liners, two nozzles, and one shroud.

"And the level of complexity of those components has gone up significantly," Blank says. They will help make that engine one-third the weight of conventional jet engine but twice as durable, and able to use 59% less cooling air.

In an engineering test in 2017 at GE's outdoor test facility outside Cincinnati, Ohio, the GE9X achieved 134,300 pounds of thrust, a world record.

CMCs have also been incorporated into GE's military engines, specifically its XA100 adaptive cycle engine, which has completed testing and is planned for the Air Force's F-35 combat aircraft. Its engineering innovations, including the use of CMCs, have contributed to a 10% increase in thrust and a 25% improvement in fuel efficiency.

CMCs are also a key part of the engineering behind the RISE program that GE initiated with its joint venture partner Safran. RISE, which stands for Revolutionary Innovation for Sustainable Engines, aims to reduce fuel consumption and carbon dioxide emissions by more than 20% compared with today's most efficient aircraft engines, a key to helping the aviation industry achieve a larger target: net-zero CO_2 emissions by 2050.

"So, we see a very bright future for CMCs," Blank says. "It's why we've invested now close to $2 billion in it."

In addition to leading the charge to commercialize CMCs, GE's research and investment led to its decade-long effort to establish an integrated CMC supply chain.

In 2017 in Huntsville, Ala., GE opened what it says is the first center to mass produce silicon carbide, the raw material used to manufacture CMCs. Two adjacent factories on 100 acres produce silicon carbide ceramic fiber, the material used to make the unidirectional CMC tape produced in the neighboring factory. The tape, which is used to fabricate CMC components, is then shipped to Asheville, N.C., where another plant condenses it, machines it, and then ships the final part to engine assembly shops in Durham, N.C., or Lafayette, Ind.

Control over the supply chain allows the company to focus on boosting production rates, refining manufacturing processes, and lowering costs, GE says.


Researchers working with CMCs at GE's complex in Evendale, Ohio. *Credit: GE Aerospace*

CMC DEVELOPMENT THROUGHOUT THE AEROSPACE INDUSTRY

GE's competitors in the aircraft engine space are also investing in CMC technology research and development.

In 2013, Rolls-Royce purchased Hyper-Therm High-Temperature Composites, a privately held company based in Huntington Beach, Calif. Then in 2016, it announced a $30 million expansion and new facility in southern California as its CMC technology hub.

"The development of lighter, stronger, composite fiber components is just part of our commitment to continuously improve the performance of our products by focusing on lowering fuel consumption, emissions, and noise," former CEO Marion Blakey said at the time.

Tubes made of nuclear-grade continuous silicon carbide, fiber-reinforced, silicon carbide-matrix composite. These tubes will be used in the development of accident-tolerant fuel cladding for light-water reactors. *Credit: ORNL*

In 2021, Pratt & Whitney opened a CMC facility in Carlsbad, Calif. This 60,000-square-foot facility focuses on the engineering, development, and production of CMCs for aerospace applications.

"Some of our best and brightest minds are innovating within this facility and they will ensure that we continue to operate on the cutting edge of aviation technology for decades to come," says Frank Preli, vice president of Propulsion and Materials Technology at Pratt & Whitney.

NEXT-GENERATION CMCS: ESTABLISHING NEW APPLICATIONS AND FABRICATION METHODS

The promise of lightweight durability in high-stress environments has scientists looking for new applications and new manufacturing methods for CMCs.

Oak Ridge National Laboratory researchers recently demonstrated the feasibility of additively manufacturing fiber-reinforced ceramic matrix composites, an advancement that will open new possibilities in the design space for these materials, says Edgar Lara-Curzio, a distinguished scientist at the national laboratory.

Researchers there are also initiating a project to test new techniques, including additive manufacturing, to fabricate furnace heating elements and components. The successful completion of that project could enable a leap in CMC capabilities by improving matrix densification, Lara-Curzio says. Another ORNL team is working to further develop CMCs for applications in nuclear energy.

Westinghouse, in partnership with San Diego-based General Atomics and the Department of Energy, has developed "accident-tolerant" nuclear fuel rods that use CMC cladding to replace the metal cladding that it typically used. The companies say the silicon carbide-based cladding allows the fuel rods to withstand temperatures of more than twice what can be sustained by metal cladding.

At GE, researchers are developing rotating engine parts using CMCs and have conducted engine tests using the material, Blank says.

Researchers at Boeing, the University of Southern California, and 3M are working on a project to ensure the affordability of CMC components for hypersonic platforms, and to use 3D vision-based sensors to reduce the cost and variability for high-rate production of CMC structures. The project recently received funding from the Advanced Robotics for Manufacturing Institute.

Clearly, the future for CMCs is attractive, as corporations, universities, and governments continue to invest in research and development for new applications. This collaborative atmosphere supports the recommendation that faculty in the Sustainable Manufacturing Systems Centre in the School of Aerospace, Transport, and Manufacturing at Cranfield University (U.K.) noted in a paper published in February 2023.

"Advanced ceramics have a tremendous amount of innovation potential, but to fully realize this potential along the entire value-added chain, significant efforts from both the academic and industrial sectors are needed," they write.

They continue, "Despite already having a plethora of uses, CMCs have not yet reached their full potential. The obstacles in the medium and long term, particularly in aeronautics and aerospace applications, will be such that the use of custom materials will necessitate a significant R&D investment."

That situation appears to be in the cards, as successes to date in critical applications of the material are leading to stepped-up investments and broader research.

OAK RIDGE NATIONAL LABORATORY-LED PROGRAM SUPPORTED R&D OF FIRST WIDELY DEPLOYED CMC PRODUCT

By Dawn Levy, senior science writer at Oak Ridge National Laboratory

This article is an edited and trimmed version from Oak Ridge National Laboratory. It is reprinted with permission. Read the original article at https://www.ornl.gov/news/ceramic-matrix-composites-take-flight-leap-jet-engine. The LEAP engine, introduced in 2016, has more than 25 million aircraft hours of service. The story of the researchers and discoveries that led to its development is still compelling.

Ceramic matrix composite (CMC) materials are made of coated ceramic fibers surrounded by a ceramic matrix. They are tough, lightweight, and capable of withstanding temperatures 300–400 degrees Fahrenheit hotter than metal alloys can endure. If certain components were made with CMCs instead of metal alloys, the turbine engines of aircraft and power plants could operate more efficiently at higher temperatures, combusting fuel more completely, and emitting fewer pollutants.

More than a quarter-century ago, the U.S. Department of Energy began a program, led by DOE's Oak Ridge National Laboratory (ORNL), to support U.S. development of CMC materials. In 2016, LEAP, a new aircraft engine, became the first widely deployed CMC-containing product. CFM International, a 50/50 joint venture of Safran and GE, manufactures LEAP.

The engine has one CMC component, a turbine shroud lining its hottest zone, so it can operate at up to 2,400°F. The CMC needs less cooling air than nickel-based super-alloys and is part of a suite of technologies that contributes to 15% fuel savings for LEAP over its predecessor, the CFM 56 engine.

"The materials developed in the DOE program became the foundation for the material now going into aircraft engines," says Krishan Luthra, who led GE Global Research's development of CMCs for 25 years.

GE's CMC is made of silicon carbide (SiC) ceramic fibers (containing silicon and carbon in equal amounts) coated with a proprietary material containing boron nitride. The coated fibers are shaped into a "preform" that is embedded in SiC containing 10–15% silicon.

ORNL's Rick Lowden did foundational work in the 1980s that paved the way for DOE programs. The key was coating the ceramic fibers.

"A ceramic matrix composite is different than almost all other composites because the matrix is ceramic and the fiber is ceramic," Lowden says.

Combining two brittle materials typically yields a brittle material, he says. But altering the bond between fiber and matrix allows the material to act more like a piece of wood. Cracks do not propagate into the fibers from the matrix around them. The fibers hold the material together and carry the load while slowly pulling from the matrix, adding toughness.

FIRING UP RESEARCH ON CERAMIC COMPOSITES

DOE's Continuous Fiber Ceramic Composite (CFCC) program ran from 1992 to 2002 and supported industrial development of CMCs by AlliedSignal, Alzeta, Amercom, Babcock and Wilcox, Dow Chemical, Dow Corning, DuPont-Lanxide Composites, GE, and Textron. Its budget averaged $10 million per year, and industry shared costs.

CFCC funded companies to make composites and national labs and universities to characterize the properties of the materials. Efforts were coordinated and funded through ORNL. Lowden wrote the program plan with Scott Richland of DOE and Mike Karnitz of ORNL and co-led support to companies with ORNL's Karren More, Pete Tortorelli, and Edgar Lara-Curzio and Argonne National Laboratory's Bill Ellingson.

"We were looking at different fibers and different interfacial coatings and different matrices," More says of ORNL's role. "We were involved in understanding the degradation mechanisms and down-selection of the more promising composites and cost-effective techniques for preparing them.

Long before ceramic fibers reinforced ceramic composites, ORNL researchers coated nuclear fuel with carbon and SiC to confine radioactivity inside tristructural-isotropic (TRISO) fuel particles. During experiments in the '70s, ORNL's Jack Lackey realized the process could be modified to manufacture ceramic composites more rapidly. With support from DOE's Fossil Energy Materials Program, his group pioneered a process to do just that.

"You take a fibrous preform, place it in a furnace, and vapor-deposit solids on and around the fibers," explains Lowden, who was Lackey's technician. To coat the whole object uniformly, the deposition process must be extremely slow—a half-inch part might take six months to process.

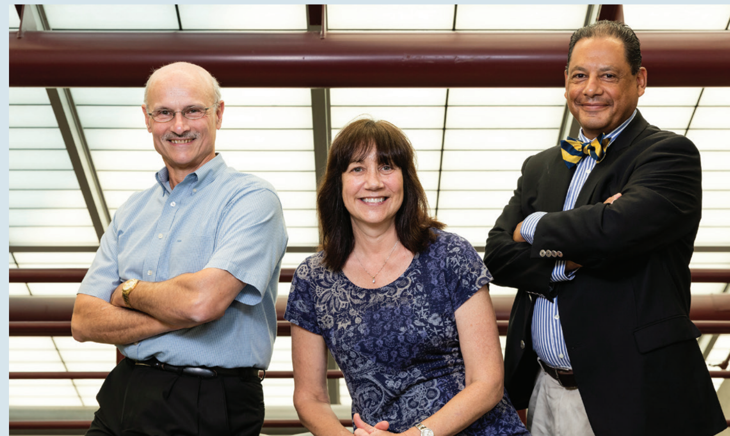
However, the ORNL team found that placing a fibrous mat on a cold plate, heating the top, and forcing gases through the mat sped up the process from months to hours.

"That's where we got involved in ceramic matrix composites," Lowden says. ORNL supplied CMCs for years to researchers evaluating CMCs for various applications.

Since CFCC, GE has tested CMCs for more than 2 million hours, including 40,000 hours in industrial gas turbines. Jim Vartuli of GE's CMC program says DOE support on large industrial gas turbines to get those first demonstrators gave GE confidence that the ceramics could survive high temperatures and stresses in turbines for long periods.

HOW DOE AND ITS NATIONAL LABS HELPED INDUSTRY

CFCC companies brought materials they had made to DOE national laboratories at Argonne for nondestructive evaluation and at Oak Ridge for microstructural characterization and stress and oxidation tests.



From left, Oak Ridge National Laboratory researchers Pete Tortorelli, Karren More, and Edgar Lara-Curzio were instrumental in advancing CMC technology. *Credit: ORNL*

"This partnership highlights the value of the national labs," More says. "We do work that is fundamental and broad to understand materials' behaviors. We provide necessary information to help the community make decisions about where to go, how to proceed." New knowledge about how materials degraded helped industry accelerate improvements and optimize manufacturing processes.

Research at ORNL ranged from development by Allen Haynes of environmental barrier coatings that could extend the lives of underlying materials five-fold to nondestructive imaging of materials with thermal cameras by Ralph Dinwiddie.

At Argonne National Laboratory, Bill Ellingson led development of broader nondestructive testing methods to ensure safe continued use of components by monitoring material degradation after intervals of usage. Without damaging the components, the inspections revealed how materials responded in an environment over time.

With ORNL researchers, Argonne scientists developed several nondestructive inspection technologies that were instrumental in determining component performance.

ORNL's Pete Tortorelli and H. T. Lin stressed materials in environmental exposure chambers to learn their points of failure. Lab colleagues Jim Keiser and Irv Federer exposed samples to corrosive gases, temperatures up to 2,550°F and pressures up to 500 psi in "Keiser rigs" that simulated conditions in turbines. These methods were also used by More, Tortorelli, and Keiser to screen protective coatings needed in combustion environments.

Meanwhile, More characterized structures of stressed materials.

"Karren More entered the picture as our microscopist, and that changed our world," Lowden recalls. "To be able to see what was happening with transmission electron microscopy, and understand what was happening at that level, was incredible."

GE had access to some techniques in-house because of its large infrastructure.

"But we got invaluable help from Karren on the fiber coatings," Luthra says. "It helped us develop the fiber coatings faster."

ORNL's early findings encouraged industry to abandon carbon as a fiber coating. Carbon oxidized, turning into carbon monoxide and carbon dioxide, and volatilized, thinning the coating. ORNL engineers recommended oxidation-resistant boron nitride instead.

Moreover, Edgar Lara-Curzio modeled and tested the mechanical performance of CMC materials under different loading conditions and their resistance to fatigue, creep, and rupture in ORNL's High Temperature Materials Laboratory. In collaboration with Matt Ferber and Chun-Hway Hsueh, he implemented experimental and analytical methods to characterize the micromechanics of fiber–matrix interfaces.

"These measurements were essential to quantify chemical bonding between fibers and matrix, residual stresses experienced by the fibers, and friction between the fibers and the matrix during fiber sliding," says Lara-Curzio, noting CMCs are tough mainly because interfacial coatings let fibers slide and bridge matrix cracks.

He and Hsueh provided key information about how a single fiber slides in a ceramic matrix. Lara-Curzio, Ferber, and Lowden then quantified the effect of the thickness of fiber coatings on sliding and discovered a value that optimized mechanical properties. Companies widely adopted this correlation to optimize their composites.

DOE's Advanced Manufacturing Office (AMO), formerly known as the Industrial Technologies Program, supports applied research, development, and demonstration of new materials, information, and processes that improve U.S. manufacturing's energy efficiency, as well as platform technologies for manufacturing clean energy products. AMO helped fund this research.

UT-Battelle manages ORNL for DOE's Office of Science. The single largest supporter of basic research in the physical sciences in the United States, the Office of Science is working to address some of the most pressing challenges of our time. For more information, please visit www.energy.gov/science.

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WELCOMING NEW FACULTY

Dr. Collin Wilkinson

Alfred University would like to introduce you to our latest faculty member Dr. Collin Wilkinson has been hired as Assistant Professor of Glass Science. Collin earned a Bachelor's in Physics at Coe College followed by a Ph.D. in Material Science at the Pennsylvania State University. He served as director of research and development and CTO of small startups focusing on next-generation recycling technology through material informatics. Collin is the inventor or co-inventor of several new glass compositions for green applications ranging from reducing greenhouse gases to improved glasses for renewable energy applications. Collin joined the faculty at Alfred University in 2022 and his current research revolves around building computational tools for simulations of extreme conditions, understanding the fundamental physics of glassy materials, and engineering better solutions for sustainable glass technology. Collin is the author of over 50 peer-reviewed publications and 4 patents. He is additionally the chair of the undergraduate research committee at Alfred University where he has created a research program for undergraduates from around the world in glass and ceramics.

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deciphering the discipline

A regular column offering the student perspective of the next generation of ceramic and glass scientists, organized by the ACerS Presidents Council of Student Advisors.

Matthew Julian
Guest columnist

Ceramics for antennas in next-gen wireless communication networks

People around the world have benefitted tremendously from the steady advancement of communication technologies.[1] Innovations in this field allow consumers to access GPS navigation directions that account for current traffic conditions, receive real-time alerts on impending natural disasters, and monitor their health via remote sensors, among other benefits.

Since 2019, rollouts of the next technological leap in communication systems—fifth generation (5G) mobile networks—are gathering momentum globally. Compared to the former generation, 5G networks are expected to provide data rates that are 10 times faster,[2] as well as lower latency and larger bandwidths to support the ever-increasing volume of data transmission.

To achieve these improvements, 5G devices operate at higher frequencies than 4G devices. While both 4G and 5G networks can operate in the same lower band of the spectrum (400–700 MHz), the 4G network only operates up to frequencies of 2.7 GHz. In contrast, the 5G network can operate in mid-band frequencies (3–5 GHz) as well as in several higher mm-wave bands (24.3–71 GHz).[3]

Currently deployed 5G systems operate predominately in the mid-band frequencies. Researchers are working to address the considerable technological challenges that hinder wide-scale adoption of mm-wave technology.

For instance, electromagnetic waves cannot travel as far at higher frequencies, which therefore reduces coverage area substantially. Higher densities of smaller base stations and repeaters will be needed to overcome this limitation. Additionally, base stations that transmit mm-waves are expected to have narrower beams that are steered to locations of demand rather than broad beams that cover areas indiscriminately.

Multiple-input multiple-output (MIMO) technology is one way of accomplishing this change to base station operation. In MIMO systems, antennas are composed of an array of several smaller radiating elements, which can alter the shape of the global radiation pattern based on demand.

The radiating elements in MIMO antennas can be made of metal, polymer, or ceramic. Metallic antennas have lower efficiencies due to high conduction losses, especially at mm-wave frequencies, so ceramic or polymer dielectric resonator antennas (DRAs) are more suitable for this application. Ceramics specifically are suited for this application because, compared to polymers, they provide better mechanical and thermal stability, superior heat dissipation, lower losses, and flexibility of chemical composition.

To ensure that a DRA operates reliably, its resonant frequency should only experience minimal drift with temperature changes. This stability can be achieved by using a ceramic resonator with a near-zero temperature coefficient. Additionally, for any given material, dielectric losses will increase with frequency. So, materials that maintain extremely low losses at high-band frequencies must be identified. Finally, miniaturization is a trend in many electronics fields, and the use of higher permittivity materials allows for the creation of compact antennas that operate in the mid-band frequencies. However, to achieve resonance at mm-wave frequencies in compact antennas, the ceramic resonator must have a low permittivity.

Multicomponent ceramics, such as silicate-based compounds,[4] are being investigated to meet the requirements for these mm-wave applications. Plus, with the advent of precision ceramic 3D printing, researchers can begin to envision printing and sintering net-shape parts with exact dimensionality, including geometries that could not be realized by conventional ceramics processing.

My research currently focuses on materials for miniaturized DRAs in mid-band 5G frequency applications. But my group is transitioning to materials for mm-wave communications, including 3D printing ceramic resonators for DRAs.

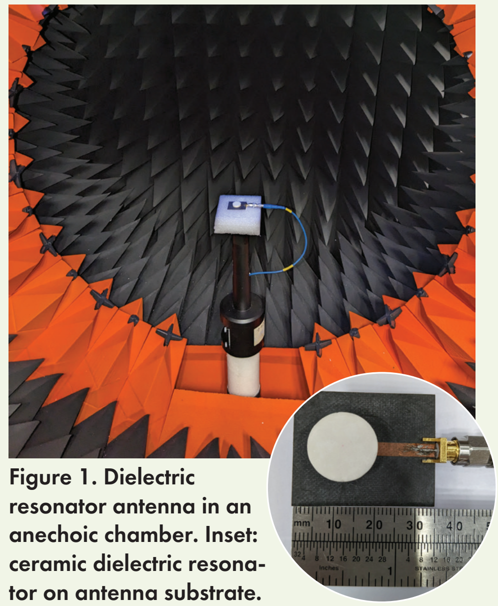

Figure 1. Dielectric resonator antenna in an anechoic chamber. Inset: ceramic dielectric resonator on antenna substrate.

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Matthew Julian is a second-year Ph.D. student in L'Institut d'Electronique et des Technologies du numéRique at the University of Rennes, France. He studies ceramics and thin films for 5G antenna applications. Outside of research, he enjoys traveling and watching soccer.

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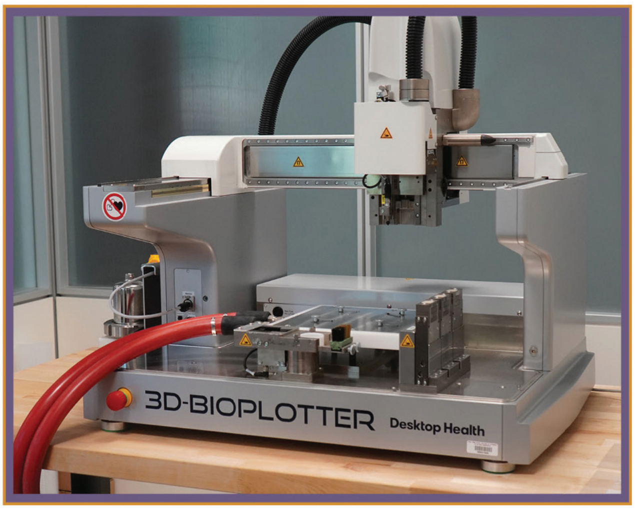

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