AMERICAN CERAMIC SOCIETY

bulletin

emerging ceramics & glass technology

APRIL 2025

Preparing for an AI-empowered workforce

AI-enhanced tools for manufacturers | Challenges and solutions for navigating AI adoption

contents

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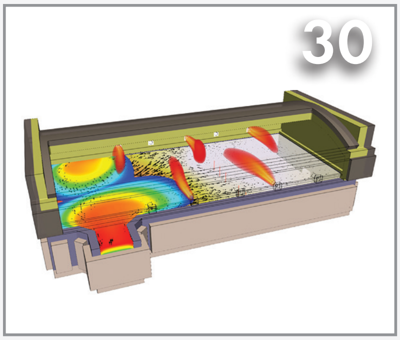
feature articles



Leveraging computational fluid dynamics for sustainable glass manufacturing

As the glass industry embarks on transformative steps toward a more sustainable future, computational fluid dynamics can help manufacturers understand and accurately predict the physical and chemical changes that occur during glass processing.

by Katelyn Kirchner, Tim van Lier, and Scott Cooper

Transformative potential: Innovative AI and ML solutions for the glass and ceramics industry

Artificial intelligence and machine learning help manufacturers avoid the costs of inefficient material design and production processes. This article highlights how AI/ML solutions provider ZW developed products tailored to support the glass and ceramics industry.

by Robert Fu, Mitch Odinak, Fangze Xu, Keith House, and John Brown

Preparing for an AI-empowered workforce

Upskilling and reskilling for artificial intelligence and machine learning are being touted as 2025 business imperatives. Public- and private-sector resources can help organizations understand the landscape and which areas of skills development are most pressing today.

by Randy B. Hecht

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As seen on *Ceramic Tech Today*...

Credit: IWMI Flickr Photos, Flickr (CC BY-NC-ND 2.0)

Scientific glassmaking: An indispensable research support

Despite the availability of mass-produced precision glassware, the need for highly skilled scientific glassmakers endures because some discoveries require the design of unique instruments that are not or cannot be mass produced.

Read more at https://ceramics.org/scientific-glassmaking

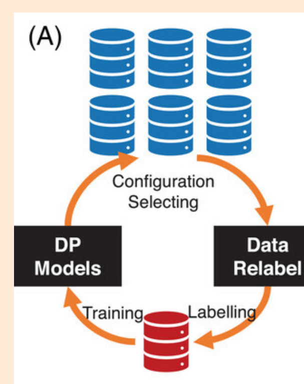
Also see our ACerS journals...

Boosting the melting point record to 4431 K: Simulated with machine learning potential at SCAN accuracy
By F.-Z. Dai, Y. Xu, J. Hu, et al.
Journal of the American Ceramic Society

Unveiling and mapping polymorphs in fluorite Y_2TiO_5 using 4D-STEM and unsupervised machine learning
By E. Hershkovitz, T. Yoo, X. Pu, et al.
Journal of the American Ceramic Society

Corrosion of zirconium-based refractories in glass-contact areas: Mechanisms and challenges
By C. P. Velasquez, M. Montazerian, and J. C. Mauro
International Journal of Applied Ceramic Technology

Insights on proton-conducting ceramic electrochemical cell fabrication
By C. Meisel, J. D. Huang, Y.-D. Kim, et al.
Journal of the American Ceramic Society



Credit: Dai et al., *JACerS*

Journal of the American Ceramic Society | International Journal of Applied Ceramic Technology | International Journal of Applied Glass Science | International Journal of Ceramic Engineering & Science

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

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ACSBA7, Vol. 104, No. 3, pp. 1–52. All feature articles are covered in Current Contents.

news & trends

Indonesian sea sand mining: History and potential ramifications of lifting the export ban

In today's world of complex global supply chains, it can be difficult to appreciate all the factors driving shortages and surpluses. For people living in Indonesia, they are experiencing first-hand the long-term ramifications of solving current challenges too hastily as a result of their government's decision to resume sea sand exports after a 20-year ban.

Indonesia: A country of land, water—and sand

The Republic of Indonesia is the world's largest archipelagic state, comprising more than 17,000 islands. Approximately 280 million people live in Indonesia, which they refer to affectionately as Tanah Air Kita, which means homeland but literally translates to "our land and water." But land and water are not the only geological components that make up their homeland—sand is also a major factor.

Indonesia has about 17.65 billion cubic meters of extractable sea sand sediment in the Java Sea, Makassar Strait, and Natuna-North Natuna waters, according to The Indonesian Ministry of Marine Affairs and Fisheries. Up until 2003, Indonesia exported this sand in large volumes, particularly to Singapore to support that country's land reclamation efforts.

Because of the substantial sand dredging, some small islands in Indonesia shrunk or were lost completely. It also destroyed fishing grounds used by coastal villages, which is significant considering Indonesia is the world's second largest aquaculture producer after China.

In February 2003, then-President Megawati Soekarnoputri issued a ban on the export of sea sand from Indonesia to help protect the environment. But two decades later, as demand for sand increased and illegal mining practices benefited from the desperate market, the Indonesian government resumed sea sand exports again in May 2023.

news & trends

Backlash to resumed sea sand exports

When the Indonesian government decided to resume sea sand exports, they claimed dredging would only take place in open-water marine areas away from coastal areas and small islands, and extraction would be focused on "sediment" that blocks shipping pathways rather than sand.

However, the new regulation refers to maritime and investment laws for its fundamental legal framework and makes no reference to environmental and conservation laws. As such, environmental experts worry that the government is not serious about protecting the ocean's health, as reported in a *Mongabay* article.

Numerous examples of fishing communities across Indonesia being affected by government-backed dredging projects support this concern. For example, one prominent case in South Sulawesi province had fishers reporting a decline in catches of up to two-thirds of the typical amount since dredging began in February 2021.

With the expanded dredging operations allowed under the new regulation, these fishing losses could amount to $77.4 million, according to the Center of Economic and Law Studies. These losses far outweigh the estimated $10.9 million in export revenue that the Indonesian government could potentially earn, as well as the $32.1 million in profits for dredging companies.

Ultimately, "These policies are not the solution to manage and resolve the problems of sedimentation at sea," says Muhamad Karim, director of the Center for Marine Development and Maritime Civilization Studies, in a *Mongabay* article. ■

Corporate Partner news

KITECH partners with Canada on battery seminar

The Korea Institute of Technology held the Korea–Canada Battery Circular Economy Seminar with the Embassy of Canada on Jan. 14, 2025. The collaboration marks significant strides between the Republic of Korea and Canada in the battery circular economy sector. Read more: https://www.businesskorea.co.kr/news/articleView.html?idxno=233620

Sandia National Laboratories co-sponsors Thunderbird Hackathon for high school students

The second annual Thunderbird Hackathon took place on Feb. 8, 2025. This event, which was sponsored by Sandia National Laboratories and Explora's X Studio, immersed high school students in coding, machine learning, and artificial intelligence. Read more: https://newsreleases.sandia.gov/hackathon

Fraunhofer IKTS collaborates on InBatt project

The Fraunhofer Institute for Ceramic Technologies and Systems, along with Automation Uhr GmbH, GÖPEL electronic GmbH, and ECT-KEMA GmbH, are collaborating on a 2.5-million-euro, three-year project that aims to develop an inline quality control system for the production of sodium battery electrolytes. Read more: https://www.ikts.fraunhofer.de/en/press_media/press_releases.html ■

bccResearch

Generative AI: Global markets

The global generative artificial intelligence (AI) market was valued at $15.4 billion in 2023 and is expected to grow at a compound annual growth rate (CAGR) of 35.3% to reach $94.4 billion by 2029.

Generative AI is a subfield of AI that specializes in creating new data. It uses pretrained learning techniques to identify underlying patterns connected with the input, which allows it to then produce new text, pictures, videos, audio, and code that replicate the training data's features (Table 1).

The landscape of generative AI is categorized into three main offerings (Table 2): software, hardware, and services (e.g., consulting, installation, and support). In 2023, the software segment dominated the market (73.6%), driven by the increasing adoption of Internet of Things technologies and the growing focus on quality assurance.

Software offerings can be grouped based on the type of foundation model used, i.e., large-scale neural networks trained on massive unlabeled datasets to handle a wide variety of jobs.

- **Statistical models** use statistical machine learning principles to capture complicated patterns in data and produce exact results. ChatGPT, DALL-E, Runway ML, DeepAI, and Jasper AI are examples of generative AI technologies that use statistical models.
- **Rule-based models** rely on predefined rules to generate outputs. They are less flexible than other models, but they can be effective in specific applications where rules are clear and well-defined. IBM uses rule-based systems in its Watson AI for decision support in specific fields, including healthcare and finance.
- **Deep learning models** are the most advanced foundation models. These models use many layers of abstraction to learn from large volumes of data, helping them comprehend and duplicate the minute characteristics that differentiate various groups within a dataset. Among deep learning model types, transformer-based large language models (LLMs) are trending thanks to advancements such as DeepSeek R1, Gemini 2.0, and Grok-3, which have increased demand for LLM-based offerings.

Table 1. Global market for generative AI, by data type, through 2029 ($ millions)

Data type	2023	2024	2029	CAGR % (2024–2029)
Text	7,503.6	10,161.5	46,503.5	35.6
Images/videos	4,933.1	6,747.8	32,453.1	36.9
Code	1,820.5	2,413.6	9,936.2	32.7
Audio/speech	1,155.5	1,507.4	5,481.9	29.5
Total	15,412.7	20,830.3	94,374.7	35.3

Table 2. Global market for generative AI, by offerings, through 2029 ($ millions)

Offerings	2023	2024	2029	CAGR % (2024–2029)
Software	11,346.3	15,361.5	70,210.4	35.5
Hardware	2,691.2	3,565.2	14,618.4	32.6
Services	1,375.2	1,903.6	9,545.9	38.1
Total	15,412.7	20,830.3	94,374.7	35.3

Many industries are embracing generative AI, and its use in on-premises and cloud environments has significantly increased. Cloud-based deployment is especially popular because of its scalability, cost-effectiveness, and simplicity of connection with other cloud services. On-premises deployments, while less common, provide additional control over data privacy and security, making them appropriate for sectors with rigorous data governance requirements.

According to the AI Index report by Standford University, since 2016, 32 countries have enacted at least one AI bill, with 148 bills passed. As of 2023, the U.S. has passed the most AI-related laws (23), with Portugal (15) and Belgium (12) also ranking highly.

In 2023, North America dominated the global generative AI market with a 39.6% share. The region is expected to maintain its dominance throughout the forecast period due to the rising adoption of technologies and significant investments in digital transformation across various industries. However, the Asia-Pacific region is expected to grow at the highest CAGR of 37.9% during the forecast period due to the rapid digital transformation across the region, increasing investments in AI technologies, and a growing number of startups focusing on generative AI applications.

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, "Generative AI: Global markets," BCC Research Report IFT308A, January 2025. https://bit.ly/BCC-January-2025-Generative-AI ■

The AMRICC Centre

By Dominic Wadkin-Snaith
Guest columnist

Enabling industrial efficiency: Data science optimizes established and emerging ceramic processes

Ceramics manufacturers have come a long way regarding emission reduction. Since reaching a peak in the early 2000s, total carbon dioxide emissions in the European ceramics industry have fallen by more than 45%, thanks largely to fuel substitution and process optimization.[1]

While these reductions are significant, overall, the production of traditional ceramic wares, including refractory bricks, clay tiles, and architectural blocks, remains similar to the industrial processes used decades ago. There is thus room for further improvements in emission reduction and energy efficiency by harnessing Industry 4.0 methods and technologies.[2]

The Fourth Industrial Revolution, commonly called Industry 4.0, represents the next major shift in manufacturing. It involves the digitization of traditional industrial processes, thus ensuring that machines communicate effectively, provide valuable insights for decision-making, assist humans in complex tasks, and function autonomously where possible.

There are many established and emerging aspects of ceramics manufacturing that are amiable to improvement through the application of Industry 4.0 data science methods.

Optimization of established industrial processes

Pitch rate (waste) is one example of how Industry 4.0 can improve established industrial processes. Manufacturers often do not know exactly which processing factors, such as drying and air ingress, contribute to pitch rate. Data science, particularly machine learning (ML) methods, can help find patterns that reveal the main factors contributing to pitch rate, thus allowing the manufacturing process to be optimized and the pitch rate reduced.

Another opportunity for Industry 4.0 technologies is the firing of wares using continuous or roller kilns. These kilns allow a panoply of ware types to be sent through the same firing profile for a given stacking configuration. ML methods can be used to determine new stacking configurations, which could allow for a change in the firing profile to reduce the quantity of fuel required (Figure 1).

Slurry tanks may also benefit from Industry 4.0. In these tanks, the flow rate of the slurry can vary depending on the slurry height. Access to real-time measurements of the height through data science methods would help mitigate disruptions to the industrial process.

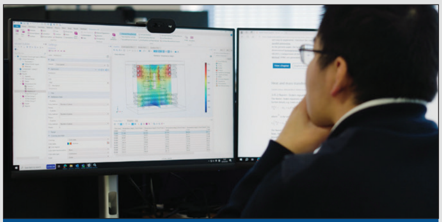
Finally, seasons can affect output due to changes in the factory's temperature and humidity. Industry 4.0 methods could monitor these changes and initiate systems to achieve environment stability.

Optimization of emerging industrial processes

Additive manufacturing (AM) is a highly promising approach to ceramics production. The variety of experimental parameters that affect its outputs is breathtakingly large, though, which hinders optimization of AM methods.

Traditionally, industrial processes are optimized using design of experiment, which involves systematically varying the value of each parameter to determine its effect. In the ceramic AM context, the temperature could, for example, be varied from 0°C to 100°C in steps of 10°C while allowing print speed to take on 10 different values for each temperature step. For six parameters, where each parameter can take on 10 values, the resultant number of experiments required would be approximately 64 million, which of course is not practical.

Standard statistical methods, such as partial factorial and Latin hypercube methods, can reduce the number of experiments required for optimization. Unfortunately, the data generated by



Credit: AMRICC, 2024

Figure 1. Visualization of a kiln heat map.

3D printers do not submit well to these standard methods. For example, in a study at the Applied Materials Research, Innovation, & Commercialisation Company (AMRICC), analysis of variance methods predicted high-quality prints in a design space known from experiments to result in low-quality prints. These false predictions were due to large scatter in the 3D-printed, nonlinear data set.

In contrast to the standard statistical methods, ML techniques can help make sense of difficult AM data sets. In the AMRICC study mentioned above, an ML method called random forest regressor successfully predicted parameters spaces for low- and high-quality prints that aligned with experimental results.

The above are just a few examples of the numerous ceramic processes that can benefit from Industry 4.0. We at AMRICC stand ready to help support the implementation of these methods.

About the author

Dominic Wadkin-Snaith is business development manager of data science at AMRICC (Stone, U.K.). Contact Wadkin-Snaith at Dominic.Wadkin-Snaith@uk.lucideon.com.

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By David Holthaus
Industry reporter

Balancing the benefits and challenges of increased AI usage in industry

Artificial intelligence (AI) is certainly not new, as many of us make use of it every day with digital assistants such as Alexa and Siri. But as the technology evolves to handle larger data sets and perform more complex tasks, the possibility of using this technology to improve industrial operations becomes more pronounced each day.

One group working to support AI adoption in industry is the Advanced Robotics for Manufacturing (ARM) Institute, a Pittsburgh-based nonprofit founded through Carnegie Mellon University in 2017. Its goals are to strengthen U.S. manufacturing through innovations in advanced manufacturing technology, particularly robotics and AI, and prepare the workforce to operate with and alongside these technologies. It is part of the Manufacturing USA network, which was established in 2014 to bring together industry, academia, and federal partners to increase U.S. manufacturing competitiveness.

Suzy Teele, chief strategy officer of the ARM Institute, sees several areas where manufacturers can make effective use of AI, including quality control, detecting defects, and ensuring consistent product quality.

"If you're a human being, and if you're looking at a ceramic piece coming off an assembly line and trying to visually inspect that, you get tired, right? You can't do that 24/7," she says in an interview. But a machine can, and AI-powered computer vision systems can inspect parts for defects more accurately than people can.

The ARM Institute collaborated with the University of Washington on a project with GKN Aerospace, a Birmingham, U.K.-based supplier that operates 32 manufacturing locations around the world. The investigating team built a robotic platform to provide inspection of complex metallic components (Figure 1). Its chief innovation was gathering imaging data that was robotically collected at the right positions and in the right environment to enable consistent and high-quality surface profiling of components at operational speed. The team said the platform consistently achieved detection rates above 95%, and it worked at a speed of approximately one minute per part, both beyond what humans can do.

Credit: i The ARM Institute

Figure 1. The GKN Aerospace project built a robotic platform that provides comprehensive parts inspection of complex metallic components.

Machines will eventually break down, but AI can provide benefits in this area as well through predictive maintenance, Teele says.

"With specialized equipment in factories, you want to be better at predicting when it might break down, because that affects your ability to meet production schedules," Teele says.

Analyzing data from machines can forecast potential failures before they happen, reducing downtime and maintenance costs. Munich-based industrial giant Siemens, for example, uses an AI module in its MindSphere platform that identifies fault patterns in motors, such as misalignment or defective bearings, at an early stage, potentially cutting back on downtime and improving maintenance processes.

Finally, AI can lead to an overall increase in productivity by predicting market factors and monitoring factory conditions continuously without any off time, Teele says.

"Something that's driven by AI can be in order 24 hours a day, seven days a week," she says. "Then you can increase productivity and, hopefully, reduce costs in your manufacturing environment."

Though AI has the potential to improve efficiency and increase productivity, there are several challenges to using the technology effectively—particularly the lack of an AI-educated workforce.

Only 22% of companies that have explored adopting AI into their processes have advanced beyond the proof-of-concept stage to generate some value, according to a report by Boston Consulting Group that surveyed 1,000 chief experience officers and senior executives from more than 20 sectors.[1] The survey revealed that 70% of these challenges stemmed from people- and process-related issues.

More resources are becoming available to support the growth of an AI-educated workforce (see "Preparing for an AI-empowered workforce" on page 40 in this issue), but even then, companies may struggle with AI adoption due to a lack of high-quality data for training the AI systems. Without relevant, accurate data to train AI models, AI algorithms will not be reliable, Teele says. And data that is stored in different systems, or siloed, can make it difficult to access and consolidate.

Besides these well-known challenges of AI adoption, a less-discussed but equally important challenge is how the adoption of AI aligns with existing environment, social, and governance (ESG) goals.

AI-driven programs require much more processing power than traditional computing systems, and the accelerated uptake of AI has raised concerns about a surge in electricity demand and its impacts.[2] Furthermore, advances in AI are expected to have far-reaching effects on privacy, physical safety, discrimination, and the labor economy.[3]

In response to these concerns, in 2024, several groups published white papers discussing responsible AI integration into ESG paradigms.[4–6] Collectively, these papers offer companies a framework to make responsible decisions related to their AI projects and investments, "ultimately contributing to a more sustainable future."[5]

About the author

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

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SOCIETY DIVISION SECTION CHAPTER NEWS

Welcome new ACerS Corporate Partners

ACerS is pleased to welcome its newest Corporate Partner:

Noritake

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

Washington DC/Maryland/Virginia Section begins 2025 with new officers and exciting activities

The ACerS Washington, D.C./Maryland/Virginia Section welcomed new leadership for 2025:

- Chair: **Carolina Tallon**, Virginia Tech
- Vice chair: **Olivia Brandt**, Naval Research Laboratory
- Programming chair: **Russell Maier**, National Institute of Standards and Technology
- Secretary: **Tony Finoli**, McDanel Advanced Material Technologies
- DEI representative: **Keith Bowman**, University of Maryland, Baltimore County

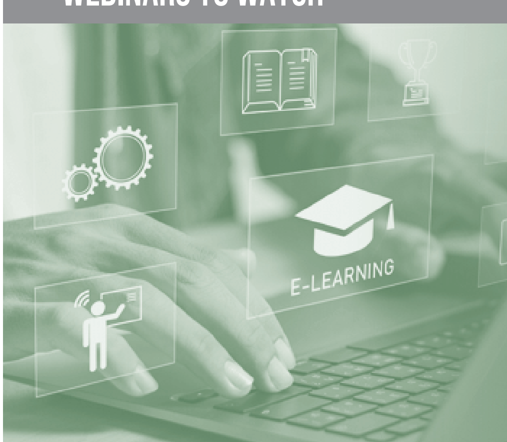
This year, the Washington, D.C./Maryland/Virginia Section plans to once again host some previously successful activities, as well as organize some new ones. These activities include

- Support for attending ACerS conferences,
- Social events at several locations within the Section's geographical area,
- Connect members with internship and employment opportunities, and
- Highlight the work of ceramic community members.

The Section will also relaunch its monthly research webinar series titled "Spotlight On Ceramics." The webinars will be held on the last Friday of each month at 12 p.m. Eastern. The first webinar of the relaunched series will feature guest speaker Olivia Brandt of the U.S. Naval Research Laboratory. Future speakers will be announced as confirmed. ■

WEBINARS TO WATCH

Check out these recent additions to the ACerS Webinar Archives:



TRANSFORMING THE BUILT ENVIRONMENT FROM A NET-CARBON EMITTER TO A CRITICAL CARBON SINK WITH CO2-SEQUESTERING CONCRETE PRODUCTS
Original air date: Feb. 5, 2025
Hosted by: Cements Division
Featured speaker: Juan Pablo Gevaudan

POWDERS SYNTHESIS AND PARTICLE MORPHOLOGY CONTROL: BETTER MATERIALS FROM CHEMISTRY and THE LAB-TO-MARKET STORY OF MICNO® PARTICLES
Original air date: Feb. 10, 2025
Hosted by: ACerS International Italy Chapter and ACerS International Türkiye Chapter
Featured speaker: Vincenzo Buscaglia and Ender Suvacı

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

Welcome new ACerS International Mexico Chapter

Welcome to the newest ACerS International Chapter! The ACerS Board of Directors approved a petition to establish an ACerS International Chapter in Mexico during their meeting at the 49th International Conference and Expo on Advanced Ceramics and Composites in Daytona Beach, Fla.

Chapter officers

- Chair: **Juan Munoz Saldaña**, Cinvestav Querétaro
- Vice chair: **Heberto Balmori-Rimirez**, National Polytechnic Institute
- Secretary: **Héctor Camacho Montes**, Autonomous University of Ciudad Juarez
- Treasurer: **Guillermo Herrera-Perez**, National Council of Humanities, Sciences, and Technologies

Contact Vicki Evans at vevans@ceramics.org for more information about this new ACerS International Chapter or to form a Chapter in your region. ■

ACerS International Northwest India Chapter leaders give invited talks at ICACC 2025

ACerS International Northwest India Chapter Chair L.K Sharma and Co-Chair Manoj attended the 49th International Conference and Expo on Advanced Ceramics and Composites in Daytona Beach, Fla., from Jan. 26–31, 2025. Both members delivered invited talks during the conference and chaired sessions, and Manoj presented a poster on his student's behalf. Additionally, Sharma received his ACerS Fellows certificate from ACerS Immediate Past President Rajendra Bordia, which he was unable to receive at ACerS Annual Meeting at MS&T24. ■

ACerS International Chapters attend Chapter Happy Hour at ICACC 2025

Members of the ACerS International Italy, Germany, Spain, Japan, Taiwan, and United Kingdom Chapters gathered for a Happy Hour at the Ocean Deck Restaurant on Monday, Jan. 27 during the 49th International Conference and Expo on Advanced Ceramics and Composites in Daytona Beach, Fla. ACerS President Monica Ferraris thanks ACerS International Italy Chapter members Lisa Biasetto and Enrico Bernardo from the University of Padova for their help and support in organizing the event. ■

MEMBER HIGHLIGHTS

Volunteer Spotlight: Corson L. Cramer

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

Corson L. Cramer is a staff scientist at Oak Ridge National Laboratory. He received a Ph.D. in mechanical engineering from Colorado State University.

Cramer has performed research and development in processing, characterization, and testing of high-temperature materials. As a staff scientist, his current areas of research include ceramic and composite materials development for additive manufacturing, development of new ceramic matrix composites, processing of ceramics, and novel processing and printing of continuous fiber ceramic matrix composites.

Cramer serves as treasurer of the ACerS East Tennessee Chapter and is the ORNL board member for the University Consortium for Applied Hypersonics.

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

ACerStudent Engagement: Elizabeth Aichele

Elizabeth Aichele is an undergraduate student in materials science and engineering at The Pennsylvania State University. She serves as a member of the ACerS President's Council of Student Advisors (PCSA) Communications Committee, where she works with student writers for the "Deciphering the Discipline" column in the *Bulletin*. She is also a divisional delegate of the ACerS Glass & Optical Materials Division.

"Being a part of PCSA has been an incredible opportunity to get to know professionals and peers with similar interests. During my search for a summer internship, I discovered that the woman interviewing me—now my supervisor—is a 2019 PCSA alumna, which gave us a great opportunity to connect."

You can take advantage of these opportunities as well by becoming a student member of ACerS. Visit https://ceramics.org/members/membership-types to learn more. ■

Ceramic Tech Chat: Monica Ferraris

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 January 2025 episode of Ceramic Tech Chat, Monica Ferraris, full professor at Politecnico di Torino, shares details about her work on the joining and coating of materials, describes her involvement with the ACerS International Italy Chapter, and discusses her plans and goals as president of ACerS this year.

Check out a preview from her episode, where she describes the importance of networking opportunities.

"I cannot tell you how many ideas, how many projects, how many activities were born in Daytona Beach or at other conferences of The American Ceramic Society during networking activity, which was during coffee break or evening together. Because, I don't know, there must be something in our brain, when we are relaxed, the brain works better."

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

FOR MORE INFORMATION:

ceramics.org/membership

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.

Aldo R. Boccaccini, FACerS, Head of the Institute of Biomaterials at the University of Erlangen-Nuremberg, Germany, was awarded the European Society for Biomaterials' 2024 George Winter Award. The award will be presented at the Society's annual conference in Turin, Italy, on Sept. 7–11, 2025.

John Mauro, FACerS, Dorothy Pate Enright Professor of Materials Science and Engineering at The Pennsylvania State University, will become head of Penn State's Department of Materials Science and Engineering effective July 1, 2025. He will succeed ACerS Fellow Susan Sinnott, who has served as the head of the department since 2015.

Lisa Rueschhoff, senior materials research engineer at Air Force Research Laboratory, received the Presidential Early Career Award for Scientists and Engineers from former U.S. President Joe Biden. She was one of nearly 400 recipients who received the award in January 2025, which is the highest honor bestowed by the U.S. government on outstanding scientists and engineers early in their careers.

more MEMBER HIGHLIGHTS

Names in the News (continued)

Henry Colorado, full professor in the School of Engineering and director of the CCComposites Lab at Universidad de Antioquia, summitted Aconcagua, a mountain in the Principal Cordillera of the Andes mountain range, on Jan. 14, 2025. Aconcagua is the seventh mountain that Colorado has summitted with the ACerS flag. ■

Edgar Dutra Zanotto, FACerS, senior professor at Federal University of São Carlos, Brazil; **Kathleen Richardson**, FACerS, Pegasus Professor of Optics and Materials Science and Engineering at the Univresity of Central Florida; and **Tsutomu Minami**, FACerS, were three of the four recipients of this year's International Commission on Glass President's Award. They received the award in January 2025 during the 27th International Congress on Glass in Kolkata, India. ■

AWARDS AND DEADLINES

Nomination deadlines for Division awards: May 15, July 1, or Aug. 1, 2025

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

Division	Award	Deadline	Contacts	Description
GOMD	**Alfred R. Cooper Scholars Award**	May 15	Steve Martin swmartin@iastate.edu	Recognizes undergraduate students who demonstrated excellence in research, engineering, and/or study in glass science or technology.
EDIV	**Edward C. Henry Award**	May 15	Christina Rost cmrost@vt.edu	Recognizes an outstanding paper reporting original work in the *Journal of the American Ceramic Society* or the *Bulletin* during the previous calendar year on a subject related to electronic ceramics.
EDIV	**Lewis C. Hoffman Scholarship**	May 15	Christina Rost cmrost@vt.edu	Recognizes academic interest and excellence among undergraduate students in ceramics/materials science and engineering.
ECD	**Mrityunjay Singh Bridge Building Award**	July 1	Amjad Almansour amjad.s.almansour@nasa.gov	Recognizes individuals outside of the United States who have made outstanding contributions to engineering ceramics.
ECD	**Global Young Investigator**	July 1	Federico Smeacetto federico.smeacetto@polito.it	Recognizes the outstanding young ceramic engineer or scientist whose achievements have been significant to the profession and to the general welfare of the community around the globe. Nominations are open to candidates from industry, academia, or government-funded laboratories around the world.
ECD	**James I. Mueller Lecture**	July 1	Jie Zhang jiezhang@imr.ac.cn	Recognizes the enormous contributions of James I. Mueller to the Engineering Ceramics Division and to the field of engineering ceramics. This award aims to recognize the accomplishments of individuals who have made similar contributions.
ECD	**Jubilee Global Diversity Award**	July 1	Michael Halbig michael.c.halbig@nasa.gov	Recognizes exceptional early- to mid-career professionals who are women and/or underrepresented minorities (i.e., based on race, ethnicity, nationality, and/or geographic location) in the area of ceramic science and engineering.
EMSD	**Outstanding Student Researcher**	August 1	Charmayne Lonergan clonergan@mst.edu	Recognizes exemplary student research related to the mission of ACerS Energy Materials and Systems Division.

PCSA engages next generation of materials scientists at ICACC 2025

CERAMIC AND GLASS INDUSTRY FOUNDATION

The President's Council of Student Advisors (PCSA) serves as the voice of ceramic and glass materials science students within ACerS, empowering them to become active and long-term leaders in the field. By fostering student engagement and professional development, the PCSA is not only shaping the future of young scientists but also strengthening the ceramic and glass materials community. Through their outreach, they inspire a new generation to explore careers in ceramics and glass, ensuring continued growth and innovation in the field.

The work of the PCSA supports the Ceramic and Glass Industry Foundation's (CGIF) goal of attracting, inspiring, and developing future professionals through student-focused programming at technical meetings and outreach initiatives. Most recently, the PCSA advanced these efforts at the 49th International Conference & Exposition on Advanced Ceramics and Composites (ICACC), held in Daytona Beach, Fla., Jan. 26–31, 2025.

At ICACC 2025, PCSA delegates hosted an interactive booth designed to introduce students and professionals to the opportunities available through the organization. To engage attendees in a fun and dynamic way, they set up a mini-golf station where participants could test their putting skills while learning about PCSA initiatives. Informational flyers provided further insight into PCSA's mission, helping to spread awareness and encourage student involvement.

One of the most anticipated events organized by the PCSA was the annual shot glass competition, which blends scientific principles with hands-on experimentation. Approximately 45 students participated in the competition, using only pipe cleaners to design protective structures for a shot glass before it was dropped from increasing heights. ACerS President Monica Ferraris enthusiastically joined the event, taking on the role of dropping the shot glasses. The competition captured the interest of a larger audience, drawing more students and professionals to PCSA's initiatives while also serving as a reminder of how important creative problem solving is in the field of materials science.

To further enhance conference participation, the PCSA organized a scavenger hunt aimed at increasing engagement with poster presentations. By encouraging attendees to interact with student researchers, the scavenger hunt enabled networking opportunities and a deeper appreciation for the research being conducted by young professionals.

All photos credit: ACerS

a) Milos Dujovic, chair of the PCSA Conference Programming & Competitions Committee, holds up the scavenger hunt used to increase engagement with poster presentations.
b) Dujovic hands ACerS President Monica Ferraris a shot glass during the annual shot glass competition at ICACC 2025. Christine Brockman, another member of the PCSA Conference Programming & Competitions Committee, stands by.
c) The PCSA booth and d) mini golf setup at ICACC 2025.

The success of PCSA's activities at ICACC 2025 highlights their expanding role in student engagement and industry outreach. By developing innovative programs, they not only support students but also help build a strong workforce for the ceramic and glass materials community.

To learn more about the PCSA and its initiatives, or to support the CGIF's outreach programs that attract, inspire, and support future ceramic and glass professionals, visit foundation.ceramics.org. ■

Heating up space science: A review of UHTCs for radiation-cooled thermal protective systems

Purdue University researchers led by ACerS Fellow Rodney Trice published an open-access review paper summarizing the radiative behavior of various ultra-high-temperature ceramics (UHTCs).

Radiation distribution and the four types of emittances

The first section of the paper familiarizes readers with the concepts of thermal radiation and emissivity, which describes how efficiently a material can radiate thermal energy. One key point is understanding how the wavelength and direction of radiation affect its distribution from a surface.

"Radiation emitted from an opaque surface at a specific orientation typically spans a range of wavelengths . . . The wavelength-dependent distribution of radiation is referred to as a spectral distribution. In addition, an opaque surface may radiate preferentially in a particular direction, creating a directional distribution of emitted radiation," the authors write.

Based on the category of radiation distribution, there can be four types of emittances: spectral emittance, total emittance, directional emittance, and hemispherical emittance. In practice, emittances defined by the spectral distribution (first two types) are coupled to those defined by the directional distribution (last two types). Measuring all four types of emittances at high temperatures is essential to determine the radiative cooling potential of various UHTCs.

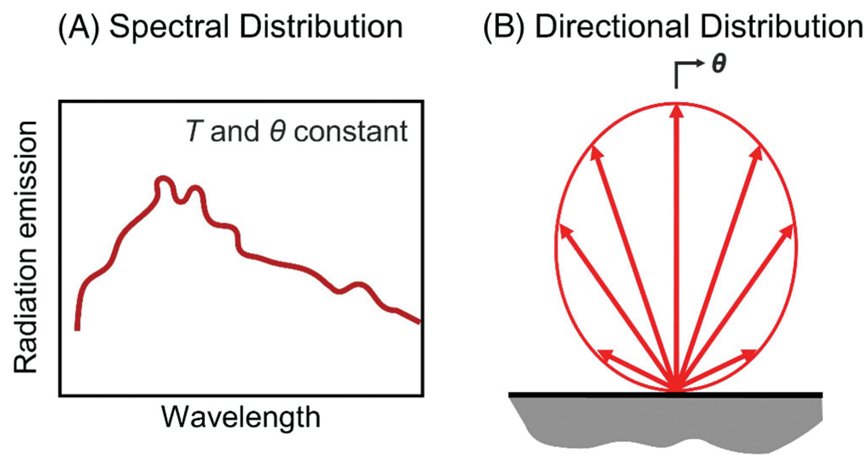


Figure 4 from the paper shows how radiation can be emitted from a surface as (A) spectral distribution and (B) directional distribution.

Measuring emittances

Emittance of a surface can be measured directly or indirectly through radiometric or calorimetric methods, respectively.

In the direct (radiometric) method, the emitted energy from a sample is measured directly using sophisticated optical instruments, such as Fourier transform infrared spectroscopy. The results are subject to systematic error due to the complexity and uncertainty augmented by multiple instruments involved in this technique.

In the indirect (calorimetric) method, the emitted energy from a sample is measured indirectly using a calorimeter. Unlike the radiometric method, the calorimetric method does not yield wavelength-specific or direction-specific radiative thermo-optical properties. On the other hand, it produces fewer erroneous results when testing at high temperatures.

Because both radiometric and calorimetric methods can be expensive to set up and operate at high temperature, some researchers have adopted an inexpensive emission measurement technique based on the principle of two-color pyrometry to estimate emittance at high temperatures. However, this method depends on correctly estimating various ratios of multiple variables as well as correctly maintaining a consistent direction of the pyrometers during testing. As such, it does not always provide accurate results.

Materials in the news

'Two-in-one' catalyst turns CO_2 into liquid methanol

Researchers led by Yale University developed a "two-in-one" catalyst that turns carbon dioxide into liquid methanol. They previously developed a single catalyst made of cobalt tetraaminophthalocyanine molecules supported on carbon nanotubes, but the reaction process had a mismatch on the single-site catalyst. The new process uses nickel tetramethoxyphthalocyanine for the conversion of CO_2 into CO. The CO then migrates onto the cobalt to complete the reduction into methanol. For more information, visit https://news.yale.edu.

Uniform nanocrystals thanks to liquid crystalline antisolvent

Researchers led by Pohang University of Science and Technology developed a new method for synthesizing perovskite nanocrystals. The new method uses liquid crystal as an antisolvent in the ligand-assisted reprecipitation technique. The elastic strains of liquid crystals restricts the growth of perovskite nanocrystals upon reaching the extrapolation length of liquid crystals, enabling mass production of uniformly sized perovskite nanocrystals without the need for additional purification processes. For more information, visit https://www.postech.ac.kr/eng/research/research_results.do.

Enhancing UHTC radiative properties

In the paper's fourth section, the authors provide a table that lists the emittance values for various UHTCs determined through past radiometric and calorimetric studies. Then, they discuss several emittance-enhancing techniques reported in the literature to improve the radiative properties.

For example, borosilicate layer-induced enhancement is commonly found in emittance studies of ZrB_2–SiC-based composites. The SiO_2-rich borosilicate layer formed through oxidation of ZrB_2–SiC can effectively improve emittance of the surface in the temperature range 1,100–1,200°C.

Additionally, rare earth oxides and rare earth ions are known for their high intrinsic emissivity in the infrared spectral region at high temperatures. Incorporating these materials into UHTCs can enhance emittance in the temperature range 1,200–1,600°C.

Finally, microstructure-induced emittance modification is also possible, as Wang et al. demonstrated in a 2015 paper. They compared the radiative performance of spherical SiC particles and longitudinal SiC whiskers used as a secondary phase in a ZrB_2–20 vol.% SiC composite microstructure up to 1,600°C. The low surface-area-to-volume ratio of whisker geometry resulted in enhanced thermal radiation.

Several other methods were also discussed, including the use of sintering additives, incorporating SiC fibers as a secondary phase, and forming UHTC matrix composites.

Future directions

The authors conclude the paper by suggesting several future directions for research. For example, they note that there is no universally accepted standard method for conducting high-temperature radiometric measurements.

"Further research is needed to design an in-situ standardized, precision emissometer so that the emittance can be measured in real-time, along with oxidation testing at temperatures over 1,800°C," they write.

Additionally, knowledge of emittance values at temperatures of more than 1,800°C is currently lacking, so methods for conducting experiments at those temperatures are needed.

Ultimately, the lessons drawn from this study should allow scientists "to measure and enhance the emissivity of UHTC materials for hypersonic applications," the authors write.

The open-access paper, published in *International Journal of Ceramic Engineering & Science*, is "Radiation heat transfer during hypersonic flight: A review of emissivity measurement and enhancement approaches of ultra-high temperature ceramics" (DOI: 10.1002/ces2.10171). ■

Toward room-temperature superconductivity: Recent studies offer insights into superconducting mechanisms

Several recent studies compared different types of high-temperature superconductors to help unlock clues to room-temperature superconductivity.

Nickel-based versus copper-based superconductors

In April 2023, Brookhaven National Laboratory announced the results of some experiments conducted on its National Synchrotron Light Source-II that revealed similarities and differences between nickel-based and copper-based high-temperature superconductors.

In both materials, the magnetic interactions between copper or nickel and oxygen ions played a role in electron movement, but the magnetic interactions among nickel atoms were slightly weaker.

The charge density wave—where electrons form a wave-like pattern that can result in a nonuniform distribution of charge in the crystal lattice—was also studied. In the nickelate, this wave depended on interactions among all different elements, whereas the cuprate's wave depended only on the interactions between copper and oxygen ions.

"These findings indicate the nickel compounds are promising to learn more about how the cuprates work, and they indicate the different ways you might want to change the nickel compounds to make them more like the cuprates," says Jennifer Sears, postdoctoral researcher at Brookhaven, in a press release.

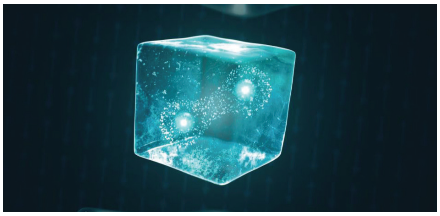
The first open-access paper, published March 2022 in *Physical Review X*, is "Role of oxygen states in the low valence nickelate $La_4Ni_3O_8$" (DOI: 10.1103/PhysRevX.12.011055).

The second open-access paper, published February 2023 in *Physical Review X*, is "Electronic character of charge order in square-planar low-valence nickelates" (DOI: 10.1103/PhysRevX.13.011021).

N-type superconductors

In August 2024, researchers from SLAC National Accelerator Laboratory, Stanford University, and other institutions observed that electron pairing, required for achieving superconductivity, can occur at much higher temperatures in *n*-type superconductors than previously thought, and in an unexpected material—an antiferromagnetic insulator.

The extremely underdoped cuprate family $Nd_{2-x}Ce_xCuO_4$ (NCCO) has not been deeply studied because its maximum superconducting temperature is relatively low—25 Kelvin (–248.2°C or –414.7°F)—compared to other cuprates. However, using angle-resolved photoemission spectroscopy, the researchers observed an anomalous normal-state energy gap in NCCO. This gap, which was an order of magnitude smaller than the antiferromagnetic gap, showed strong resemblance to a superconducting gap based on shape and sharpness.



Credit: Greg Stewart, SLAC National Accelerator Laboratory

Illustration of how electrons pair together in a superconducting material.

The researchers believe this normal-state gap originated from incoherent Cooper pairing of electrons, and this gap persisted up to about 140 K (–133°C or –207°F), which is much higher than the zero-resistance state of 25 K.

For compositions where $x = 0.11$, this gap became undetectable at temperatures around 50 K (–223.15°C or –369.67°F), which coincided with a minimum resistivity measurement. The resistivity increased as the temperature dropped below 50 K, which was attributed to a depletion of unpaired carriers.

These findings suggest that "the lack of higher-T_c superconductivity in *n*-type cuprates is primarily attributable to the limited mobility of Cooper pairs," the researchers write in the paper.

Though NCCO may not itself reach superconductivity at room temperature, the findings "suggest the potential for high-temperature [*n*-type] superconductivity comparable to the maximum transition temperatures observed in the *p*-type cuprates," the researchers write.

The open-access paper, published in *Science*, is "Anomalous normal-state gap in an electron-doped cuprate" (DOI: 10.1126/science.adk4792).

Materials in the news

New type of microscopy based on quantum sensors

Researchers at Technical University of Munich invented a new field of microscopy: nuclear spin microscopy. The technique involves using a microscope containing a tiny diamond chip to visualize magnetic signals of nuclear magnetic resonance. The diamond serves as a quantum sensor to convert the signals into light, enabling extremely high-resolution optical imaging. The resolution of the new microscope reaches ten-millionths of a meter—which is so fine that even the structures of individual cells can be made visible in the future. For more information, visit https://www.tum.de/en/news-and-events.

Deep nanometry reveals hidden nanoparticles

Researchers from the University of Tokyo and the University of Birmingham developed an analytical technique called deep nanometry. This technique combines advanced optical equipment with a noise removal algorithm based on unsupervised deep learning. It can detect particles as small as 30 nanometers at a rate of more than 100,000 particles per second. This technique proved its potential by detecting extracellular vesicles, which are an early sign of colon cancer, and it hopefully can be applied to other medical and industrial fields. For more information, visit https://www.u-tokyo.ac.jp/focus/en/press/z0508_00391.html.

Entangled quantum and classical signals successfully traverse fiber-optic cable simultaneously

A recent study by Northwestern University engineers demonstrates how quantum devices could be integrated into existing infrastructure and systems.

Their study involves the emerging field of quantum communications, which uses optical fibers to transmit quantum information over long distances. Whether quantum communications can be realized on a large scale, however, "will depend on the ability to propagate quantum signals in the same fiber as high-power classical signals," the engineers write in their open-access paper.

Current experiments on quantum–classical coexistence have focused on systems that directly transmit quantum information between network nodes. In other words, information is transferred without relying on the quantum phenomenon of entanglement, which is when the quantum state of two particles remains correlated regardless of the distance between them.

However, "many next-generation quantum applications require the disembodied transfer [entanglement] of quantum states between users," the authors write, "but teleportation over fibers carrying conventional communications has yet to be demonstrated."

In their paper, they describe a three-node quantum state teleportation system that simultaneously carries high-power C-band classical communications at a rate of 400 Gbps. Both the quantum and classical signals traverse a shared distance of 30.2 km, and the classical signal traverses an additional 48 km beyond that.

In a Northwestern University press release, first author Jordan Thomas, a Ph.D. candidate in the group of lead author Prem Kumar, says this ability to send information without direct transmission "opens the door for even more advanced quantum applications being performed without dedicated fiber."

The authors now plan to extend the experiments over longer distances, as well as use two pairs of entangled photons—rather than one pair—to demonstrate entanglement swapping. They will also explore the possibility of carrying out experiments over real-world, inground optical cables rather than on spools in the lab.

The open-access paper, published in *Optica*, is "Quantum teleportation coexisting with classical communications in optical fiber" (DOI: 10.1364/OPTICA.540362). ■

Mixed melt synthesis creates transparent glass composites from conventionally incompatible materials

Researchers led by Shifeng Zhou, professor at South China University of Technology, developed a method for fabricating transparent glass composites with high crystallinity (HC-TGC).

Currently, the selection of glass chemical formulations that can be directly crystallized to a volume fraction beyond 80% is quite small. In addition, it is challenging to combine thermally incompatible materials with strongly deviating stability ranges or materials with high mutual solubility within a single composite.

As a result, most current transparent glass composites derive from oxide phases; "combining non-oxide crystals with an oxide glass matrix at a high crystal volume fraction has been outside of current technology," the researchers write.

To overcome these challenges, the researchers carefully considered the solidification process of some well-known melts. They hypothesized that by mixing melts that exhibit very different crystallization habits at similar temperatures, it may be possible to achieve synchronous solidification of both a glassy and crystalline phase. If successful, there would be no need for extensive thermal processing, which often leads to competing phase transitions and crystal growth, among other secondary reactions.

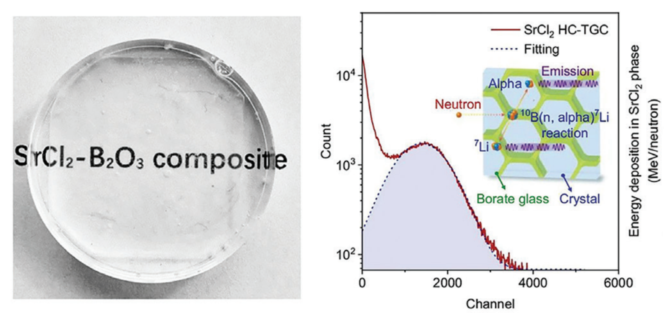
To validate this hypothesis, the researchers designed an oxychloride system composed of crystalline strontium chloride and a borate glass phase. First, they performed molecular dynamic simulations to understand the composite's likely structure evolution from melt to solid. They then fabricated the HC-TGC materials by melt-quenching mixtures of halide crystal powders and halide oxide glass powders.

Characterization of the HC-TGC material revealed it had a homogenous microstructure consisting of dense particles surrounded by a thin, glassy boundary layer. Further analysis of its optical and scintillation properties revealed its potential as a neutron detection system.

Neutrons are neutrally charged subatomic particles that many scientific and technological fields find useful to monitor, such as for radiation protection in nuclear energy and medicine. However, because the particles do not have an electric charge, they must be detected using indirect methods based on nuclear reactions.

Single crystals and glasses are often used in these detection systems because certain compositions have a high likelihood of interacting with incident neutrons. However, single crystal detector materials are currently available only in limited sizes, while current detector glasses have low light yield.

The new HC-TGC material overcomes both these limitations, offering large-scale sizes and record-high scintillating yield. In fact, the composite even captured large amounts of single neutron events during testing.



Left: Sample photograph of a transparent glass composite with high crystallinity. Right: Energy spectrum of the thermal neutron obtained by using the composite material.

The success of these tests led the researchers to fabricate oxybromide and oxyiodide composite systems as well using the mixed melt synthesis method. Based on this further confirmation of the method's generality, the researchers conclude that "these findings may help to bring about a generation of fully inorganic, transparent composites with synergistic combinations of conventionally incompatible materials."

The open-access paper, published in *Nature Communications*, is "Transparent composites for efficient neutron detection" (DOI: 10.1038/s41467-024-51119-w). ■

Tears of wine phenomenon inspires high-speed, large-area deposition of uniform nanofilms

In a recent paper, researchers from Nagoya University in Japan described a new simple solution-based deposition technique that not only overcomes the challenges of chemical vapor deposition (CVD) but does so with reduced environmental effects.

Currently, nanomaterials are often produced using CVD techniques. However, these processes are inherently energy intensive, and they can sometimes produce toxic byproducts. Applying green chemistry principles to CVD processes can make this manufacturing approach more sustainable, but it remains limited in its ability to allow damage-free and highly efficient transfer of layered 2D films onto arbitrary substrates.

As an alternative to CVD, researchers have investigated using solution-based deposition techniques to create well-packed, multilayered nanosheets on a mass scale. But to date, these approaches have been hindered by long processing times, complicated deposition operations, and limited coating sizes.

The new solution-based deposition technique developed by the Nagoya University researchers involves the well-known tears of wine phenomenon. This phenomenon is named after the thin film of liquid that creeps along the inside of a glass of wine. It is the result of the alcohol in wine evaporating faster than the water, which creates an interfacial tension gradient that pulls the wine upward.

In their method, the researchers created water/ethanol suspensions of 2D nanosheets with a cationic surfactant (tetrabutylammonium hydroxide). Then, with an ordinary pipette, they injected the suspension onto water in a petri dish.

As the ethanol evaporated, a surface tension gradient formed between regions with higher and lower ethanol concentrations. This gradient caused a spontaneous spreading of the nanosheet suspension from the center (low surface tension) to the edges (high surface tension), resulting in the formation of large, uniform monolayers of the nanomaterials within seconds.

The researchers successfully applied the technique to various nanosheet compositions and structures, including metal oxides, hexagonal boron nitride, and molybdenum disulfide. The technique also worked when using different organic solvents, including acetone, formamide, and isopropyl alcohol.

In addition to its versatility of composition, the method required only a small amount of suspension. This situation stands in contrast to those of previous deposition techniques, which typically wasted more than 90% of the suspension for monolayer coating.

The paper, published in *Small*, is “Ultrafast 2D nanosheet assembly via spontaneous spreading phenomenon” (DOI: 10.1002/smll.202403915). ■

Next step in cement-free refractories: Follow-up study confirms potential of geopolymer binders

Researchers at the Federal University of São Carlos in Brazil published a follow-up study that confirmed the potential of a new geopolymer composition to replace calcium aluminate cement (CAC) binders in monolithic refractories.

CAC is a rapid-hardening cement that is resistant to high temperatures and corrosive substances. However, to create CAC, a lime-containing material is reacted with an aluminous material, producing carbon emissions. Additionally, CAC-bonded refractories must undergo a carefully controlled drying process, which involves high energy consumption and significant financial costs.

Instead of CAC binders, geopolymers have emerged as a promising binder option. Geopolymers are a class of inorganic aluminosilicate materials that consist of well-polymerized nanoparticles ranging in size from 5 to 40 nm. Advantages of using geopolymers as refractory binders include quick setting, reduced risk of explosions while drying, and optimized mechanical behavior at both low and high temperatures. Plus, geopolymers can be synthesized from industrial waste and byproducts at lower temperatures.

Credit: HWI. A member of Calderys: YouTube

A worker at HarbisonWalker International transfers a refractory product from the assembly line to the stack of finished goods. In the future, different materials may be used as binders in refractories to reduce the industry's carbon emissions.

In September 2023, the Federal University of São Carlos researchers designed new geopolymers derived from metakaolin, a dehydroxylated form of the clay mineral kaolinite, and synthesized them using several different alkaline silicate-containing liquid reagents. The geopolymers synthesized using the sodium-based liquid reagent demonstrated the most desirable properties, with geopolymer-bonded high-alumina castables exhibiting faster setting times and enhanced flexural strength compared to CAC-bonded high-alumina castables.

These results were only preliminary, however, because commercial refractory compositions "are inherently more complex than the ones investigated in this study, as they incorporate both fine and coarse aggregates," the researchers wrote. In the original study, the experimental castables only contained fine aggregates.

In the follow-up study, the researchers explored how well the geopolymer binder performed in the presence of fine and coarse aggregates. They synthesized high-alumina castables that either partially or fully replaced the traditional CAC binder with the sodium-containing geopolymer binder. The researchers drew several conclusions after testing the castables:

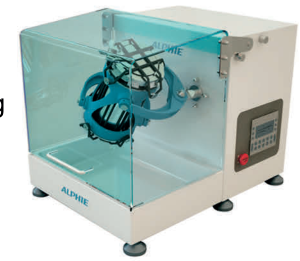
1. **Rheological behavior.** A higher weight percent of geopolymer binder in the castable required larger quantities of liquid to facilitate the mixture of components.
2. **Flexural strength.** The geopolymer and CAC binders endow the castable with flexural strength through different mechanisms. In castables containing blends of CAC and geopolymer binders, the traditional cement hydration process was inhibited while the geopolymerization process was enhanced.
3. **Microstructure.** During processing, the geopolymer binder forms a liquid phase that vitrifies upon cooling. This vitrification provides a strong interfacial bond between the fine and coarse components of the castables, resulting in robust castables with cohesive and rigid microstructures.

Using this knowledge, the researchers determined that optimal thermal and mechanical performance was achieved using a combination of CAC (2.7 wt.%) and geopolymer (1.3 wt.%) binders. At 1,400°C, these samples displayed shrinkage of 1.18%, elastic modulus of 135 GPa, and flexural strength of 39.1 MPa. They also demonstrated high thermal shock resistance after 10 cycles at 1,025°C (ΔT ~1,000°C).

"The obtained results demonstrate that the evaluated geopolymer binders are promising options for developing new ceramic compositions for cement-free or ultralow-cement-containing advanced refractory castables," the researchers conclude.

The 2023 paper, published in *International Journal of Applied Ceramic Technology*, is "Design, characterization, and incorporation of geopolymer binders in refractory ceramic compositions" (DOI: 10.1111/ijac.14507).

The 2024 paper, published in *Journal of the European Ceramic Society*, is "Geopolymers: A viable binder option for ultra-low-cement and cement-free refractory castables?" (DOI: 10.1016/j.jeurceramsoc.2024.02.013). ■




ceramics in biomedicine

Flexible artificial retinas: Emerging paradigm with big potential for treating eye diseases

Retinitis pigmentosa, a hereditary eye disease that causes progressive visual loss, affects more than 1.5 million people globally. To address this serious health issue as well as other retinal diseases that can lead to blindness, researchers around the world are working to develop retina prostheses.

Retinal prostheses are implantable electronic devices designed to stimulate sensation of vision in the eyes of individuals with significant retinal diseases. To date, efforts to develop rigid, electrode-based retinal prostheses have achieved limited success. Instead, researchers now are investigating flexible, biocompatible implants using a variety of technologies and materials.

In December 2023, Sungkyunkwan University researchers published a paper describing a new bioinspired artificial retina based on a simple resistor structure. To develop this structure, they used a fibrous platform rather than the planar platform reported in many previous studies. This approach more closely mimics the structure of the human retina and fiber-shaped optic nerve.

Their retina consists of three layers formed vertically on a polyurethane fiber:

- ZnO nanorods form the sensing layer, which functions in a manner similar to that of photoreceptor cells. In other words, the nanorods absorb the incident light and generate electron–hole pairs.
- The electron–hole pairs form the depletion (intermediate) layer, which operates like a bipolar cell. These cells transmit signals from the photoreceptors to the ganglion cells.
- A polymer mixture, PEDOT:PSS, forms the output or bottom layer, which acts like a ganglion cell. These cells send information from other retinal neurons to the rest of the brain. The depletion layer modulates this layer's electrical conductivity, generating synaptic behavior.

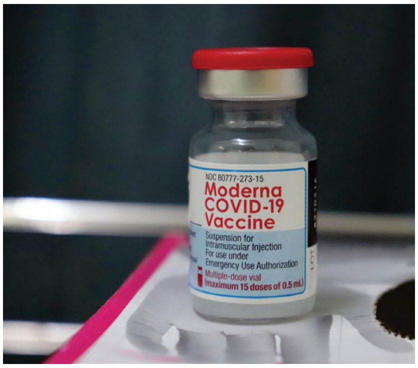
Gold electrodes on the fiber, which mimic the function and structure of a fiber-shaped optic nerve, detect the output layer's synaptic behavior for further analysis and image processing.

Testing showed the artificial retina offered several advantages, including a similar structure to that of a natural retina, the ability to work in both dark and light conditions, and no significant mechanical degradation during operation.

The paper, published in *Advanced Functional Materials*, is "Bio-inspired artificial retinas based on a fibrous inorganic–organic heterostructure for neuromorphic vision" (DOI: 10.1002/adfm.202309378). ■

Global experts DELIVER a framework for translating nanomedicines to the clinic

A global team of expert scientists in academia and industry developed a set of standards to help slash costs and reduce the time it takes to develop nanomedicine treatments and make them available for patients.



Credit: Mufid Majnun, Pexels

There are more than 50 nanomedicine products currently approved for clinical use, including mRNA vaccines to immunize against coronavirus, which were made possible by lipid nanoparticles.

The so-called DELIVER framework, as described in a recent paper, comprises core principles for early-stage development. By following these guidelines, researchers will be able to more quickly "deliver nanomedicines to clinical development, regulatory approval, and market registration," the authors write.

The principles are categorized as either "Essential," "Important," or "Useful." For example, while it is "Essential" to use biocompatible and nontoxic nanomaterials, using biodegradable nanomaterials is only considered "Important," while a "Useful" practice is undertaking silico toxicity screening.

The authors note that the DELIVER framework's emphasis on early-stage development complements existing guidelines for late-stage development, such as those by the U.S. Food and Drug Administration and the International Organization for Standardization. However, they emphasize that the framework should not be used to advocate against exploratory or "blue sky" research activities that have no or little intention of immediate clinical translation.

"Fundamental research is critical for progressing the field of nanomedicine and is necessary to uncover the underlying mechanisms that underpin nanomedicine efficacy and toxicity, as well as contribute to radically new concepts and solutions," they write. "Fundamental investigators must continue to develop and explore novel nanomedicines and inform translational investigators of the mechanisms driving disease pathology, the bio-barriers limiting therapeutic efficacy, the need for patient stratification, and the future strategies that can be employed for optimizing nanomedicines efficacy."

The paper, published in *Nature Nanotechnology*, is "A translational framework to DELIVER nanomedicines to the clinic" (DOI: 10.1038/s41565-024-01754-7). ■

ceramics in the environment

'Design for Demise' offers greener approach to space exploration

Looking up at the nighttime sky, it can be easy to forget that the peaceful, twinkling stars belie the harsh environment existing beyond our atmosphere. In addition to extreme temperatures that run hundreds of degrees below and above zero, high-energy radiation and ultrahigh vacuum make space a difficult place to safely visit.

For this reason, spacecraft typically consist of materials that can withstand the harsh environment, such as ceramics and glass. Unfortunately, designing all equipment to be this sturdy has led to a new hazard—space debris.

In our 60+ years of space activities, the European Space Agency (ESA) reports that more than 6,050 launches have resulted in some 56,450 tracked objects in orbit, of which about 28,160 remain in space and are large enough to be cataloged. When accounting for miniscule pieces—such as lens covers, peeling insulation, and fragments produced from colliding objects—that number rises to the millions.

Considering that a piece of space debris the size of a blueberry can create the impact of a falling anvil, it is important for spacecraft to avoid colliding with this junk. But steering clear of debris is becoming increasingly challenging as private space entrepreneurs add to the rubbish cloud by launching unprecedented numbers of new satellites into orbit.

The problem of space debris has been a topic of discussion since the late 1970s, but it is only recently that governments have expanded from funding programs that simply track the junk to actively supporting initiatives that remove or prevent it.

For example, in 2014, the ESA announced the Clean Space program, which aims to safeguard the terrestrial and orbital environments from space debris. As explained in the launch video (below), the problem of space debris will be tackled through several pathways, including by designing satellites to have less than a one in 10,000 chance of surviving reentry to Earth's atmosphere.

This "Design for Demise" approach to satellite construction has led to several innovations. For instance, as explained in a SpaceNews article, engineers from Portuguese space technology company LusoSpace worked with the ESA Clean Space team to test a new magnetorquer design. They purposefully exposed a portion of the device's core, which allowed it to burn up completely when separated from the spacecraft. In contrast, previous magnetorquer models had only a 60% chance of burning up when released.

Besides ESA, several university research groups have successfully applied "Design for Demise" principles. For example,

- **Brown University**: In March 2023, the university reported on the success of a 3D-printed drag sail created by students to bring satellites out of orbit much more quickly than usual.
- **Boston University**: In May 2024, the university reported that several students won first place in the second annual Collegiate Space Competition. They proposed using nanosatellites to move space debris into position for reentry.

Credit: Marco Cross, Brown University

Brown University graduate Marco Cross holds the SBUDNIC satellite, which he led development on. This satellite is designed to reenter Earth's atmosphere more quickly than normal, thus helping reduce space debris.

Doing so would allow satellites to use all the fuel on board rather than saving some for reentry, thus extending their lifecycle and reducing the number of new satellites sent to space each year.

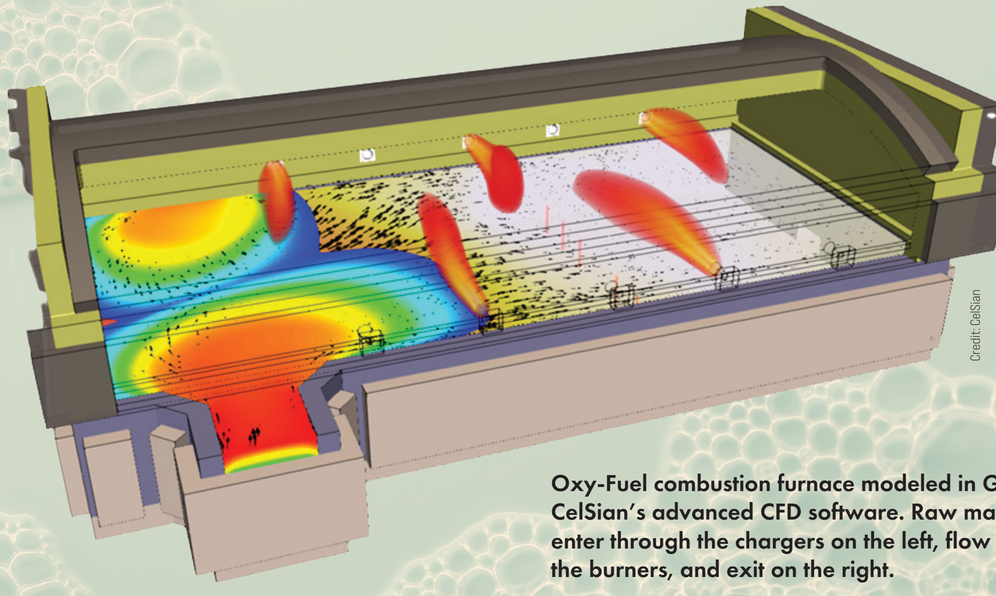
- **Kyoto University**: In June 2024, Nature magazine reported on a satellite created by researchers at Kyoto University and Tokyo-based logging company Sumitomo Forestry. Called LignoSat, the satellite is made of magnolia-wood panels and an aluminum frame, which should allow it to incinerate easily upon reentry.

Despite the benefits of adopting a "Design for Demise" mentality, space agencies around the world have typically applied the approach in an ad hoc manner. But that may change with the new Zero Debris Charter.

Facilitated by ESA, the Zero Debris Charter is a community-driven and community-building document and initiative for the global space community. It contains both high-level guiding principles and specific, jointly defined targets to get to zero space debris by 2030.

The charter was finalized in spring 2023 and unveiled at the ESA Space Summit in November. In May 2024, ESA and 12 countries signed the charter. More than 100 organizations, including industrial and academic institutions, promised to sign the community-led endeavor in the coming months. Organizations can register their intent to sign the charter at https://esacontact.esa.int/zero-debris-charter-registration. ■

Leveraging computational fluid dynamics for sustainable glass manufacturing



Oxy-Fuel combustion furnace modeled in GTM-X, CelSian's advanced CFD software. Raw materials enter through the chargers on the left, flow under the burners, and exit on the right.

By Katelyn Kirchner, Tim van Lier, and Scott Cooper

In today's rapidly evolving glass industry, two critical—but often distinct—priorities dominate the conversation: industry's focus on improving sustainability, reducing costs, and maintaining product quality and academia's pursuit of a deeper, theoretical understanding of the chemistry and physics underlying glass-forming systems.

At first glance, these goals may seem divergent, with one rooted in practical application and the other in fundamental science. However, the path to addressing industrial challenges lies in bridging these two realms. The key is leveraging cutting-edge scientific research to build advanced, physics-based manufacturing tools capable of navigating the complexities of modern glass production.

Through this lens, this article outlines how computational fluid dynamics (CFD) serves as more than just an engineering tool; it is a gateway to uncovering the physical and chemical changes that occur during glass processing. As the industry embarks on larger transformative steps toward a more sustainable future, understanding and accurately predicting these fundamental intricacies at a deeper level will prove crucial for ensuring advancements can be implemented reliably.

Glass processing challenges in industry and academia

Industry

With growing consumer demand for environmentally friendly products, increasing regulatory pressures to reduce carbon emissions, and shifting energy sources and costs, manufacturers face unprecedented challenges. Various alternative fuel sources and heating technologies (e.g., hydrogen combustion[1] and electric furnaces[2]) have emerged as potential future paths.

One industry-ready alternative heating technique that does not require a completely new furnace rebuild is the transition from air-fuel to oxy-fuel combustion. However, even this relatively small change in the melting method can profoundly impact the final glass because the combustion atmosphere affects everything from heat transfer efficiency to prevalent chemical reactions, which can lead to compromised product quality, enhanced refractory corrosion, increased emissions, and/or inefficient energy use.

Academia

Academia has made significant strides in unraveling the fundamental physics and chemistry of glass-forming systems. Advances in glass formation, characterization, and atomistic simulations provide critical insights into phenomena such as viscous flow, network structure evolution, and ionic diffusion. Resulting implications for the industry range from optimizing melting processes to developing new glass compositions with tailored properties.

However, the challenge lies in translating these theoretical insights into practical applications. For instance, understanding the atomic-scale interactions that govern viscosity is crucial, but how can this knowledge be applied to improve the energy efficiency of a commercial furnace? Similarly, while fundamental research has elucidated the effects of various dopants on glass properties, how can manufacturers use this information to design new compositions that meet stringent environmental standards?

Computational fluid dynamics: Bridging fundamental science and applied practice

A solution to these challenges lies in advanced modeling and simulation tools that make use of the fundamental physics and chemistry observed in microscopic simulations and lab-scale testing. Here computational fluid dynamics (CFD) modeling excels.

CFD's foundations trace back to Newton (1687) and Navier-Stokes (1822), but its true potential emerged with the development of programmable computers in the 1940s.[3] This modeling technique works by dividing a physical domain into a grid or mesh, which consists of a set of millions of smaller cells (Figure 1a). Using numerical methods, the computer iteratively solves governing equations in each cell, simulating how fluid moves, mixes, or interacts with surfaces and boundaries (Figure 1b). These properties can then be monitored across a full endport-fired furnace (Figure 1c). Result accuracy depends heavily on the mesh quality, boundary conditions, and fundamental mathematics implemented to represent the behaviors of the system.

From jet engine design to weather models to glass furnaces, if the correct mathematical models and boundary conditions are established, CFD has the capability to model a vast range of dynamic processes that are otherwise difficult to visualize or expensive to investigate experimentally.

Within the past five to 10 years, the CFD tools designed for glass melting dynamics have greatly improved. One such advanced CFD software for the glass industry is CelSian's GTM-X,[4] which is routinely and strategically implemented to enhance energy efficiency, improve product quality, reduce emissions, and increase furnace lifetimes, as well as reveal new understanding of the fundamental glass science driving structure–property–performance relationships.

For one example of how CelSian's GTM-X software helps improve glass furnace operations, consider the scientific findings revealed from modeling the transition from air-fuel to oxy-fuel combustion.

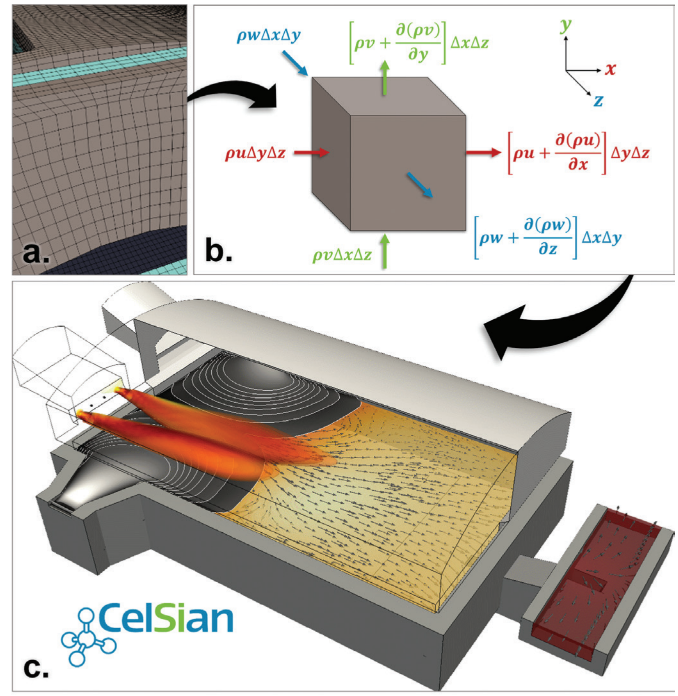


Figure 1. Example CFD model of a portfolio endport-fired combustion furnace. a) Meshed grid representation of the physical system. b) Pictograph to represent example properties calculated within each grid cell (e.g., mass/heat flux, species concentration, reaction rates, pressure, density). c) Sample output from GTM-X, CelSian's advanced CFD software. In part c, the arrows denote normalized velocity vectors at the interface between the combustion space and glass melt. The grey circles are the charging zones where raw material is introduced.

Combustion in glass manufacturing

Combustion is a critical process in traditional glass manufacturing, providing the high temperatures needed to melt raw materials into molten glass. For combustion to occur, three essential components are required: fuel, an oxidant, and ignition. The fuel reacts with oxygen from the oxidant to produce heat and other byproducts, such as water vapor and carbon dioxide for the case of natural gas (methane) fuel sources.

In air-fuel combustion, the oxidant is air, which consists of roughly 21% oxygen and 78% nitrogen. The nitrogen in air remains largely inert, absorbing heat and reducing overall efficiency. The appeal of oxy-fuel combustion is that it uses pure oxygen as the oxidant, which eliminates the heat lost to nitrogen, resulting in higher energy efficiency. It also results in a significant reduction in nitrous oxide (NO_x) emissions, which are a cause of acid rain and thereby a regulated pollutant.

The reduction of nitrogen from the combustion process reduces the total volume of gases exiting the furnace (called flue gases), thereby concentrating the emitted CO_2. This concentrated source could improve efficiency of future carbon capture technologies. Additionally, the reduced flue gas volume lowers the overall greenhouse gas emissions per unit of glass produced, thereby providing a clear pathway for meeting sustainability targets.

Oxy-fuel combustion, as compared to other alternative technologies, leverages the current furnace infrastructure. This use of existing equipment makes oxy-fuel combustion a more accessible and cost-effective stepping stone for manufacturers aiming to reduce their carbon footprint without major disruptions to production.

However, a common problem when transitioning to oxy-fuel combustion is increased foaming of the glass melt, which occurs when gas bubbles become trapped at the surface of molten glass (see sidebar: "Foaming in oxy-gas atmosphere"). If foaming is not understood and controlled, manufacturers can experience major furnace upsets resulting in glass quality issues, refractory degradation, and production loss. Foam also insulates the molten glass, thereby reducing heat transfer efficiency through the melt and decreasing homogenization, leading to quality defects and operational instability.

To better understand the observed foaming, lab-scale studies have quantified the off-gassed species to reveal how raw material selection and atmospheric changes impact foam height as a function of time and temperature. Additionally, recent work simulating nucleation, growth, and interactions of gas bubbles at the atomic scale have revealed how controlled oxygen partial pressure can affect bubble stability and dissolution rates, as well as how changes to glass structure and network modifier concentrations can impact gas retention.

These studies provide critical insights into the mechanisms underlying foaming and have demonstrated how factors such as interfacial tension, gas diffusion rates, and local temperature gradients influence bubble behavior in molten glass. Such scientific findings define the mathematics underlying advanced CFD software to explore these phenomena in real, large-scale furnaces.

Foaming in oxy-gas atmosphere

Under oxy-gas conditions, the reduced nitrogen content leads to a 35 vol.% increase in water vapor in the atmosphere above the glass melt. Water vapor reduces the solubility of sulfur in the melt, causing its potential decomposition into bubbles in the molten glass. The increased gas release subsequently creates bubbles and foaming.

To combat this issue, one solution is to decrease the amount of sulfur dissolving in the melt by decreasing the sulfur content in the batch materials. Another solution is to shift the furnace to a reducing atmosphere. A lower redox promotes the decomposition of sulfates earlier in the process, minimizing the release of SO_2 at higher temperatures and reducing excessive bubbling in an oxidized glass.

Harnessing CFD to optimize bubbling and fining

Some extent of bubble formation is necessary to promote product quality, in a process called fining. Fining relies on growing bubbles within the melt to promote buoyancy. Increasing the partial pressure of gases dissolved in the melt drives them into bubbles, causing them to be stripped from the molten liquid. Once the gas reaches the surface, it gets trapped in a foam layer or exchanges out of the melt and into the combustion space.

Breaking up the foam layer is critical to avoid excessive foaming. CFD analysis reveals how higher velocities in air-fuel combustion can help overcome surface tension constraints and pop bubbles to enable a thinner foam layer. However, CFD redox calculations confirm that forcing higher velocities in oxy-fuel combustion would correspond with higher oxygen concentrations and thereby a more oxidized condition, which in this case promotes excessive foaming. Therefore, the burner configurations and gas flow velocities need to be finely tuned and highly understood to enable efficient fining and avoid excessive foaming.

Similarly, slight changes in localized temperature, pressure, or velocity will impact the bubbling dynamics. For example, fining gases such as SO_2 and O_2 released in the glass melt help bubbles grow and rise to the melt surface. In locations where the partial pressure of the gases in the melt is below the atmospheric pressure, SO_3 and O_2 will instead remain dissolved in the glass. By tracking the path of dissolved raw material particles and gaseous bubbles, the precise pressure and temperature profile modeled in CFD will dictate the effectiveness of the fining process, as shown in Figure 2.

Figure 2 shows an example CFD output for the fining process. The behavior of gaseous SO_2 in the melt is temperature dependent, so Figures 2a and 2b show the mole fraction of SO_2 and corresponding temperature streamlines in a standard flint soda lime silicate melt. Here the combustion space is omitted from the visualization to focus the discussion on the dynamics within the melt.

Most of the sulfate enters as batch materials introduced at the chargers, shown at the top right end of the furnace. In regions with sufficient temperature and time, sulfate reacts to form SO_2 gas. Figures 2c and 2d track the SO_2 content and diameter of a sample bubble that forms near the batch charger. The bubble follows the local convective flow of the liquid melt. When the bubble receives SO_2 from chemical reactions occurring further down tank, it increases in diameter up to 400 µm. However, the bubble does not reach the melt surface and thus remains trapped in the melt.

From here, the bubble follows the convective flow pattern back toward the charger. At this point, the bubble reverses in direction below the batch, decreases in temperature, and thus increases the sulfur solubility back into the melt. As the convective force causes the bubble to flow down tank again, its temperature increases, which allows the bubble to receive more gas from the continued melt reactions. The bubble's diameter subsequently increases, and the resulting buoyancy effects drive the bubble to the surface, where it exchanges out of the melt.

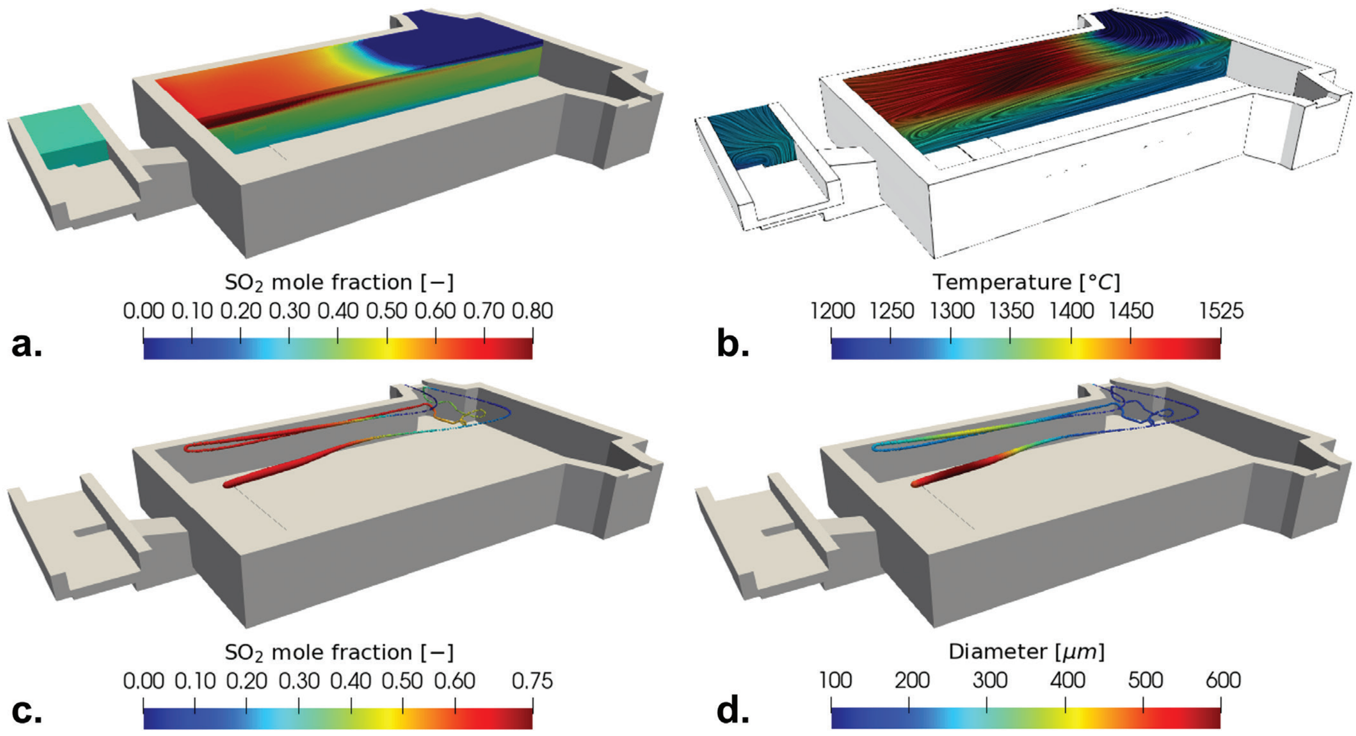


Figure 2. A sample output from GTM-X, CelSian's advanced CFD software, of a portfolio endport-fired combustion glass furnace. The color bars denote a) the SO_2 mole fraction and b) the temperature within the glass melt during steady-state operating conditions. Parts c) and d) visualize the SO_2 mole fraction and diameter of a single bubble as it moves from its formation in the top right to its dissolution in the bottom left.

With CFD modeling, researchers can test adjustments to operating conditions, convective flows, and furnace designs to optimize the fining process and achieve improved final product quality. Recent CFD developments have unlocked improved capabilities to couple detailed redox chemistry with bubble growth, sand dissolution, coloration, dynamic foam layers, and time-transient analyses. Such software additionally captures glass melt flow, temperature gradients, raw material melting, impact of flame and combustion chemistry on the melt, combustion dynamics, corrosion, evaporation and depletion, and melt homogeneity.

Preparing for future innovations

As the glass industry faces increasing pressure to decarbonize, manufacturers will need a deep understanding of how the transition to alternative energy sources and advanced process control systems may impact glass forming and furnace dynamics. Accurately validated simulation tools such as CFD are poised to play a pivotal role in enabling this transition by allowing for the exploration of scenarios that would be prohibitively expensive or time-consuming to investigate in pilot experiments. Furthermore, artificial intelligence-driven systems that run together with these physics-based simulations can predict glass quality based on real-time parameters in the furnace, thus enabling the use of real-time data to make decisions on the fly.

To realize this potential, academia and industry must work together to wed their respective knowledge of fundamental science and applied practice. Only then can we prepare for the next great leap in glass manufacturing—one simulation at a time.

About the authors

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Transformative potential: Innovative AI and ML solutions for the glass and ceramics industry

By Robert Fu, Mitch Odinak, Fangze Xu, Keith House, and John Brown

Artificial intelligence and machine learning help manufacturers avoid the costs of inefficient material design and production processes. This article highlights how AI/ML solutions provider ZW developed products tailored to support the glass and ceramics industry.

In the past 15 years, the evolution of artificial intelligence (AI) and machine learning (ML) systems has unequivocally cemented this technology's role as the cornerstone of the Fourth Industrial Revolution.[1–4] It has enabled the development of high-performance laptops that can accomplish in minutes what once required weeks of intensive computing on supercomputers. This transformation is not merely incremental; it has redefined the possibilities of data-driven solutions.

The year 2024 stands as a watershed moment in the integration of AI/ML into science and industry, with Nobel Prize laureates in physics and chemistry underscoring the profound impact of these technologies. The momentum is clear: Those who adopt AI/ML solutions gain a decisive competitive edge, while those who delay risk obsolescence in a rapidly evolving marketplace.

This article is dedicated to empowering professionals in the glass and ceramics sector—scientists, engineers, project managers, and business leaders alike—to navigate this paradigm shift effectively. We will explore

- **Critical advantages of embracing AI/ML solutions now**, with examples from highly technical materials industries;
- **Risks of hesitating to adopt these technologies**, including competitive disadvantages and lost opportunities; and
- **Practical strategies for leveraging AI/ML**, with examples pulled from the product offerings of AI/ML solutions provider ZW (Chapel Hill, N.C.).

AI and ML advantages: Overcoming limitations of traditional engineering tools

The glass and ceramics industry is navigating an era of unprecedented complexity, marked by multifaceted challenges involving raw material supply chains, energy sources, and emissions concerns, among others. Efforts to address these challenges have exposed the limitations of traditional engineering tools.

Conventionally, manufacturers used statistical methods that rely on linear approximations or isolated parametric studies to model manufacturing processes and industrial systems. However, advanced manufacturing in the glass and ceramics sector involves orchestrating hundreds or even thousands of interdependent variables, and the traditional statistical methods often miss the complex, nonlinear interactions within these intricate systems. For instance, simplifying chemical kinetics or particulate-media radiative heat transfer models can introduce inaccuracies that undermine decision-making.

Similarly, conventional modeling and simulation tools struggle to generate reliable universal equations and boundary conditions. This challenge is especially pronounced in dynamic scenarios involving intricate interactions among material compositions, thermal properties, and manufacturing parameters. As a result, manufacturers relying solely on these tools often face suboptimal outcomes, missed optimization opportunities, and inefficiencies that hinder growth.

In contrast to the traditional methods, AI and ML technologies are explicitly designed to handle the scale and complexity of modern manufacturing datasets. Large language models (LLMs) and deep neural networks (DNNs) specifically can enable regression and classification tasks across vast variables with exceptional accuracy.[5] By training on extensive historical datasets, these models can autonomously uncover intricate patterns and relationships that are otherwise imperceptible to conventional methods.

> "AI has brought the Fourth Industrial Revolution to an inflection point, and manufacturers must choose a path forward: innovate, accelerate, or follow fast."
>
> –McKinsey & Company, February 2024

Below are some of the most pressing challenges in industrial environments today that can benefit from AI and ML solutions:

- **Material composition discovery and optimization:** Quickly invent new compositions and enhance product performance through precise adjustments to raw material combinations.
- **Manufacturing process optimization:** Reduce energy consumption and increase throughput by optimizing heating cycles, furnace operations, and other parameters.
- **Defect detection and yield improvement:** Identify and mitigate flaws in real time to boost production quality.

Additional challenges unique to certain highly technical material industries can be seen in the sidebar "Market segments for AI/ML solutions."

Market segments for AI/ML solutions

Advanced glass and ceramics manufacturing:
The glass and ceramics industry stands to gain significantly from AI/ML capabilities. Manufacturers producing components for semiconductors, electronics, photovoltaic systems, telecommunications, photonics, consumer, biopharma, electric vehicles/batteries, automotive/aerospace, and air/emissions treatment face the challenge of optimizing material compositions and manufacturing processes to meet increasingly stringent performance and sustainability standards.

Manufacturing equipment and refractory material suppliers:
Manufacturing equipment and refractory material suppliers are the backbone of many advanced manufacturing processes, and they encounter the challenge of delivering high-performance solutions tailored to specific industrial sectors, ranging from telecommunications and biopharma to automotive and aerospace.

Polymer and organic material enterprises:
Industries relying on polymers and organic materials, including healthcare, biopharma, electric vehicles, and aerospace, face highly specialized challenges in material development and product performance. These applications require polymers with unique thermal, mechanical, or biocompatible properties, necessitating complex design and testing processes.

CNC, 3D printing, and injection molding shops:
Small and medium-sized enterprises specializing in computer numerical control machining, 3D printing, and injection molding are integral to the production of custom components for industries such as semiconductors, healthcare, renewable energy, and automotive. These shops often grapple with the dual pressures of maintaining competitive pricing while ensuring precision and quality in their outputs. ■

Risks of delayed AI/ML adoption

AI and ML technologies are no longer a nascent or experimental field; they are a transformative force reshaping industries by unlocking unprecedented efficiency, precision, and cost reductions. If manufacturers do not adopt AI and ML solutions into their workflow, they risk falling behind competitors in several key areas (Figure 1):

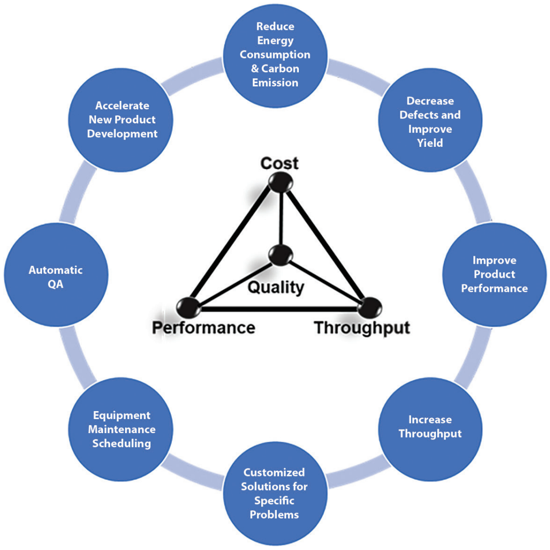
- **Product development:** AI/ML solutions can accelerate new product development by identifying optimal product design, materials discovery, and system integrations.
- **Sustainability goals:** AI/ML models can optimize energy usage, enhance raw material conversion rates, and reduce emissions. These solutions directly support environmental compliance and sustainability targets without compromising output quality or profitability.
- **Manufacturing efficiency:** AI/ML solutions can optimize key process parameters, mitigate overshoot in control systems, and reduce defect rates. Such improvements help reduce overall manufacturing costs, boost throughput, and minimize the need for capital-intensive investments in new production lines.

Practical strategies for leveraging AI/ML in industry

As manufacturers advance further into the Fourth Industrial Revolution, adopting AI and ML solutions becomes imperative to avoid the costs of inefficient material design and production processes. To make these solutions effective, however, requires the development and optimization of some key AI and ML aspects:

- **Train customized LLMs:** Manufacturing processes make use of many specific linguistic, contextual, and analytical requirements. The ability of LLMs to deliver actionable insights with unparalleled precision can be improved through techniques such as prompt engineering, fine tuning, and retrieval-augmented generation.
- **Employ specialized DNNs:** DNNs can be designed to tackle a wide range of complex tasks, including sophisticated regression, advanced pattern recognition, and adaptive control systems. These networks also excel in dynamic job scheduling and automatic hyperparameter optimization, enabling streamlined operations and enhanced efficiency.
- **Develop advanced optimization algorithms:** Advanced optimization algorithms enable manufacturers to identify optimal solutions in multidimensional parameter spaces, facilitating superior decision-making and resource utilization.
- **Rely on extensive domain expertise:** Manufacturers know best what operational challenges they face, and garnering input from experienced employees can allow seamless integration of AI/ML solutions, ensuring that the technology is not only innovative but also deeply aligned with real-world manufacturing needs.

As manufacturers begin exploring the adoption of AI and ML technologies, they should keep three things in mind when considering potential AI/ML solution providers:



Credit: ZW LLC

Figure 1. AI/ML solutions can help manufacturers address four key manufacturing aspects: cost, quality, performance, and throughput.

- **Experience:** Providers that employ staff with a background in materials R&D and manufacturing will more intimately understand the complex challenges of the manufacturing industry and how AI/ML technologies can effectively solve them. This background ensures solutions that are both innovative and practical.
- **Comprehensive solutions:** Providers that offer a holistic end-to-end approach, from AI model development to deployment in production environments, will allow the delivery of fast, reliable, and impactful results, tailored to the specific needs of the business.
- **Value focused:** Providers that prioritize outcomes that matter most—lowering costs, boosting throughput, and enhancing profitability—will more successfully design and deploy systems that deliver tangible business benefits and strengthen the bottom line.

ZW's AI/ML solutions for glass and ceramics

AI/ML solutions provider ZW has developed three flagship products—Z-MAP®, Z-FASTQ®, and Z-AI®—specifically tailored to support the glass and ceramics industry.

Z-MAP: Trusted AI personal assistant: Z-MAP redefines the role of AI in advanced manufacturing by functioning as an intelligent, user-centric assistant designed for scientists, engineers, and business leaders. Unlike traditional analytical tools, Z-MAP integrates advanced AI technologies, such as prompt engineering, fine-tuned LLMs, and retrieval-augmented generation, to deliver actionable insights in under 15 minutes.

Z-MAP is not just about speed—it has been trained using extensive historical material datasets so it can deliver highly reliable and accurate outputs tailored to the nuanced demands of glass and ceramics manufacturing. Operating within a secure environment, it eliminates data security concerns often associated with cloud-based solutions. By empowering users with instant, actionable intelligence, Z-MAP accelerates workflows and reduces time-to-insight in the manufacturing sector.

Z-FASTQ: Instant and reliable quotation generation: In today's fast-paced manufacturing environment, speed and precision are paramount, especially during the quotation process. ZW's Z-FASTQ automates and streamlines this critical function, delivering highly accurate, professional-grade quotations within three minutes. Powered by customized LLMs and deep integration with client-specific data, Z-FASTQ ensures that each quotation reflects the manufacturer's unique capabilities, eliminating errors associated with generic or manual approaches.

The system's speed and accuracy translate directly into increased competitiveness. By responding to requests for quotations faster than manual approaches, manufacturers can secure more business opportunities while reducing operational inefficiencies. Z-FASTQ's secure deployment ensures that sensitive data remains protected, providing peace of mind to users while enhancing their operational effectiveness.

Z-AI: Comprehensive and seamless system integration: ZW's Z-AI integrates advanced generative AI, DNNs, and causal AI with ZW's extensive industrial domain expertise to seamlessly integrate model development and deployment into production systems. By automating traditionally time-consuming tasks and offering solutions that adapt to specific manufacturing environments, Z-AI allows manufacturers to deploy reliable, secure AI-driven solutions within one week. Moreover, its low-cost subscription model, coupled with an average return-on-investment that is 10x the original costs, ensures accessibility and value for businesses of all sizes.

Glass and ceramics manufacturers have made use of ZW's AI/ML tools to reduce energy consumption and increase production throughput while maintaining high quality control during operations. In one case, a client achieved more than $500,000 in annual manufacturing cost savings, equivalent to a 6% reduction, while another client increased production throughput by 6.5%, contributing an additional $3.5 million in annual revenue.

ZW's market traction continues to accelerate, with engagements underway with 10 additional potential customers. These prospective clients span diverse sectors outside of glass and ceramics, reflecting the broad applicability and growing demand for ZW's innovative offerings.

Future of AI/ML solutions in advanced manufacturing

ZW's achievements since its inception in 2022 exemplify the transformative potential of AI and ML technologies in advanced manufacturing. By partnering with AI/ML solution providers such as ZW, glass and ceramics enterprises can lead the charge in innovation, ensuring that they remain at the forefront of this revolution.

About the authors

Robert Fu is CEO and cofounder; Mitch Odinak is chief commercial officer and cofounder; Fangze Xu is senior R&D manager and senior AI/ML engineer; Keith House is senior technology advisor in glass, ceramics, and chemicals; and John Brown is senior technology advisor in glass at ZW LLC (Chapel Hill, N.C.). Contact Fu at robertfu89@zw-ml.com.

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Z: Founding and future goals

Fu

Odinak

Founded in 2022 by Robert Fu and Mitch Odinak, AI/ML solutions provider ZW (Chapel Hill, N.C.) offers cutting-edge AI and ML solutions for advanced materials industries, particularly glass and ceramics, with applications in semiconductors, electronics, telecommunications and photonics, biopharma and biotechnology, automotive and aerospace, renewable and clean energy technologies, CO_2 treatment, and more.

ZW's three AI/ML solutions— Z-MAP®, Z-FASTQ®, and Z-AI®—are meticulously crafted to expedite new product development, facilitate swift market entry, and optimize manufacturing processes for diminished costs and amplified profitability. This suite of solutions effectively tackles challenges that conventional statistical methods, modeling and simulation, and typical AI/ML technologies struggle to resolve.

The team at ZW collectively has decades of experience in the glass and ceramics industry, which uniquely positions their product to address significant challenges in this sector. Their ultimate goal is to empower glass and ceramics enterprises to accelerate new product development by five times, reduce manufacturing costs by 50%, and cut CO_2 emissions by 30% within five years.

Though the company currently focuses on clients in the glass and ceramics industry, it is expanding to clients in specialty chemicals and organics industries as well. Learn more about the company at https://www.zw-ml.com. ■

Preparing for an AI-empowered workforce

By Randy B. Hecht

Upskilling and reskilling for artificial intelligence (AI) and machine learning (ML) are being touted as 2025 business imperatives.

The catch is that many organizations have yet to get a firm grasp on how they should be using AI and ML, which makes it difficult to define training priorities. A further complication is resistance to change.

"If you're not thinking about resistance from the start, you're not approaching it seriously," says author, speaker, and advisor Greg Satell, a contributor to the book *Reskilling and Upskilling: The Insights You Need from Harvard Business Review* (https://s.hbr.org/4hVWqIW), which was published in March 2024. "One of the first things we do with an organization working on the change initiative is walk them through a resistance inventory."

He adds, "Shifts in knowledge and attitudes don't necessarily result in shifts in practice. People adopt the changes they see working around them, not the ones that they just hear about." With that in mind, he advises starting with small projects that can be scaled.

Where to begin? Public- and private-sector resources can help organizations understand the landscape and which areas of skills development are most pressing today.

FEDERAL GOVERNMENT

In late January 2025, the National Artificial Intelligence Advisory Committee submitted a draft report to the White House with its recommendations regarding the current state of United States' competitiveness and leadership in AI. The report's focus areas include AI and the workforce; AI awareness and literacy; AI in science; and AI to empower small businesses, entrepreneurs, and nonprofits.

More specifically, the report's recommendations include the scope and scale of U.S. investments in AI research and development in the international context; issues related to AI and the U.S. workforce; and opportunities for international cooperation on AI research activities, standards development, and the compatibility of international regulations.

Read the full report at https://bit.ly/NAIAC-Insights-on-AI.

STATE GOVERNMENTS

The National Conference of State Legislatures published a database of 2024 AI legislative initiatives that is searchable by state. View the database at https://bit.ly/NCSL-AI-legislation-by-state.

Legislative activity included in the database was not limited to states regarded as centers of AI/ML innovation. For example, Utah passed the Artificial Intelligence Policy Act, the first of its kind in the United States. It "establishes liability for use of artificial intelligence (AI) that violates consumer protection laws if not properly disclosed; creates the Office of Artificial Intelligence Policy (office) and a regulatory AI analysis program"; and "requires disclosure when an individual interacts with AI in a regulated occupation." The full text of the Act is at https://le.utah.gov/~2024/bills/static/SB0149.html.

THE GLOBAL PERSPECTIVE

Companies and research institutes that do business with entities in Europe should keep abreast of the regulatory environment there. In May 2022, the European Parliament published the study "AI and digital tools in workplace management and evaluation: An assessment of the EU's legal framework" (https://bit.ly/EPRS_STU-2022-729516). Other documents in this vein published over the years include

- What if AI regulation promoted innovation? (https://bit.ly/EPRS_ATA-2022-729515)
- What if AI could help us become 'greener'? (https://bit.ly/EPRS_ATA-2020-656316)
- What if Europe championed new AI hardware? (https://bit.ly/EPRS_ATA-2024-762881)

A final resource to highlight is the study "Regulating disinformation with artificial intelligence," which touches on emerging threats to organizations' reputation management (https://bit.ly/EPRS_STU-2019-624279).

COMPLIANCE AND ETHICS CONCERNS

The International Compliance Association published the report "AI and ethics: Why does it matter for compliance?" (https://bit.ly/ICA-AI-ethics). Topics in the report include

- Ethical and legal challenges to AI;
- AI, bias, and threats to fairness;
- Issues surrounding accountability and privacy; and
- Where the AI and ethics agenda is headed.

The International Organization for Standardization examines such issues as principles of responsible AI, promoting responsible AI practices, and keeping up with AI best practices in the article "Building a responsible AI: How to manage the AI ethics debate" (https://www.iso.org/artificial-intelligence/responsible-ai-ethics).

The World Economic Forum's article "Why corporate integrity is key to shaping the use of AI" notes that AI regulatory landscape "is complex and inconsistent, with approaches ranging from voluntary industry codes of conduct to binding risk-based regulations at the national or supra-national level…in the United States alone, while 73% of C-suite executives believe that ethical AI guidelines are important, only 6% have developed them." It encourages the adoption of "non-binding codes of corporate conduct, promoted by initiatives like the G7 Hiroshima Process" to "help guide global business approaches to AI deployment." Read the article at https://www.weforum.org/stories/2024/10/corporate-integrity-future-ai-regulation.

RESKILLING AND UPSKILLING RESOURCES

Stanford University publishes an annual AI Index report. The seventh edition, published in 2024, "introduces new estimates on AI training costs, detailed analyses of the responsible AI landscape, and an entirely new chapter dedicated to AI's impact on science and medicine." Read the full report at https://aiindex.stanford.edu/report.

The IBM blog post "Upskilling and reskilling for talent transformation in the era of AI" looks at how to approach workforce training. Read the blog post at https://www.ibm.com/think/insights/ai-upskilling.

In the report "Five must-haves for effective AI upskilling," Boston Consulting Group acknowledges that "upskilling is also a major bottleneck for companies that want to scale AI and GenAI across their organizations" and looks at "which approach to AI upskilling yields the biggest return on the twin investments of time and resources." Read the full report at https://www.bcg.com/publications/2024/five-must-haves-for-ai-upskilling.

In the report "Future of work," the Advanced Robotics for Manufacturing Institute details how "advanced technologies, chiefly robotics, automation, and AI, are changing the nature of manufacturing careers and the actions needed to prepare the U.S. manufacturing workforce for these changes." Read the full report at https://arminstitute.org/the-future-of-work.

In the Oracle article "Upskilling & reskilling in the era of AI," content strategist Natalie Gagliordi writes, "With AI, businesses can prepare for future skill requirements and emerging trends in the job market by proactively identifying skills gaps and designing upskilling and reskilling programs that align with workforce needs." Read the article at https://www.oracle.com/human-capital-management/ai-upskilling.

FOR A DEEPER DIVE

Courses and certificate programs in AI are available from, among others, the following institutions:

- American Management Association (https://bit.ly/AMA-AI-certificate)
- Berkeley Executive Education (https://bit.ly/Berkeley-AI-program)
- Cornell University (https://online.cornell.edu/ai)
- Massachusetts Institute of Technology (https://bit.ly/MIT-AI-short-course)
- The University of Texas at Austin (https://bit.ly/UTAustin-AI-program)

Further resources are available from the Association of Data Scientists (https://adasci.org), Association for the Advancement of Artificial Intelligence (https://aaai.org), and the International Society of Automation (https://www.isa.org). ■

ABOUT THE AUTHOR

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

Jonathon Foreman
ACerS journals managing editor

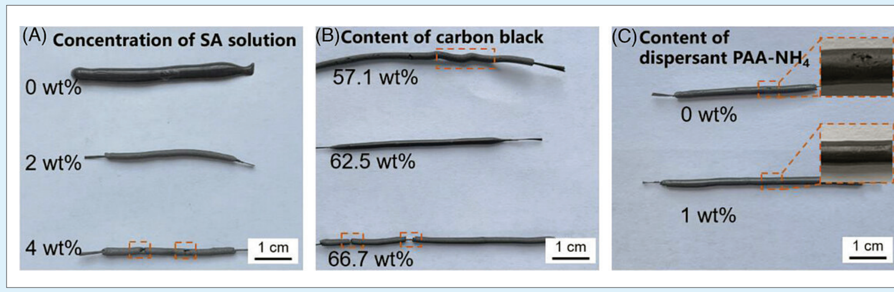
AI-enabled additive manufacturing of ceramic matrix composites

The recent explosion in the use of generative artificial intelligence (AI) tools such as ChatGPT has sparked excitement for AI's possibilities in both everyday and industrial settings. Regarding industrial settings, it is expected that AI models and algorithms could be used to improve many aspects of manufacturing, including material composition, equipment operation, and processing parameters.

Additive manufacturing (AM) is a fabrication process that could greatly benefit from the use of AI tools. AM involves the deposition of materials layer by layer to form parts with (typically) complex geometries. This process involves many variables: from the material being deposited (including constituent powders, binders, dispersants, and viscosity modifiers) to the processing parameters (including nozzle characteristics, line sizes, dispensing rates/pressures, and printing patterns). This complexity offers an attractive arena for AI-driven research and development.

In the paper "Future directions in ceramic additive manufacturing: Fiber reinforcements and artificial intelligence," Rueschhoff et al. describe the benefits and challenges of using AI to develop additively manufactured ceramic matrix composites (CMCs).[1] CMCs add another layer of complexity to the AM process compared to monolithic ceramics because they consist of reinforcing materials, such as carbon fibers, embedded in the majority material.

Three recent articles published in ACerS journals exemplify the research process for AM of CMCs. They share some similarities. For example, Chen et al.[2] and Cox et al.[3] used raw silicon carbide powder as the majority material along with aluminum and yttrium oxides as sintering aids. On the other hand, Liu et al.[4] began with carbon black and



Credit: Liu et al., *Int. J. Appl. Ceram. Technol.*

Figure 1. Effect of slurry stability on extruded filament morphology. (A) Morphology of extruded filaments with sodium alginate (SA) concentration of 0, 2, and 4 wt.%. (B) Morphology of extruded filaments with carbon black contents of 57.1, 62.5, and 66.7 wt.%. (C) Morphology of extruded filaments with ammonium polyacrylate (PAA-NH4) of 0 and 1 wt.%.

pre-ceramic polymers in the slurry and formed silicon carbide through reactive melt infiltration on the parts after printing and binder burnout. Chen and Liu experimented with continuous carbon fibers, while Cox explored the effects of printing direction using short (chopped) carbon fibers.

An interesting difference between continuous versus chopped fibers is how the fibers are incorporated into the majority material. Chopped fibers are mixed into the printing paste, allowing control over paste flow rates. Continuous fibers are threaded through a needle at the center of the paste dispensing nozzle. Drag forces from the pressure-driven flow draw the fibers into the paste.

Each study crafted the paste formulations and sintering profiles through early-stage testing of characteristics such as viscosity profile or densification. Then, each study focused on a specific aspect of the printing process.

Cox focused on printing direction and found the best properties (least warping and cracking along with highest strength) with unidirectional printing and bend testing perpendicular to the print direction. Chen explored using polycarbosilane to treat the carbon fibers and found it protected the carbon fibers, leading to higher sintered densities.

Liu varied the number of continuous fibers fed into the nozzle and found that the best properties resulted using 1,000 fibers. However, the resulting bending strength was far below that seen in the two prior studies.

It is notable that only Liu explored the effects of paste formulation on printing quality (Figure 1). Testing only one or two dimensions is a common research methodology, but product fabrication must account for the interdependency of the materials and processing conditions. AI can assist in uncovering these connections by finding patterns within the large volumes of seemingly disparate literature data—thus helping significantly accelerate the research and development process.

References

[1]Rueschhoff L. M. et al., "Future directions in ceramic additive manufacturing: Fiber reinforcements and artificial intelligence," *J. Am. Ceram. Soc.* 2024, **107**(3): 1505–1522.

[2]Chen R. et al., "Additive manufacturing of high mechanical strength continuous Cf/SiC composites using a 3D extrusion technique and polycarbosilane-coated carbon fibers," *J. Am. Ceram. Soc.* 2023, **106**(7): 4028–4037.

[3]Cox K. R. et al., "Slurry material extrusion of chopped carbon fiber reinforced silicon carbide ceramic matrix composites (CMCs)," *Int. J. Appl. Ceram. Technol.* 2025, **22**(1): e14915.

[4]Liu K. et al. "Additive manufacturing of continuous carbon fiber–reinforced silicon carbide ceramic composites," *Int. J. Appl. Ceram. Technol.* 2023, **20**(6): 3455–3469. ■

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"We are excited to celebrate the 10th edition of Ceramics Expo in Michigan and to once again bring together industry leaders, innovators, and decision-makers from across the supply chain. As we continue to support the growth of high-tech manufacturing sectors, we are proud to unite suppliers and manufacturers of ceramic engineering solutions with technical experts from industries such as electronics, semiconductors, advanced manufacturing, automotive, aerospace, and defense."

–Andrew Tucker, exhibition director

DRIVING INNOVATION ACROSS INDUSTRIES

Ceramics Expo 2025 is the premier event for professionals across the advanced ceramics supply chain. It will feature industry leaders such as Custom Powder Systems, STC Material Solutions, GNPGraystar, Axiom Materials, Exentis, QorTek, Hindalco, Netzsch, Saint-Gobain Ceramics, Fiven, GeoCorp, ALTEO, McDanel Advanced Ceramics, Rath, Schott, Huber Engineered Materials, Engineered Pressure Systems, and Almatis.

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Advanced ceramics are transforming industries such as electronics, semiconductors, aerospace and defense, electric vehicles, and medical devices, propelled by cutting-edge manufacturing techniques and supportive government policies.

Ceramics Expo 2025 offers attendees the chance to learn more about these innovations and explore real-world solutions by connecting with key suppliers from all segments of the advanced ceramics and glass supply chain.

Key conference topics for 2025 include: ceramics innovation in aerospace, automotive, defense, and electronics; supply chain resilience for technical ceramics; wide-bandgap semiconductor materials

WHAT TO EXPECT

- **State-of-the-art ceramic materials:** Discover the newest materials driving innovation across industries.
- **Advanced manufacturing processes:** Explore cutting-edge techniques such as 3D printing and precision machining designed to improve quality and reduce costs.
- **High-performance ceramic components:** See ceramic parts and solutions tailored to applications in aerospace, automotive, electronics, energy, and more.
- **Supplier and manufacturer showcases:** Meet leading suppliers and manufacturers from the upstream and midstream segments offering tailored solutions.
- **Technology demonstrations:** Witness live demos of ceramic technologies, materials testing, and product innovations pushing the industry's boundaries.

in power electronics; piezoelectric ceramics for next-gen applications; and scaling up ceramic additive manufacturing to volume production. Notable sessions will cover reshoring technical ceramics supply chains, ceramic matrix composites, and advanced processing and machining techniques.

Ceramics Expo 2025 will feature a powerhouse lineup of speakers to elaborate on these topics, including

- **Michael Silver**, founder of American Elements
- **Nikolai Sauer**, chief technology officer of Bosch Advanced Ceramics
- **Claire Theron**, vice president of materials and technology at STC Material Solutions
- **Guy Zimmerman**, CEO of XJet 3D
- **William Dickson**, chief commercial officer of Canopy Aerospace

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WHO SHOULD ATTEND

- **Manufacturing engineers** seeking cutting-edge ceramic materials and innovative processing techniques.
- **Design engineers** looking for advanced ceramic solutions to integrate into end-user products.
- **Product managers** in industries such as automotive, aerospace, electronics, and energy, aiming to source high-performance ceramics.
- **Procurement and supply chain managers** sourcing materials and components for production.
- **R&D specialists** exploring new applications and developments in technical ceramics.
- **Operations directors** focused on improving efficiency and optimizing ceramic production processes.
- **Business development managers** looking for new partnerships and opportunities in the ceramics sector.

AGENDA AT A GLANCE*

Gain crucial insight into the most pressing trends, challenges, and innovations influencing the use of advanced ceramics.

Day 1 – Tuesday, April 29

The Geopolitics of Critical Minerals in the 21st Century

Shoring Up Resilience in the Technical Ceramics Supply Chain

Revolutionizing Power Electronics with Silicon Carbide and Gallium Nitride

Pushing Beyond the Edge in Space, Aerospace and Defense with Next-Gen Ceramics

Outperforming Polymers and Metals with Advanced Ceramics Processing and Machining

Day 2 – Wednesday, April 30

Ceramics in Semiconductors and Microelectronics

Innovating in Aerospace with Ceramic Matrix Composites

Miniaturizing Sensors, Actuators and Microelectronics with Textured Piezo

Scaling Up Ceramics Additive Manufacturing to Volume Production

*Correct at time of publishing. Visit ceramicsexpousa.com for live information.

All photos credit: ACerS

SUNNY DAYS BRING SHINING OPPORTUNITIES FOR ATTENDEES OF ICACC 2025

The 49th International Conference and Expo on Advanced Ceramics and Composites took place Jan. 26–31, 2025, and welcomed more than 900 attendees from 43 countries, including about 250 students. The concurrent expo also welcomed its best turnout since the COVID-19 pandemic, with more than 1,100 visitors coming to talk and network with the 32 exhibitors over two nights.

OPENING CEREMONY RECOGNIZES AWARD WINNERS AND NEW SESSIONS, OPPORTUNITIES

The conference kicked off Monday morning with ECD Chair Jie Zhang presenting several awards before the award and plenary lectures commenced.

Manisha Vidyavathy of Anna University, Wan Si Tang of the Electrochemical Safety Research Institute, and Elisa Moretti of the University of Venice were presented with the ECD's Jubilee Global Diversity Award, and Daniel Oropeza of the University of California, Santa Barbara was presented with the 12th Global Young Investigator Award. Zhang also presented five individuals with the 2025 Global Star Award: Alberto Ortona, Hyun-Sik Kim, Ravi Kumar NV, Wei Ji, and Kamala Raghavan.

ICACC 2025 program chair Amjad Almansour then took the stage to highlight two new focused sessions at ICACC 2025: Ceramics for Global Decarbonization, and Innovative Material Processing for Diverse Resource Circulation Loops.

He also called out the new "Poster Preview Pitch" initiative, which gives poster presenters the opportunity to give a two-minute presentation on their poster, which would be on display at the expo, during a corresponding conference session. Nearly 35% of all poster presenters took advantage of this opportunity.

AWARD AND PLENARY LECTURES EXPLORE THE POTENTIAL OF THE NANO WORLD

Subhash Risbud, Distinguished Professor in materials science and engineering at the University of California, Davis, gave the 2025 James I. Mueller Lecture. His talk focused on mullite, the "quintessential" engineered ceramic, but he also used this time to thank everyone who guided him along his research journey.

Csaba Balazsi, scientific advisor in the HUN-REN Centre for Energy Research of Hungarian Academy of Sciences, was the 2025 Mrityunjay Singh Bridge Building awardee. He provided an in-depth discussion of nanocarbon-added ceramics, highlighting the drastic effects these additions can have on the thermal, mechanical, and electrical properties of ceramic materials.

Following the award lectures, the first plenary speaker, Ungyu Paik, professor in energy engineering at Hanyang University, gave an enlightening talk on how nanotechnology and energy technologies can be influenced by nanoparticle engineering. The second plenary speaker, Yury Gogotsi, Distinguished University Professor and Charles T. and Ruth M. Bach Endowed Chair of the Department of Materials Science and Engineering at Drexel University, spoke on how 2D ceramics, specifically MXenes, will become the building blocks of the future.

"Quinta nostra" was the name of this year's winning team of the Shot Glass Competition. The team members came from the University of Limoges in France, and here they stand with ACerS President Monica Ferraris (center), who helped drop all the shot glasses during the event.

This year, the ECD Bridge Building Award was renamed in honor of Mrityunjay Singh, an influential and distinguished figure in the field of engineering ceramics. Pictured is Singh (far left) with this year's recipient of the award, Csaba Balazsi (far right), and Balazsi's family.

Participants in the Conference Mentor Program at ICACC 2025. Forty attendees (20 mentors and 20 mentees) participated in the program at this conference.

STUDENTS ENJOY ESTABLISHED AND NEW EVENTS AT ICACC 2025

Student attendees at ICACC 2025 enjoyed the return of multiple beloved conference activities in addition to several new offerings.

Among the returning activities, students participated in the longstanding Shot Glass Competition and Poster Scavenger Hunt. The President's Council of Student Advisors also maintained a booth during the entirety of the conference where students could convene to network and discuss the interesting things they had learned at ICACC 2025.

Conference attendees followed along with all the exciting activities taking place at ICACC thanks to ACerS' new Social Media Liaisons program, which worked with student members Christine Fiedler and Francesco Bertolini to post about the conference on social media.

View more images from the conference on ACerS Flickr page at https://bit.ly/ICACC-2025. The Golden Jubilee Celebration of the 50th ICACC will take place Jan. 25–30, 2026, in Daytona Beach, Fla. ■

EMA 2025 WELCOMES RECORD NUMBER OF ATTENDEES TO DENVER

All photos credit: ACerS

As the winter chill faded, Denver, Colo., basked in beautiful weather, setting the stage for the highly anticipated Electronic Materials and Applications Conference, which took place Feb. 25–28, 2025.

EMA is coorganized by ACerS Basic Science and Electronics Divisions. For EMA 2025, Basic Science Division organizers were Fei Peng of Clemson University and Ming Tang of Rice University. Electronics Division organizers were Mina Yoon of Oak Ridge National Laboratory and Reeja Jayan of Carnegie Mellon University.

This year's conference marked a significant milestone as the largest EMA gathering to date, welcoming more than 400 attendees from 17 countries. Additionally, the event's prime location near the Colorado School of Mines facilitated the participation of more than 100 students.

PLENARY LECTURES: ADVANCING MATERIALS DESIGN WITH MACHINE LEARNING

Two insightful plenary lectures on Wednesday and Thursday mornings highlighted the integration of data science, specifically machine learning, in materials design.

Jian Luo of the University of California, San Diego delivered the first plenary lecture, which overviewed his team's work on developing grain boundary phase diagrams, "arguably the most useful materials science tool" for understanding material behavior at the atomic level. Luo described how they used a combination of thermodynamic models, atomistic simulations, and machine learning to develop the diagrams, and then showed how they aided in the investigation of electric field-induced grain boundary phase transitions.

Sergei Kalinin of the University of Tennessee, Knoxville delivered the second plenary lecture, which highlighted the emerging field of machine learning-assisted materials design. He described how his team has used machine learning techniques to optimize synthesis and characterization workflows. Specifically, by introducing a reward function concept, Kalinin showed how his team successfully bridged the gap between experimental processes and real-world applications, ultimately enhancing the throughput of material discoveries.

TUTORIALS AND RECEPTIONS EMPOWER STUDENT PARTICIPATION AT EMA

One of the highlights of EMA 2025 was the remarkable level of student participation, with students making up more than 25% of the total attendees. Several special events at EMA 2025 helped empower this participation.

First, two student-focused tutorials took place on Tuesday and Wednesday evenings. The first tutorial, organized by the Basic Science Division, explored machine learning in materials science, and it drew wide interest from both students and professionals. The second tutorial, organized by the Electronics Division, discussed electron ptychography of ceramic materials. While the Basic Science tutorial is a long-standing event, this year was the first time the Electronics Division held a tutorial, and attendees welcomed this addition to the programming.

A Student and Young Professionals Mixer also took place on Thursday evening. More than 100 attendees attended the event and engaged in networking bingo, which allowed them to foster valuable connections with their peers and seasoned colleagues.

The conference ended on Friday with the ever-popular "Failure: The Greatest Teacher" symposium, where established researchers share stories about experiments that did not work out to show students that failure is a natural part of doing science. This year, Katherine Page shared her personal experience with failures in a presentation titled "Craze-y Ruddlesden-Popper complex ceramics."

View more images from EMA 2025 on ACerS Flickr page at https://bit.ly/EMA-2025. ■

A NEW CHAPTER: ACERS SPRING MEETING 2026

Next year, the Basic Science and Electronics Divisions will come together with the Bioceramics, Energy Materials and Systems, Glass & Optical Materials, and Manufacturing Divisions at the new ACerS Spring Meeting, which will take place April 12–16, 2026, in Bellevue, Wash. This expanded event welcoming six ACerS Divisions will create more opportunities for cross-disciplinary collaborations.

EMA 2025 organizers Fei Peng (Basic Science Division) and Mina Yoon (Electronics Division), right in each photo, presented their Division's respective plenary lecturers, Jian Luo and Sergei Kalinin, with certificates of appreciation following their talks on Wednesday and Thursday mornings.

A game of networking bingo helped break the ice for attendees at the Student and Young Professionals Mixer on Thursday evening.

Attendees enjoyed games of giant chess, foosball, and air hockey during the Celebration of EMA reception on Thursday evening.

UPCOMING DATES

HILTON HYATT REGENCY VANCOUVER,
VANCOUVER, BRITISH COLUMBIA, CANADA

Join us in Vancouver for the 16th Pacific Rim Conference on Ceramic and Glass Technology and the Glass & Optical Materials Division Meeting (GOMD 2025).

GREATER COLUMBUS CONVENTION CENTER,
COLUMBUS, OHIO

Join us in Columbus for the annual Materials Science & Technology technical meeting and exhibition series. MS&T is a long-standing, recognized forum for fostering technical innovation at the intersection of materials science, engineering, and application.

HILTON DAYTONA BEACH OCEANFRONT RESORT,
DAYTONA BEACH, FLA.

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

HYATT REGENCY BELLEVUE ON SEATTLE'S EASTSIDE
BELLEVUE, WA, USA

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

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Interested in Corporate Partnership?
Contact Yolanda Natividad at ynatividad@ceramics.org or 614-794-5827 to learn more.

calendar

Calendar of events

April 2025

1–24 ★ Introduction to Electronic Ceramics – Virtual; https://ceramics.org/course/brennecka-electronic-ceramics

15–June 20 ★ Properties of Refractories – Virtual; https://ceramics.org/course/homeny-properties-of-refractories

29–30 ➡ Ceramics Expo USA – Suburban Collection Showplace, Novi, Mich; https://ceramics.org/event/ceramics-expo-2025

May 2025

4–9 16th Pacific Rim Conference on Ceramic and Glass Technology and the Glass & Optical Materials Division Meeting – Hyatt Regency Vancouver, Vancouver, Canada; https://ceramics.org/pacrim16

June 2025

9–11 ACerS Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Birmingham, Ala.; https://ceramics.org/clay2025

11–13 15th Advances in Cement-Based Materials – Boulder, Colo.; https://ceramics.org/cements2025

July 2025

8–11 ➡ The 8th International Conference on the Characterization and Control of Interfaces for High Quality Advanced Materials – Highland Resort Hotel & Spa, Fujiyoshida, Japan; https://ceramics.ynu.ac.jp/iccci2025/index.html

15–18 ★ Properties and Testing of Refractories – Westerville, Ohio; https://ceramics.org/course/homeny-properties-and-testing-refractories

September 2025

16–Dec. 4 ★ Refractory Manufacturing – Virtual; https://ceramics.org/course/homeny-refractory-manufacturing

17–18 ★ Tools for Visualizing and Understanding the Structure of Crystalline Ceramics – Virtual; https://ceramics.org/course/sparks-crystalline-ceramics

28–Oct. 1 ACerS 127th Annual Meeting with Materials Science and Technology 2025 – Greater Columbus Convention Center, Columbus, Ohio; https://www.matscitech.org/MST25

October 2025

27–30 ➡ Unified International Technical Conference on Refractories – JW Marriott Cancún Resort & Spa, Cancún, Mexico; https://unitecr2025.com

January 2026

25–30 Golden Jubilee Celebration of the 50th International Conference and Expo on Advanced Ceramics and Composites (ICACC 2026) – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla.; https://ceramics.org/icacc2026

April 2026

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

May 2026

31–June 5 12th International Conference on High Temperature Ceramic Matrix Composites (HTCMC 12) and Global Forum on Advanced Materials and Technologies for Sustainable Development (GFMAT 2026) – Sheraton San Diego Hotel & Marina, San Diego, Calif.; https://ceramics.org/htcmc12_gfmat2026

June 2026

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

5–25 ➡ CIMTEC 2026 – Perugia, Italy; https://ceramics.org/event/cimtec-2026

August 2026

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

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

Entries in **BLUE** denote ACerS events.

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

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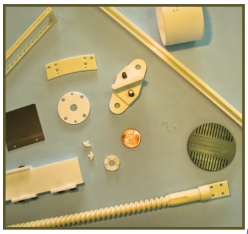

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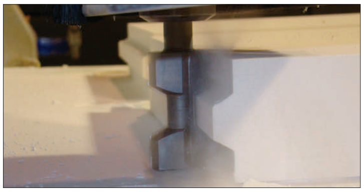

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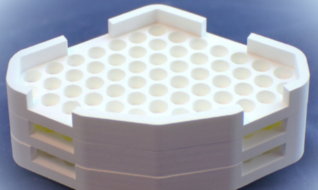

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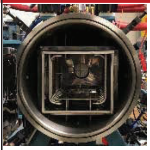

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By Ebenezer B. Owusu, Amiya Chowdhury, and Christine Brockman

Guest columnists

deciphering the discipline

A regular column showcasing the expertise of emerging ceramic and glass scientists, organized by the ACerS President's Council of Student Advisors.

AI-enabled development of corrosion-resistant paint

Corrosion is a significant challenge across all industrial sectors. It causes weakening of equipment and structures that may lead to potential failures, costing about $2.5 trillion per year globally. Implementing appropriate preventive measures, such as paint, could save $375–875 billion per year.[1]

Paint helps prevent corrosion by slowing the ionic transfer between the anodic and cathodic sites, for example, in steel, which corrodes in the presence of water and oxygen.[2] Ion permeability through paint limits its effectiveness, but engineering paint to modify anodic reactions can improve its protection.[3]

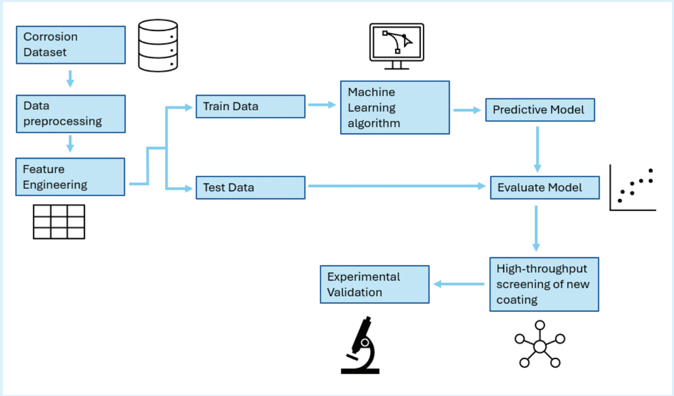
The raw materials used in making paints can be generalized as resins, solvents, pigments, and additives.[4]

- **Resin** is the matrix that binds all the other components together. It is classified as either convertible binders, which complete polymerization after application, or nonconvertible binders, which are fully polymerised before application.
- **Solvent** dissolves the resin and other components to make the paint flowable for effortless application. Solvent selection depends on factors such as cost, toxicity, and evaporation rate.
- **Pigments** are particulates that are added to achieve certain aesthetic and functional properties, such as corrosion resistance. Typically, organic pigments are used in decorative paints whereas inorganic pigments are for protective paints.
- **Additives** enhance the paint's functional properties, for example, thickness, anti-foaming, and light stabilizing.[2,4]

Developing a paint that can effectively alter the anodic reaction for corrosion resistance is challenging because the potential composition space for these materials is enormous. Furthermore, determining the corrosion resistance of these new formulations is complicated by the variety of factors, such as humidity, that affect corrosion rate in different environments. Using artificial intelligence (AI) and machine learning (ML) methods to explore this range of possible materials can greatly speed up the time- and resource-intensive development process (Figure 1).[5]

In recent literature, AI and ML methods have been applied to various aspects of corrosion-resistant paint development. For example, Liu et al. applied active learning with a random forest model to identify the best formulation for a corrosion-resistant, self-healing epoxy coating containing ZIF-8@Ca microfillers.[6] An experimental dataset with 32 data points was used to train the model, and a further 30 data points were generated using active learning to train the model, thus achieving an acceptable level of predictive ability in a cost-effective manner.

In conclusion, paint is an important tool in the fight against corrosion. AI and ML can provide a more time- and resource-efficient approach to corrosion-resistant paint development.



Credit: Amiya Chowdhury

Figure 1. Schematic representation of AI-enabled formulation of corrosion-resistant paint.

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[1]G. Koch et al., "Assessment of the global cost of corrosion," NACE International IMPACT, 2016. Accessed 24 Feb. 2025. http://impact.nace.org/economic-impact.aspx

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[3]I. Felhősi et al., "Corrosion protection and heat resistance of paints for outdoor use," *Materials* 2023, **16**(7): 2753.

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[5]L.B. Coelho et al., "Reviewing machine learning of corrosion prediction in a data-oriented perspective," *npj Mater. Degrad.* 2022, **6**: 8.

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Ebenezer B. Owusu is a Ph.D. student in materials engineering and material design at the University of Nottingham, U.K. His research focuses on the discovery, manufacture, and performance analysis of ytterbium disilicate environmental barrier coatings. In April 2024, Owusu ran at the ancient Olympia stadium in Greece.

Amiya Chowdhury is a Ph.D. student in materials engineering and material design at the University of Nottingham, U.K. His research focuses on using machine learning to develop high-entropy ceramics with low thermal conductivity. Chowdhury enjoys trying different cuisines from around the world.

Christine Brockman is a Ph.D. student in materials science and engineering at Oklahoma State University. Her research focuses on the high-temperature mechanical testing of ceramic matrix composites and thermal properties of disilicate systems for environmental barrier coatings. In her free time, Brockman enjoys learning pottery, painting, and trying new recipes. ■

WELCOMING NEW FACULTY

Mario Caccia, Ph.D.

Alfred University welcomes Assistant Professor of Ceramic Engineering Dr. Mario Caccia. Dr. Caccia holds a Ph.D. and M.S. in Materials Science from the University of Alicante, Spain. Prior to his current role, Dr. Caccia was an Assistant Professor at Montana Tech (2022-2024), Senior Research Engineer, and Postdoctoral Researcher at Purdue University (2016-2021). Over the years he has collaborated with several institutions throughout Europe, and he is interested in further cultivating research relationships between the US and Europe. Dr. Caccia is also interested in working on materials science-based industrial projects through Alfred's Center for Advanced Ceramic Technology

His research focuses on the design and development of advanced ceramics and ceramic composite materials, with a particular emphasis on processing of non-oxide ceramics, reactive melt infiltration and processing-property relationships.

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