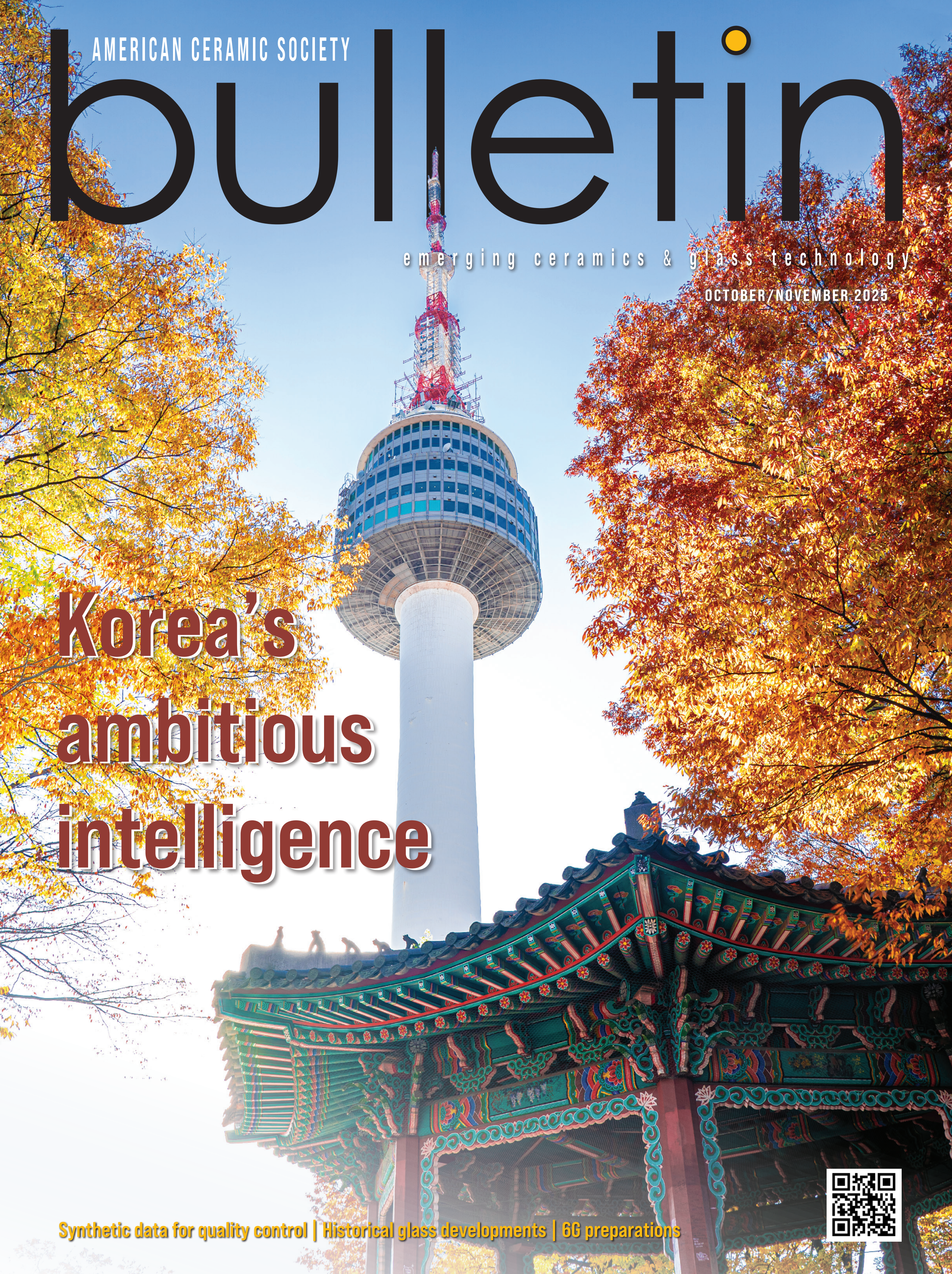

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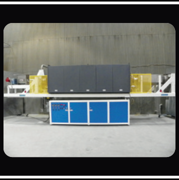


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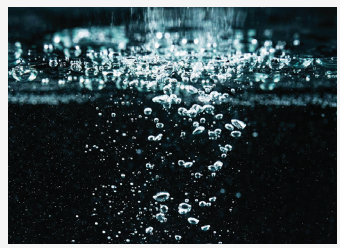
As seen on *Ceramic Tech Today*...



Credit: cottonbro studio, Pexels

Deep-sea mining considerations: Polymetallic nodules may play role in 'dark' oxygen production

In an open-access paper, an international team of researchers proposed a preliminary hypothesis that polymetallic nodules may play a role in deep-sea oxygen production. If confirmed, this discovery would have implications for deep-sea mining.

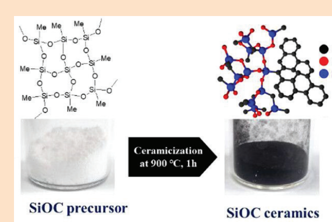
Read more at https://ceramics.org/dark-oxygen

Also see our ACerS journals...

These articles come from the October 2025 special issue of *JACerS*, which contains invited articles from the conference Material Challenges in Alternative and Renewable Energy 2024.

Simultaneous modulation of oxygen and carbon compositions in SiOC ceramics for high-capacity and durable anode materials
By J.-H. Kim, H. R. Lee, M. K. Kim, et al.
Journal of the American Ceramic Society

Characteristics of $(Sr_{0.92}Y_{0.08})_{0.85}Ti_{1-x}Ni_xO_{3-\delta}$ (x = 0.05, 0.10, 0.15, 0.20) perovskites for internal dry methane reforming in solid oxide fuel cells
By J. H. Kim, S. I. Mo, G. S. Park, et al.
Journal of the American Ceramic Society



Credit: Kim et al., *JACerS*

Structure and electrochemical performances of NiCo hydroxide with anion exchange by carbonates for hybrid supercapacitor
By H.-J. Lim, Y. S. Park, and S.-H. Baek
Journal of the American Ceramic Society

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ACSBA7, Vol. 104, No. 8, pp. 1–48. All feature articles are covered in Current Contents.

letter to the editor

Unequal access, untapped potential: Reimagining global ceramic education

To the editor:

Some gaps in science are obvious. They are typically missing data, untested hypotheses, or outdated models. But others are more subtle and systemic, embedded in how we educate and train future scientists.

As a materials science student from Ghana now conducting graduate research at the University of California, Davis, I have walked both ends of the educational spectrum: one grounded in theory and traditional practices and the other immersed in cutting-edge technologies and applications. This journey highlights a crucial disparity: While ceramic education holds global relevance, accessibility is uneven, especially in developing countries.

Ceramics play an integral role in shaping our modern world, yet my early education in materials science placed noticeably greater emphasis on metals and polymers, with ceramics content largely confined to classic examples such as refractories. Consequently, the broader relevance of ceramics to emerging technologies often felt underrepresented.

This perceived undervaluation of ceramics within materials science education was reinforced throughout my undergraduate education. For example, the curriculum at my undergraduate institution in Ghana provided a comprehensive overview of the fundamental principles governing ceramic behavior, and it thoroughly addressed phase equilibria and conventional processing techniques in lecture-based formats. However, this information was delivered in an environment where opportunities for practical experimentation and hands-on learning were minimal. Laboratory facilities were often outdated, lacked critical instrumentation, or were altogether unavailable for ceramic-specific applications. This disconnect between theoretical knowledge and applied experience made it difficult to fully grasp the practical relevance and transformative potential of engineered ceramics.

Despite these challenges, the intellectual curiosity of students was anything but lacking. There was a genuine eagerness to understand how materials worked, to test concepts in a lab setting, and to see firsthand how microstructures influenced properties. Unfortunately, the absence of resources often meant that this curiosity could not be translated into experimental inquiry, which subtly—but powerfully—shaped perceptions of ceramics not as dynamic contributors to innovation but as a field relegated to academic abstraction or industrial tradition.

In contrast, during my graduate experience at UC Davis, ceramic materials are not approached as an isolated subfield. Instead, they are positioned as integral components of a broader, interdisciplinary landscape, one which actively embraces sustainability, computational modeling, and real-world applicability. Access to advanced instrumentation, once aspirational, is now routine. Students are empowered to operate scanning electron and atomic force microscopes independently, to interrogate their capabilities, and to push the boundaries of their applications.

Furthermore, the culture surrounding ceramics research at UC Davis is dynamic and collaborative. Industry partnerships, data-informed experimentation, and sustainability-focused design are not peripheral or optional—they are embedded into the core of the graduate training experience. As a result, this environment not only bridges the gap between theory and practice but also repositions ceramics as central to addressing some of the most urgent materials challenges of our time.

This clear contrast between my undergraduate and graduate experiences highlights an important reality: The problem is not a lack of student talent or interest but rather unequal access to resources and opportunities. The UNESCO Science Report (2021) puts this observation into a global perspective, showing that Africa contributes less than 2% of the world's scientific research. Challenges such as outdated course materials, poorly funded labs, and too few trained instructors continue to hold back progress. Even more troubling is the lack of international collaboration, which makes it difficult for students and researchers to connect with mentors, form research partnerships, or stay up to date with new technologies.

So, what can be done?

Curriculum reform is essential. Blended learning models that incorporate remote access to simulations, virtual instrumentation, and interactive lab modules can help mitigate resource constraints. Programs such as the United States Agency for International Development's Partnerships for Enhanced Engagement in Research (PEER) provide frameworks for fostering collaboration between institutions in the Global North and South. Similarly, regionally anchored equipment-sharing initiatives could help democratize access to essential technologies, reducing redundancy and maximizing educational impact.

Professional societies such as The American Ceramic Society are uniquely positioned to serve as catalysts for this kind of change. Targeted mentorship programs for students in under-resourced regions, international summer schools that integrate theoretical instruction with hands-on training, and global networks for instrumentation access are just a few possibilities.

Through these initiatives and other programs, we can shift educational paradigms and enable a more inclusive and equitable future for ceramic science.

Sincerely,
Petrina Okrah

Graduate student in the Risbud Group
University of California, Davis

news & trends

The unstoppable growth of renewables: National roadmaps help guide the clean energy transition

Global renewable energy capacity grew by a record-breaking 15.1% in 2024, according to the International Renewable Energy Agency, accounting for 92.5% of total power capacity expansion last year. This growth, along with large-scale decommissioning of fossil fuel power plants in several regions, allowed renewables' share of global installed power capacity to rise from 43% to 46.4%.

Despite these gains, the industry is still slightly behind the rate needed to deliver on the global goal to triple available renewable energy by 2030. Fortunately, more and more countries are releasing or updating national energy roadmaps to help guide their transition to a clean energy economy, including quite a few notable announcements in the past year.

July 2024

Uruguay published the Roadmap for Green Hydrogen and Derivatives, which describes the country's strategy to reach a production of 1 Mt/year of green hydrogen by 2040.

Kazakhstan adopted the National Infrastructure Plan until 2029, which aims to have renewable energy sources account for 12.5% of the country's total energy production by that time.

August 2024

Brazil launched the National Energy Transition Policy, which will help coordinate the country's energy transition.

Panama published two roadmaps aimed at reducing methane and black carbon emissions.

Israel's Ministry of Energy and Infrastructure published a roadmap for net-zero emissions by 2050, which describes three scenarios for achieving this goal.

September 2024

With support from the European Commission and the World Bank Group, Romania published the Offshore Wind Roadmap for Romania to help realize the vast potential of offshore wind in Romania.

During the Roadmaps to New Nuclear 2024 conference in Paris, France, government representatives from 21 countries released a communiqué highlighting their commitment to nuclear technology and pledging to work together to fully unlock its potential.

Decree No. 2.553/24 came into effect in Paraguay, establishing a new energy policy to reduce the country's dependency on hydrocarbons and align with global energy transition efforts.

Several institutions led by the Kuwait Foundation for the Advancement of Sciences prepared an energy transformation white paper to serve as the country's first energy transition roadmap.

October 2024

Türkiye unveiled the 2035 Renewable Energy Roadmap, which aims to quadruple the country's wind and solar capacity to 120 GW over the next decade.

November 2024

The Republic of Maldives launched the updated Energy Sector Road Map for 2024–2035 at the United Nations Framework Convention on Climate Change. The roadmap outlines a plan to have renewable energy make up 33% of the country's electricity sector by 2028.

January 2025

Nepal approved the Energy Development Roadmap and Working Guideline, which aims to generate 28,500 MW of electricity in the next decade via mainly hydropower projects.

February 2025

The Republic of Korea finalized its 11th Basic Plan for Long-Term Electricity Supply and Demand, which outlines energy supply and generation strategies through 2038. Under the new plan, the country will build three additional nuclear reactors by 2038.

Rwanda unveiled a new energy policy, which updates the 2015 policy to account for emerging challenges and realities as well as technological developments in the energy sector.

March 2025

Laos approved the Lao PDR National Green Hydrogen and Ammonia Roadmap to deliver opportunities for decarbonized hydrogen and ammonia.

April 2025

South Africa approved the South African Renewable Energy Masterplan, a roadmap to boost energy security and industrial development planning to increase its renewable capacity by up to 5 GW annually.

Vietnam approved the amended Power Development Plan VIII, which not only boosts the share of renewable energy in the plan but now also includes nuclear power.

June 2025

The European Commission released a proposal to phase out Russian oil and gas imports. The plan was initially due out in March 2025, but the Commission delayed the plan's release as it weighed the impact of the U.S. administration's pivot on Ukraine. ■

Corporate Partner news

Borregaard appoints new CEO and continues commitment to growth

On Aug. 1, 2025, Tom Erik Foss-Jacobsen began his role as the new CEO of Norway-based Borregaard, which operates one of the world's most advanced and sustainable biorefineries and provides wood-based alternatives to fossil-based chemicals and polymers. Foss-Jacobsen plans to continue building on Borregaard's legacy and drive sustainable growth. Read more: https://www.borregaard.com/company/news-archive

Dorst Technologies joins the Hydrogen Alliance Bavaria

The Hydrogen Alliance Bavaria, coordinated by Zentrum Wasserstoff.Bayern, aims to foster collaboration, knowledge exchange, and innovation while working toward a common goal of strengthening Bavaria's hydrogen technology hub. Dorst Technologies joined the alliance among nearly 400 other partners. Read more: https://www.dorst-technologies.com/en/dorst/news

HarbisonWalker International partners with Electrified Thermal Solutions

HarbisonWalker International, a member of Calderys, partnered with Boston-based Electrified Thermal Solutions to develop and produce electrically conductive firebricks to be used in Electrified Thermal's JouleHive Thermal Battery. The collaboration aims to help provide a new solution to reduce emissions while maintaining reliable performance. Read more: https://thinkhwi.com/newsroom

Lucideon and Manufacturing Technology Centre enter strategic partnership

Lucideon and Manufacturing Technology Centre signed a memorandum of understanding to accelerate industrial applications of advanced ceramics. Lucideon will lead materials analysis, evaluation, and development of high-performance ceramic technologies, while MTC will focus on full system and product design as well as industrial-scale implementation. Read more: https://www.lucideon.com/insights/news ■

Global edge AI market

The global market for edge artificial intelligence was valued at $8.7 billion in 2024 and is expected to grow at a compound annual growth rate (CAGR) of 36.9% to reach $56.8 billion by the end of 2030.

Edge computing refers to data processing that occurs closer to where the data is generated—at the "edge" of a network—rather than on centralized data centers or cloud. Edge AI builds on this concept by using AI algorithms and machine learning models on local devices, such as edge servers, sensors, and other Internet of Things devices, to improve on the real-time data processing benefits of edge computing.

Three recent developments illustrate the effectiveness of implementing AI models at the edge:

- **Maturation of neural networks:** Neural networks and related AI infrastructure have evolved to allow for generalized machine learning, which allows organizations to deploy AI models in production.
- **Advances in computer infrastructure:** Distributed computational power is required to run AI at the edge. Recent advances in highly parallel graphics processing units enable the units to execute neural networks.
- **Implementation of Internet of Things devices:** The rapid proliferation of data collection capabilities through industrial sensors, smart cameras, robotics, and other connected devices enables the technological infrastructure necessary for edge AI. 5G allows these devices to operate faster and more securely.

Despite its market potential, edge AI faces some challenges with deployment. The computing, memory, and storage capabilities of edge devices are limited, restricting their potential for inference and training. This limitation is especially relevant for edge AI solutions, as machine learning models often rely on dedicated hardware and require a lot of memory.

The development of edge-native AI models will help address the issues of deploying complicated AI algorithms on devices with limited computational resources. Other hardware components that can aid in edge AI deployment are

- **AI accelerators:** Specialized hardware components designed to accelerate the execution of AI algorithms on edge devices. They are implemented either as dedicated chips or integrated components, and they are optimized for the parallel processing of AI workloads.
- **Field-programmable gate arrays:** Unlike general-purpose processors, field-programmable gate arrays allow for parallel processing and reprogramming based on the task. Because they are reconfigurable, they balance efficiency and flexibility, making them suited for use in autonomous vehicles and industrial automation.

In 2024, the IT and telecom industry was the largest end-user segment of edge AI (Table 1). This ranking is due to the industry's rollout of 5G networks, growing reliance on real-time data processing for network optimization, and the need to support billions of connected devices. Telecom operators are leveraging edge AI to manage traffic efficiently, reduce latency, and enable new services such as immersive virtual/augmented reality experiences and autonomous systems.

North America held the largest share of the global market for edge AI in 2023 (39.6%). This ranking is attributed to its ecosystem of tech companies and their high levels of investment in R&D. However, China, Japan, and Korea are increasingly investing in AI-driven edge computing, semiconductor production, and AI-powered automation.

Table 1. Global market for edge AI, by end-user industry, through 2030 ($ millions)

End-user industry	2024	2025	2030	CAGR % (2025–2030)
IT and telecom	2,323.3	3,145.7	15,271.6	37.2
Healthcare	1,948.8	2,615.1	12,150.5	36.0
Automotive	1,564.0	2,164.3	11,702.7	40.2
Retail and consumer goods	1,133.1	1,547.9	7,854.5	38.4
Manufacturing	1,004.7	1,323.4	5,623.7	33.6
Other*	758.9	1,006.0	4,172.9	32.9
Total	8,732.8	11,802.4	56,775.9	36.9

*Other end-user industries include smart cities, energy and utility, smart farming, and security and defense.

About the author

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

Resource

BCC Publishing Staff, "Global edge AI market," BCC Research Report IFT310A, June 2025. https://bit.ly/June-2025-edge-AI

By Yilong Yin and Yi Yang
Guest columnists

industry perspectives

Sustainable transition of the semiconductor industry

The semiconductor industry is fundamental to contemporary technological advancement, powering everything from mobile phones and computers to electric vehicles and artificial intelligence applications.

Semiconductor manufacturing is resource intensive, involving high energy consumption, extensive chemical use, and significant emissions of greenhouse gases, notably fluorinated gases, which possess a high global warming potential. The sector emitted approximately 64.24 million tons of CO_2-equivalent gases in 2020 alone,[1] accounting for a significant portion of emissions from the broader information and communication technology industry.[2] Addressing these emissions is crucial for the industry's sustainable transition.

Process optimization and technological innovation are key drivers of carbon mitigation in the semiconductor industry, enabling the sector to meet growing demand while minimizing its environmental impact. Artificial intelligence technologies offer significant potential for enabling real-time monitoring and dynamic process optimization in semiconductor manufacturing. For instance, in chemical vapor deposition chamber cleaning processes, AI-enabled plasma-based techniques can serve as an alternative to traditional endpoint detection in etching procedures involving fluorinated gases.[3]

In addition to optimization, substituting gases with high global warming potentials with lower-impact alternatives is an effective mitigation strategy.[4] However, this approach is often impractical in numerous plasma etching processes.[5] Therefore, when assessing alternative chemicals, it is crucial to consider more than just their environmental impact. A thorough evaluation must include safety and health risks related to factory operations, employee protection, and the surrounding environment. This systemic method guarantees that the selected alternatives successfully cut greenhouse gas emissions, meet safety regulations, and support the long-term health and stability of the semiconductor manufacturing ecosystem.

Beyond fabrication, design innovations in low-power integrated circuits are helping to reduce the energy consumption of semiconductor devices themselves. Techniques such as dynamic voltage scaling and power gating are increasingly used to maintain performance while lowering operational energy use.[6]

Furthermore, waste heat recovery and reuse technologies have become widely adopted in the semiconductor industry. Recently, some prominent semiconductor manufacturers have begun implementing waste heat recovery systems, converting excess heat from production into usable energy for heating or other manufacturing processes.[7]

Supply chain management and optimization are crucial for carbon reduction in the semiconductor industry. The supply chain spans multiple stages, from raw material procurement to product delivery, with emissions generated at each step. Due to the complexity and multi-tiered nature of the supply chain, effectively reducing its carbon footprint requires comprehensive optimization from upstream to downstream, particularly in green procurement, logistics optimization, and intelligent supply chain management.

Finally, supply chain collaboration and standardization are effective strategies for driving overall carbon reduction in the semiconductor industry. For example, the Semiconductor Industry Association (SIA) and other relevant industry organizations are establishing unified emission reduction standards and encouraging green collaboration among companies.[8]

Decarbonizing the semiconductor industry is an urgent and multifaceted challenge that demands coordinated, systemic solutions. Ultimately, technological progress alone will not be sufficient. A successful transition demands collaborative engagement from all stakeholders, including manufacturers, suppliers, policymakers, and researchers.

About the authors

Yilong Yin and Yi Yang are researchers in the Key Laboratory of the Three Gorges Reservoir Region's Eco-Environment, Ministry of Education, Chongqing University, China. Contact Yang at yi.yang@cqu.edu.cn.

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*All references verified as of Aug. 15, 2025. ■

This article is excerpted from "Sustainable transition of the global semiconductor industry: Challenges, strategies, and future directions," *Sustainability* 2025, **17**(7): 3160. https://doi.org/10.3390/su17073160 (CC BY 4.0)

By David Holthaus
Industry reporter

Lessons learned from the rollout of 5G technology help guide 6G preparations

While it may seem like the 5G communications and data network has just been rolled out—and is, in fact, still in the process of being deployed—communications providers, governments, and researchers are already preparing for the sixth generation of wireless technology, or 6G.

Compared to 5G, which aimed to expand the bandwidth of wireless communications into the high-frequency millimeter wave range (> 24 gigahertz), 6G systems are expected to leverage an even wider range of frequencies that expand into the submillimeter band, i.e., more than 300 gigahertz (Figure 1). Expected usage scenarios for 6G include immersive communication, such as interactive video experience; super-reliable and low-latency (faster) communication to enable intelligent industrial applications and management of energy and power grids; improved connectivity, especially in rural and remote areas; and expanded use of Internet of Things devices and applications in next-generation transport systems, such as autonomous vehicles.

SK Telecom, a South Korean wireless telecommunications operator, is among the commercial enterprises taking the lead on preparing for the next generation of mobile networks.

"It is essential to identify 6G products and services, to define simple architecture options, and to develop technologies for coverage expansion," the company says in a white paper released in August 2023.[1]

The company, like many other entities involved in the wireless communications sector, says it expects 6G to roll out globally around 2030. Its efforts to prepare for this rollout will receive significant government backing, considering the Korean government announced its "K-Network 2030 Strategy" in February 2023, which aims to support investment in 6G technology and standards development.

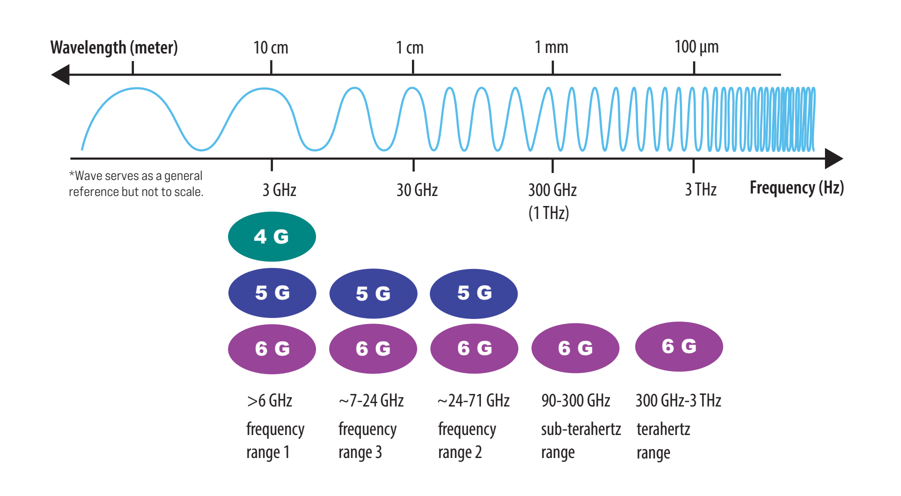

Figure 1. Expected frequency ranges for each generation of the cellular network.

SKT notes that lessons learned from the 5G rollout could be applied to the development of 6G networks. Chief among them is expectations for applications that were unreasonably high.

"A variety of visionary services were expected, but there was no killer service," SKT says in the paper. "Even at the time when preparing for 5G, services such as autonomous driving, XR, hologram, and digital twin had appeared as expected, but most of them did not live up to expectations."

As a result, the hype around 5G may have been a bit too much, the company suggests, and says, "We should have taken a more objective perspective."

The gap between expectations and reality is the result of a combination of factors, according to the paper, including the constraints of wireless devices and service technologies, low or nonexistent market demand, and policy and regulation issues. Regarding that first factor, the use of millimeter-wave signals in particular present new technological hurdles.

Higher frequencies result in greater attenuation of the electromagnetic waves, requiring closer and denser stations and antennas. Building out the additional infrastructure can mean high costs as well as siting difficulties in local jurisdictions, according to Michael Hill, technical director of research and development at Trans-Tech, Inc.

Trans-Tech is an Adamstown, Md.-based provider of radio frequency and microwave components to communications providers, military, aerospace businesses, and others. Hill and his team have been involved in developing the technologies that will be needed for both the 5G and upcoming 6G deployment, such as the dielectric resonators, bandpass filters, and circulators that provide frequency control and signal clarity for communication systems.

The challenges with high-frequency signals mean that current 5G networks do not use the millimeter wave range as much as originally expected. Hill believes that new frequency bands will be implemented as 5G deployment progresses, but "If we look at 6G as jumping wholeheartedly into the greater-than-20-gigahertz bands, there's going to be significant changes there," he says.

As service moves up in the frequency range, ceramic thin film technologies are going to become more desirable, Hill says. He also foresees a greater emphasis on additive manufacturing so small components and devices with unusual shapes can be formed. Additionally, there may develop an emphasis on photonics as frequencies continue to go higher, which could impact makers of specialty glasses and fused silica.

But even if the technology and infrastructure for 5G and eventually 6G networks exists, delays and inconsistencies in spectrum auctions and allocation may slow deployment in some regions, as demonstrated in an assessment by LuxCarta, a digital mapping firm based in Sophia-Antipolis, France.[2] Standards for deploying these new systems effectively are essential, and a recent framework published by the International Telecommunication Union (ITU) may help.[3]

ITU is an agency of the United Nations based in Geneva. The details contained in its Recommendation ITU-R M.2160 provide guidance on technology trends and spectrum harmonization for next-generation cellular networks and identifies focus areas for further study.

Ultimately, by learning from the hurdles experienced during the 5G rollout, cellular communication manufacturers and businesses can "continue to better serve the needs of the networked society, for both developed and developing countries in the future," the ITU framework says.

About the author

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

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SOCIETY DIVISION SECTION CHAPTER NEWS

FOR MORE INFORMATION:

ceramics.org/spotlight

Edwin Rudolph Fuller Jr., DLM, past president, 1943–2025

Edwin Rudolph Fuller Jr. died on Aug. 1, 2025, at the age of 81. He was an ACerS Fellow (1983), Distinguished Life Member (2023), and past president (2009–2010).

Fuller was born in Albemarle, N.C., to Elaine and Edwin R. Fuller. His undergraduate studies took place at the University of North Carolina, where he received a bachelor's degree in physics while also being a member of the university wrestling team. After graduating, Fuller married Barbara Parker, and they moved to Illinois so he could pursue his Ph.D. in solid-state physics from the University of Illinois Urbana-Champaign.

During his graduate studies, Fuller often studied in the ceramics library, which was across the street from the physics building, because it was very quiet. However, "I didn't think anything at all about ceramics," Fuller said in his 2023 DLM profile, until he joined the National Bureau of Standards, now the National Institute of Standards and Technology (NIST), as a National Research Council Postdoctoral Fellow.

Fuller initially planned to conduct research on traditional physics topics, but he became fascinated with the field of fracture mechanics after sharing an office with ACerS DLM Anthony "Tony" Evans. Attending the ACerS Annual Meeting during the second year of his postdoc solidified his interest in the ceramics field.

During his time at NIST, from which he retired in 2008, Fuller conducted research in areas spanning geothermal cements, Skylab windows, reliability of decorative marble panels, thermal barrier coatings for aircraft engine blades, and power generation turbines. He also made seminal contributions to the field of computer simulations. He led development of the computer software program Object-Oriented Finite Elements, or OOF, which was one of the earliest computational tools developed to predict material behavior by inputting either experimental and/or fundamental data.

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

Besides his expansive engagement across multiple ACerS Divisions, Fuller also was involved in the Baltimore–Washington Section (now the Washington, D.C./Maryland/Northern Virginia Section), where he served in all leadership positions. After retirement, he and his wife, Barbara, returned to North Carolina to be near their only child and his family, and Fuller became actively involved in the Carolinas Section.

During his term as ACerS president, Fuller was seen as a "consensus builder" who made sure that member opinions were heard and considered in Board decisions. As described by Mark Mecklenborg, ACerS executive director, "He made sure that all members were welcomed at our events, and that all staff members knew that he and the Society valued the work that they do for the ceramics and glass community."

Following news of Fuller's death, many friends and colleagues reached out to share their warm memories of Fuller. A few of these many touching sentiments are included on the following page.

In his 2023 DLM profile, Fuller shared that over the course of his career, ACerS became a "natural home" full of supportive mentors who aided his growth as a young professional. To help others access these same opportunities, he requested that an option to donate to ACerS be included in his obituary: https://secure.qgiv.com/for/acers. ■

Words of remembrance

"Ed and I were colleagues for many years at NIST, and we also had several papers together. He was an amazing and wonderful person, and I'm glad I got a chance to know him." –**Winnie Wong-Ng**, DLM

"Ed was my officemate at NBS/NIST for a time, a bridge partner, and a good friend. He was great to work with and a brilliant problem solver. He was always willing to help. He will be sorely missed."
–**Steve Freiman**, DLM

"I followed Ed as ACerS president, so we spent several years working together. Ed was just an all-around wonderful guy: smart, funny, easy-going, and ever the gentleman. I will miss his smile and his kindness."
–**Marina Pascucci**, DLM and past president

"I was fortunate to follow Ed on the Board and then shortly afterwards as Society president. He was generous with his time and thoughtful with his advice, always with an added touch of good humor."
–**Dick Brow**, DLM and past president

"I have fond memories of Ed coming to Northwestern to serve on the Ph.D. committees of some of my students. He was great with students—asking just the right questions and giving them such encouragement."
–**Katherine T. Faber**, DLM and past president

"Ed and I were friends for several decades. I learned so much from him—not only through his scientific insights but also through his sincere and humble approach to exploring the unknown."
–**Tatsuki Ohji**, DLM and past president ■

ACerS and USACA receive two-year extension funding for hypersonic materials training program

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

The original program, part of IBAS' National Imperative for Industrial Skills initiative, attracted more than 220 participants from industry, government, and academia and delivered three full-day short courses and two half-day online courses focusing on materials for hypersonic applications. The two-year extension will expand this successful model with a comprehensive training approach targeting workforce development in this critical national defense sector.

"The overwhelmingly positive response to our initial program demonstrated the significant demand for specialized knowledge in these advanced materials," says Mark Mecklenborg, ACerS executive director. "Nearly 60% of attendees came from prime contractors or their supply chains, with another 25% representing military and government entities, validating our approach to workforce development in this critical field."

The extension program has three objectives: (1) reach new industry and agency audiences not currently served; (2) increase visibility of hypersonic materials workforce development through strategic marketing; and (3) introduce K–12 students to materials science career opportunities, including hypersonics.

"This ACerS–USACA partnership fills a critical knowledge gap for engineers, designers, technicians, and allied personnel working with hypersonic materials," says Ken Wetzel, USACA executive director. "This extension represents more than additional training. It's a comprehensive approach to building a sustainable hypersonics workforce pipeline. By combining professional development for today's engineers with outreach to tomorrow's talent through K–12 initiatives, we're creating a long-term strategy to ensure U.S. leadership in hypersonic materials science and engineering for decades to come."

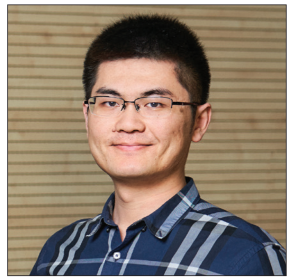
The expanded program includes 18 planned activities over two years, featuring conference-based short courses, regional in-person training, virtual courses, in-house training at prime contractors and DOD facilities, and K–12 teacher training workshops with the Ceramic and Glass Industry Foundation.

Questions and queries to get involved in the program can be directed to Amanda Engen, ACerS director of communications and workforce development, at aengen@ceramics.org. ■

MEMBER HIGHLIGHTS

Volunteer Spotlight: Yang Bai

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



Yang Bai is associate professor in the Microelectronics Research Unit at the University of Oulu, Finland. He received his bachelor's degree in materials science and engineering from Tianjin University, China, and his Ph.D. from the University of Birmingham, U.K. He was a researcher at the Central European Institute of Technology in the Czech Republic before receiving the European Union's Marie Sklodowska-Curie Individual Fellowship and moving to the University of Oulu.

Bai's research interests include energy harvesting technologies and sustainable microelectronics, with focuses on photoferroelectrics, piezoelectrics, self-sufficient Internet of Things systems, and recycling of hazardous piezoelectric ceramics. He has been granted five patents worldwide for research in these areas.

Bai is a lifetime member of ACerS, and currently he is chair of the Energy Materials and Systems Division.

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

Names in the News

Members—Would you like to be included in the Bulletin's Names in the News? Please send a current head shot along with the link to the article to mmartin@ceramics.org.

David Poerschke received a planned $2 million multi-institutional award from the Defense Advanced Research Projects Agency to lead a collaborative project as part of the agency's Intrinsically Tough and Affordable Ceramics Today (INTACT) Disruption Opportunity program. The project aims to develop dislocation-dense ceramics via cold spray collision process optimization. ■

FOR MORE INFORMATION:

ceramics.org/membership

Ceramic Tech Chat: Carolyn Primus

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

In the August 2025 episode of Ceramic Tech Chat, Carolyn Primus, medical device consultant, shares her journey into the field of dental materials, provides a glimpse of the history and variety of ceramic materials used in dentistry, and describes some of the ways she's personally contributed to this field.

Check out a preview from her episode, where she describes the dental area in which she specializes: endodontics.

"*Endodontics is the treatment of the pulp system within the tooth. When I got into the consulting mode, that's when I got into endodontics, which I loved because it wasn't just replacing or trying to mimic the enamel that was lost; you were really trying to heal the tooth and prevent it from any further illness that often leads to extraction.*"

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

IN MEMORIAM

H. Kent Bowen
Rolf Clasen
Edwin R. Fuller

AWARDS AND DEADLINES

Nomination deadline for Society awards: Jan. 15, 21, 31, or March 1, 2026.

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

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

A lasting partnership: How the CGIF and Alexandra Zevalkink transformed materials science outreach at Michigan State

Over the past seven years, Alexandra Zevalkink of Michigan State University has built a dynamic and evolving outreach program that introduces students of all ages to the fascinating world of materials science. With consistent support from the Ceramic and Glass Industry Foundation (CGIF) through its project grant program, her initiatives have grown from simple crystal identification activities to sophisticated optical materials labs that are now part of the university curriculum.

This long-standing partnership began in 2018, when Zevalkink received her first CGIF project grant to develop the "Science of Crystals" outreach activity. The goal was to engage girls in materials science and teach them about ceramics and crystal growth through hands-on experiences.

"We requested funds to develop and implement hands-on activities and demonstrations for a series of annual outreach events organized by the Women in Engineering program at Michigan State," Zevalkink shares.

The program was an immediate success, with Zevalkink noting that "beautiful rainbow" crystals such as bismuth and labradorite were a huge hit with students, as well as the colorful cubic zirconia gemstones. The activities were designed to be accessible and engaging, even for students unfamiliar with engineering.

"The major strength of this project is the broad appeal of crystals, even to students who are not necessarily interested in traditional engineering topics such as bridges, cars, or robots," Zevalkink explains.

In 2021, the Zevalkink group was awarded a second project grant to adapt their outreach to a virtual format during the COVID-19 pandemic. They mailed Mini Materials Kits to participants and hosted Zoom sessions for Michigan State's "Introduce a Girl to Engineering Day."

"We did achieve our major objective of hosting a virtual materials science demonstration for local 4–8th grade girls via Zoom," she reports. The kits were also used in Michigan State's Engineering Summer Camp, where students explored crystal properties and shape memory alloys.

"The kids greatly appreciated all the activities and were very enthusiastic, especially to have the possibility of closely examining the crystals," she says.

These early projects laid the foundation for a more ambitious initiative in 2023: the development of an Optical Properties of Materials Lab for both undergraduates and high school students.

"Our goal was to develop a hands-on lab for undergrads and summer camp students to learn about optical properties of materials," she explains.

With a third project grant, the team purchased a handheld spectrometer, an iPad, color filters, and light sources to create a portable, interactive lab experience. The lab was implemented in fall 2024 as part of a materials science and engineering course (MSE 331).

"The lab taught the students how materials properties such as band gap and impurity concentration control whether the material is transparent, opaque, or colored," she writes in a report on the project.

CERAMIC AND GLASS INDUSTRY FOUNDATION

Alexandra Zevalkink (in green) and students examine a silicon boule at Michigan State University's Introduce a Girl to Engineering Day (2018).

Students investigate natural and synthetic single crystals during a classroom activity (2021).

Student feedback was overwhelmingly positive, with Zevalkink saying, "During the following semester, students told me how much they had enjoyed using the spectrometer to test different crystals. One of the students in MSE 331 was even inspired to create a scaled-down version of the activity as a demo for a different course."

Throughout all three projects, Zevalkink continued to use and expand the original crystal collection funded by the CGIF in 2018.

"We continue to use the large library of natural and synthetic crystals that were purchased using the CGIF funding every winter and summer for various outreach activities, reaching hundreds of students per year," she writes in a report on the project. "Students frequently comment on how much they enjoy seeing and handling real, high-quality specimens."

What began as a single outreach activity has grown into a multitiered educational program that spans K–12 outreach, summer camps, and undergraduate education. Zevalkink's sustained collaboration with the CGIF has not only enriched her own teaching and research but has also introduced hundreds of students to the possibilities of a future in materials science.

As she continues to expand and refine these programs, her work stands as a model for how long-term support and vision can create lasting impact. The CGIF is proud to have been a partner in this journey, helping to inspire the next generation of materials science professionals.

Help us inspire the next generation of ceramic and glass professionals. Give now at https://foundation.ceramics.org/get-involved/donate. ■

Hypersonic flight: Redefining the aerospace frontier

While earlier aerospace efforts focused on stealth technology—such as reducing radar cross sections through faceted designs—modern advancements increasingly emphasize speed.

Hypersonics, defined as flight at speeds equal to or greater than Mach 5 (~3,838 mph or 6,174 km/h), represents this new frontier. Much like the transition from single-shot firearms to revolvers, hypersonic vehicles represent a quantum leap in capability and strategic advantage in aerospace engineering.

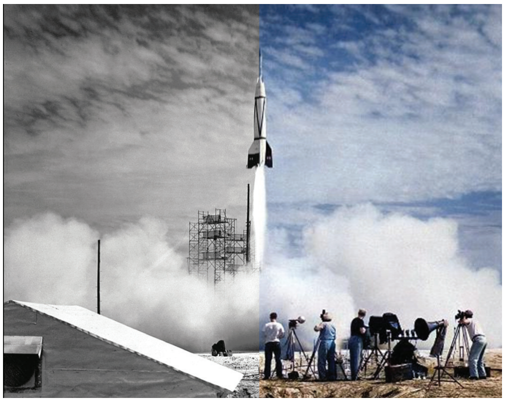
Early hypersonic achievements

While the earliest manufactured object to achieve hypersonic speeds did so under its own power (more on that in the next section), most of the earliest hypersonic speeds were achieved not through propulsion but by leveraging the principles of gravity and reentry.

Historically, spacecraft returning to Earth have reached hypersonic velocities due to the speeds of reentry. This natural acceleration paved the way for future developments in hypersonic technology.

In April 1961, Soviet cosmonaut Yuri Gagarin became the first human to achieve hypersonic speeds during his historic orbital flight. Shortly afterward, Alan Shepard achieved hypersonic speeds during Project Mercury.

Though these missions primarily achieved hypersonic speeds passively during atmospheric reentry, challenges such as material degradation foreshadowed the significant technical hurdles in achieving sustained hypersonic flight.



Credit: NASA/U.S. Army, Wikimedia

Launch of the Bumper 8 rocket in July 1950. The Bumper program, which launched eight rockets between May 1948 and July 1950, resulted in the first manufactured objects to achieve hypersonic speeds. Picture rendered with a color tool for effect.

Toward sustained hypersonic flight

The RTV-G-4 Bumper rocket

The journey toward sustained hypersonic flight began with the RTV-G-4 Bumper rocket. This rocket, which combined the German V-2 rocket and the WAC Corporal sounding rocket, was used to investigate launching and separation techniques for two-stage rockets at high velocity.

In February 1949, the fifth rocket launched under the U.S. Bumper program (May 1948–July 1950) achieved hypersonic speeds of 5,150 mph (>Mach 6) thanks to the unique two-stage separation "bumper" design. However, the rocket faced challenges, including severe thermal stress leading to charring upon reentry, highlighting the difficulties of sustaining such high velocities.

The X-15 program

The next major leap in sustained hypersonic flight came with the X-15 program. During the 1960s, the North American X-15, a rocket-powered aircraft, set the bar high for manned hypersonic flight by achieving speeds exceeding Mach 6 and altitudes of more than 50 miles. This program provided invaluable data on high-speed aerodynamics, thermal protection, and human factors in extreme flight conditions.

NASA's X-43A and scramjet propulsion

In the early 2000s, NASA's X-43A project introduced "scramjet" (supersonic combustion ramjet) technology into the hypersonic arena. Unlike traditional rockets, the scramjet engine uses atmospheric oxygen for combustion rather than carrying an oxidizer onboard, which allows it to operate efficiently at high speeds.

The X-43A set a new speed record for aircraft powered by air-breathing

Materials in the news

Unified theory may reveal superconducting materials

Researchers at The Pennsylvania State University developed a new approach to predict which materials could behave as superconductors. Conventional superconductors, which operate at very low temperatures, are typically understood through the Bardeen-Cooper-Schrieffer theory, which says the ability to conduct electricity with no resistance relies on electron pairs that move through the material in a coordinated way to avoid collisions with atoms. The Penn State researchers found a way to connect this theory with density functional theory, a popular computational method not originally designed for studying superconductivity. For more information, visit https://www.psu.edu/news.

Simple magnetic trick could change quantum computing

Researchers from Chalmers University of Technology in Sweden and Aalto University and the University of Helsinki in Finland unveiled a new quantum material that could make quantum computers much more stable by using magnetism to protect delicate qubits from environmental disturbances. Unlike traditional approaches that rely on rare spin-orbit interactions, this method uses magnetic interactions—common in many materials—to create robust topological excitations. Combined with a new computational tool for finding such materials, this breakthrough could pave the way for practical, disturbance-resistant quantum computers. For more information, visit https://www.chalmers.se/en/current/news.

engines, reaching Mach 9.6 in 2004. This innovation marked a significant stride in propulsion technology, demonstrating the potential for sustained hypersonic flight.

International developments and modern hypersonic missiles

Hypersonic technology has seen rapid development globally, with various approaches being explored to achieve sustained hypersonic flight.

China's DF-ZF and Russia's Avangard are examples of boost-glide systems that have reportedly achieved operational status. These systems use a combination of rocket boosters and aerodynamic gliders to achieve hypersonic speeds and maneuverability, presenting new challenges and strategic considerations for global security.

Meanwhile, the United States has pushed the boundaries of hypersonic flight by investing in the development of scramjet-powered missiles. As described in the section above, scramjet is an air-breathing engine that efficiently compresses incoming supersonic airflow without moving parts, enabling sustained hypersonic flight by combusting fuel in a high-speed air stream.

These advanced systems promise not only extraordinary speeds but also enhanced maneuverability and reduced detection capabilities, which are gamechangers for modern warfare.

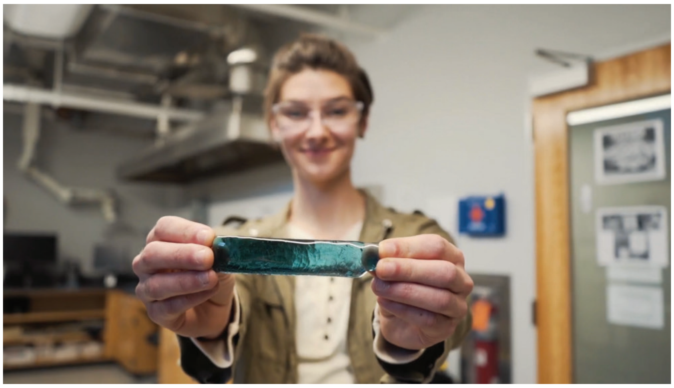
Advanced materials for hypersonics

Ultrahigh-temperature ceramics (UHTCs), including zirconium diboride and hafnium carbide , are capable of withstanding extremely high temperatures above 3,000°C. Because of the excellent thermal and mechanical properties of UHTCs, they are very promising for application in leading edges, nose caps, and other high-stress parts in hypersonic aircrafts and shuttles. Learn more about current industrial applications of UHTCs in the January/February 2025 *Bulletin* cover story.

Carbon–carbon composites consist of carbon fibers interlaced in a carbon matrix, which gives the composites excellent thermal conductivity and mechanical stability. Their ability to dissipate heat efficiently makes them widely used in thermal protection systems and reentry vehicle components. Learn more about a new class of ultrahigh-density carbon–carbon composites for aerospace applications in the April 2024 *Bulletin*.

Interested in learning more about the science and engineering of materials for hypersonic applications? The American Ceramic Society, in partnership with the United States Advanced Ceramics Association, has developed a workforce training program on hypersonic materials. Contact Amanda Engen, ACerS director of communications and workforce development, at aengen@ceramics.org for more information on the program. ■

Reducing waste of waste glass: Container glasses of different colors safely melted together


Credit: PennStateMatSE, YouTube

Katy Gerace, previously a doctoral student at The Pennsylvania State University and now research and development senior engineer at Vitro Architectural Glass, holds a piece of glass created from recycled bottles.

Researchers at The Pennsylvania State University showed that container glass, which has less stringent quality tolerances than flat glass, can accommodate mixed colored glass waste more easily than previously believed.

Glass is colored by adding different metal oxides to the composition. But as the authors Katy Gerace and ACerS Fellow John Mauro show in their paper, the main difference between glasses of different colors is not the presence nor absence of certain oxides but rather the amount of each oxide.

"For example, cobalt oxide was identified in each bottle composition; however, the amount of cobalt oxide in cobalt blue bottles (648.6 ppm) was two orders of magnitude larger compared to clear bottles (8.3 ppm) and one order of magnitude larger compared to amber bottles (23 ppm)," they write.

Besides these small differences in the colorants and some fining agents, the average base glass composition of soda–lime silicate was nearly the same across clear, cobalt blue, emerald green, forest green, and amber bottles. This extreme similarity meant the glasses demonstrated a consistent viscosity profile between the different color families, which is necessary for efficient melting and processing.

As such, "color contamination is not a technical risk, but instead, an economic risk as color contamination impacts the optical properties and aesthetic of the final product," they explain.

Though stringent color profiles may be necessary for some container manufacturers, for companies such as Remark Glass, a Philadelphia-based glass reuse business that partnered with Gerace and Mauro on this project, the focus is on keeping glass waste out of landfills more so than exact color matches. But even if the reused colored glass is not an exact shade, consistent color can still be achieved by adjusting the particle size of the cullet and the temperature and time of the remelting process.

Ultimately, what this study shows is that the major risk of reusing glass from single-stream recycling systems is not the compositional variation among bottle brands but the level of non-glass contamination. This understanding can help improve the rates of glass waste reuse in container manufacturing, Gerace and Mauro conclude.

The open-access paper, published in *International Journal of Ceramic Engineering & Science*, is "Characterization of soda–lime silicate glass bottles to support recycling efforts" (DOI: 10.1002/ces2.10217). ■

Sourcing from waste: Molten salt electrochemical processing of cemented carbide scrap

Researchers from Beijing University of Technology and Xiamen Tungsten Co. experimented with recovering tungsten and cobalt from cemented carbide scrap using molten salt electrochemical extraction.

Molten salt electrolysis is a relatively low-temperature process in which an electric current is passed through a molten salt to facilitate chemical reactions. The researchers previously used this method to extract tungsten and cobalt from cemented carbide scrap, but the electrolysis process was carried out in an argon atmosphere. This time, they carried out the process in air, "which can simplify the equipment to some extent and enhance its practical applicability," they write.

For this study, a two-electrode system was used for the all air-based electrolysis experiments. A tungsten carbide cobalt block or tungsten rod was used as the soluble anode, and a copper plate was used as the cathode. Both cathode and anode were immersed in molten salt (sodium tungstate) at 900°C.

For comparison, some experiments were carried out in an argon protective atmosphere using a three-electrode system. The working and reference electrodes were platinum wires, and the counter electrode was a tungsten rod.

Testing confirmed that both tungsten and cobalt could be successfully extracted by three-stage, constant-current electrolysis in an air atmosphere. Compared to experiments in the argon atmosphere, the dissolution rate could be accelerated by increasing the air flow rate in the air atmosphere. The dissolution rate remained steady after the air flow rate reached 0.2 L/min.

"It can be concluded that electrolysis in an air atmosphere may be a viable option," the researchers conclude.

The paper, published in *International Journal of Refractory Metals and Hard Materials*, is "Study on the air atmosphere molten salt electrolytic extraction of tungsten and cobalt from cemented carbide scrap" (DOI: 10.1016/j.ijrmhm.2024.106636). ■

Greenhouse gases reduce the number of satellites that can safely orbit the Earth

The stars have served as a guiding light for millennia, allowing humans to make transoceanic journeys without relying on modern guidance systems and technologies. Yet ironically, those modern systems require satellites that are quickly becoming a major obstruction to learning from the night sky.

In the six years since SpaceX launched the first 60 satellites in its much-hyped Starlink constellation, the total number of artificial satellites orbiting the Earth has more than doubled. While Starlink has been a game changer for people living in rural areas, the constellation is increasingly interfering with astronomy from both an optical and radio perspective.

The short lifespan of Starlink satellites is another drawback of this controversial system. They are designed to last about five years, which means the constellation requires constant replenishment.

SpaceX argues that the need to retire hundreds of satellites each year is not a concern because the satellites are designed for demise. This emerging approach to satellite construction involves using materials and architectures that can burn up in the atmosphere upon reentry, thus reducing the amount of debris left in space.

However, the atmosphere's ability to burn up old space junk is not something to be taken for granted, according to a new open-access paper by Massachusetts Institute of Technology engineers.

MIT associate professor Richard Linares and Ph.D. candidate William Parker worked with University of Birmingham research fellow Matthew Brown to determine the effects of carbon dioxide and other greenhouse gases on the upper atmosphere. They specifically looked at the thermosphere, where the International Space Station and most satellites orbit today. This atmospheric region naturally contracts and expands in response to changes in solar ultraviolet radiation and solar-driven geomagnetic activity.

They found that greenhouse gases can cause cooling in the thermosphere, which causes it to contract. Upon contraction, the thermosphere's density decreases and reduces atmospheric drag—the force that scientists rely on to pull old satellites and other debris down to altitudes where they will burn up.

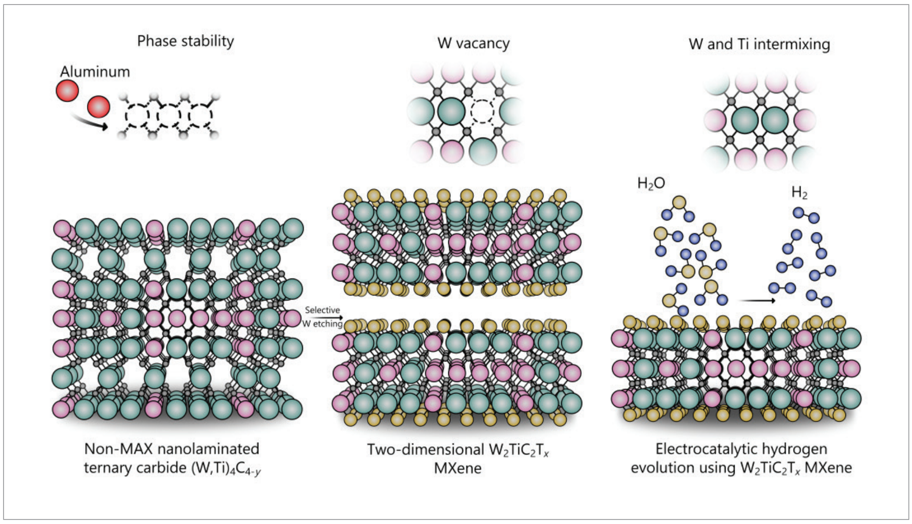
Based on modeled emissions over the next century, the researchers determined that the atmosphere's satellite carrying capacity would reduce by 50% to 66% between the altitudes of 200 and 1,000 km. If this reduced capacity is ignored and satellites continue being sent to space, the researchers predict that overcrowded regions will experience "runaway instability," or a cascade of collisions that would create so much debris that satellites could no longer safely operate there.

Ultimately, "Our behavior with greenhouse gases here on Earth over the past 100 years is having an effect on how we operate satellites over the next 100 years," says Linares in an MIT press release.

The open-access paper, published in *Nature Sustainability*, is "Greenhouse gases reduce the satellite carrying capacity of low Earth orbit" (DOI: 10.1038/s41893-025-01512-0). ■

advances in nanomaterials

Novel MXene synthesis method creates cost-effective catalyst for hydrogen production



Credit: Babak Anasori, Purdue University

Illustration showing a novel synthesis method for etching tungsten-based MXenes from nanolaminated ternary carbide precursors.

Researchers led by Babak Anasori of Purdue University reported the successful synthesis of a tungsten-based MXene using a novel processing route.

MXenes are a family of 2D transition metal carbides, nitrides, and carbonitrides known for having excellent electrical conductivity, hydrophilicity, high specific surface area, and desirable electrochemical properties.

Tungsten-based MXenes are predicted to be good electrocatalysts for hydrogen production due to having low overpotential. In other words, the difference between the actual potential required for an electrochemical reaction to occur and the theoretical potential is minimal, meaning the reaction requires less energy to occur efficiently.

Synthesizing tungsten-based MXenes has proven difficult, however. MXenes traditionally are fabricated by strategically etching away the "A" layer in a precursor MAX phase. But theoretical predictions indicate that tungsten-based MAX phases are inherently unstable. As such, there were no reports of successfully synthesized tungsten-based MXenes in the literature—until the recent paper, that is.

Instead of etching a traditional MAX precursor, which is metallically bonded, the Purdue-led researchers instead etched a nanolaminated ternary carbide precursor, which is covalently bonded. It is the first time anyone has etched a layered carbide consisting entirely of transition metals, Anasori explains in an email.

To accomplish this feat, the researchers first used density functional theory to calculate the energy required for etching each layer. They also investigated the effect of intermixing transition metals—tungsten and titanium—and the effect of vacancies in tungsten atomic layers.

Using the knowledge gained from these calculations, they mixed tungsten, titanium, and carbon together with some aluminum to control the arrangement of tungsten and titanium atoms in each atomic layer. They then etched the mixture using hydrofluoric acid in a process carried out over four days at 55°C. The process yielded a multilayered structure that could then be delaminated to obtain the tungsten-based MXenes.

The tungsten-based MXene with composition $W_2TiC_2T_x$ had the lowest overpotential (~144 mV), which is about 25% lower than the overpotential (~186 mV) of the previously best performing MXene electrocatalyst ($Mo_2Nb_2C_3T_x$) reported by Anasori's group. This value is noticeably closer to the overpotential of platinum-based catalysts, which ranges between 20–40 mV in acidic electrolytes.

While low overpotential alone does not guarantee improved electrocatalytic activity, several other parameters indicated this MXene would perform well as a hydrogen catalyst. Specifically, the MXene had a low Tafel slope, which suggests faster reaction kinetics, and experimentally confirmed stability for about 24 hours in an acidic environment. The researchers attribute these desirable properties to tungsten's highly active and ordered basal planes.

The success of this new MXene and MXene synthesis method "opens avenues for future research in exploring the synthesis of other non-MAX nanolaminated ternary carbide precursors," the researchers write.

They expect future studies will reveal many more applications for the tungsten-based MXenes besides just hydrogen production. For example, preliminary analysis of the MXenes in this study revealed desirable electronic and optoelectronic behaviors that could be used for various photonic and optoelectronic applications, such as optical limiting and all-optical switching.

The paper, published in *Nature Synthesis*, is "Synthesis of a 2D tungsten MXene for electrocatalysis" (DOI: 10.1038/s44160-025-00773-z). ■

Ordered 2D silk films show potential for next-generation bioelectronics

Researchers led by Pacific Northwest National Laboratory investigated the possibility of growing ordered fibroin films on graphene, a van der Waals material.

Fibroin is one of the two main protein components of natural silk fibers, which are a promising material for next-generation flexible electronics and transistors. It has excellent biocompatibility and biodegradability, along with other attractive properties including high optical transmittance, mechanical durability, lightweight, and ease of processing.

However, natural fibroin has a disordered structure, resembling spaghetti, which makes it unable to modulate electronic signals uniformly or accurately. Fortunately, by depositing fibroin on surfaces with which the protein has some affinity, studies have shown that unique, highly ordered 2D phases of fibroin can form.

In the recent paper, the authors dissolved lyophilized fibroin powder in deionized water, resulting in a disordered solution with a high content of random coils and negligible beta sheet conformation. But after incubating the solution with highly oriented pyrolytic graphite, fully ordered monolayers of beta sheet lamellae (layers) successfully formed.

The researchers determined that the new 2D crystalline phase forms when the solution's fibroin concentration is above a minimum value needed to drive nucleation but below the concentration at which fibroin begins to assemble before incubation.

They then used a variety of techniques—atomic force microscopy, synchrotron-based nanoscale Fourier transform infrared spectroscopy, and molecular dynamics—to show that assembly of the ordered structure proceeds along two distinct pathways:

1. At low fibroin concentrations (0.01 to 0.08 μg/ml), direct epitaxial growth occurs.
2. At high fibroin concentrations (> 0.1 μg/ml), a two-step process occurs. This process involves the conversion of a metastable phase consisting of unfolded fibroin molecules into the structured film through folding and reorganization.

Regarding the second pathway, the folding transition was found to be rate limiting because the fibroin concentration had little or no effect on the growth rate of formed lamellae. Instead, the growth rate was determined by the transformation rate. The speed remained the same even when the concentration increased threefold. Initial formation of the unstructured film was rapid, covering the entire surface at a higher concentration before any ordered structures appeared.

Based on these results, the authors believe highly ordered 2D fibroin layers can be created on multiple van der Waals materials, thus providing "an unexplored strategy for both extending and improving the performance of silk in electronic and optical applications."

The open-access paper, published in *Science Advances*, is "Two-dimensional silk" (DOI: 10.1126/sciadv.ado4142). ■

Managing your stress: Improved cortisol detector offers glimpse at future point-of-care testing

Researchers from Xi'an Jiaotong-Liverpool University (China) and Abertay University (U.K.) developed an improved cortisol detector to assess stress levels.

The steroid hormone cortisol, along with insulin, helps regulate blood sugar (glucose) levels in the human body. When stressed, cortisol production increases and allows the body to release more glucose, which is used as fuel by the brain to process information more quickly.

The devices currently available for measuring cortisol levels rely mainly on electrochemical sensing. In this process, the electrical properties of an electrode are measured during a biochemical reaction.

Electrodes made of silver/silver chloride are typically used as the reference electrodes in these devices because they have a stable and well-known electrode potential. However, these electrodes have poor stability in extreme and fluctuating conditions, such as changing pH and temperature. As such, the devices have a short shelf life and so are difficult to produce commercially.

To overcome this stability challenge, researchers have investigated placing protective layers on the silver/silver chloride reference electrodes. The recent study described the potential of using iridium oxide as a protective layer.

Iridium oxide is a well-established material in the chemical sensing world. In addition to being used as a stable pH sensor, iridium oxide also has been used to detect glucose, hydrogen peroxide, glutamate, and organophosphate pesticides, among other substances.

The iridium oxide-coated electrodes not only were more stable against environmental stimuli but also showed ultrasensitivity to cortisol. Specifically, the device detected cortisol molecules at a concentration 3,000 times lower than the normal range of cortisol in human blood, which "makes our device sensitive enough for commercial use," says coauthor Qiuchen Dong, assistant professor at Xi'an Jiaotong-Liverpool University, in a press release.

Another benefit of the coated electrodes was that they demonstrated good selectivity between different types of hormones.

"One problem with the current solutions is that there is much similarity between cortisol and other hormones such as progesterone, testosterone, and corticosterone. Our iridium oxide-modified electrode is selective enough to distinguish the different hormones and helps solve this issue," says Graham Dawson, associate professor at Xi'an Jiaotong-Liverpool University, in the press release.

In the future, the development and commercialization of long-lasting cortisol detectors could revolutionize point-of-care testing. At-home cortisol tests exist, but the samples must be mailed back to a lab for analysis. If the test kits included cortisol detectors, then everything from sample collection to analysis could be done at home.

The paper, published in *Talanta*, is "Iridium oxide-modified reference screen-printed electrodes for point-of-care portable electrochemical cortisol detection" (DOI: 10.1016/j.talanta.2024.126776). ■

Supporting bone healing: Strategies to improve the mechanical strength of bioceramic scaffolds

In an open-access review paper, researchers from various institutes and universities across Europe look at the strategies used to improve the mechanical strength of bioceramic scaffolds for bone healing.

They begin by noting that porosity is a key factor in mechanical strength. Studies on hydroxyapatite and tricalcium phosphate scaffolds have generally found that as porosity increases, compressive strength decreases. The extent to which this inverse relationship holds is affected by the materials used, particle and pore size, and manufacturing process, among other factors.

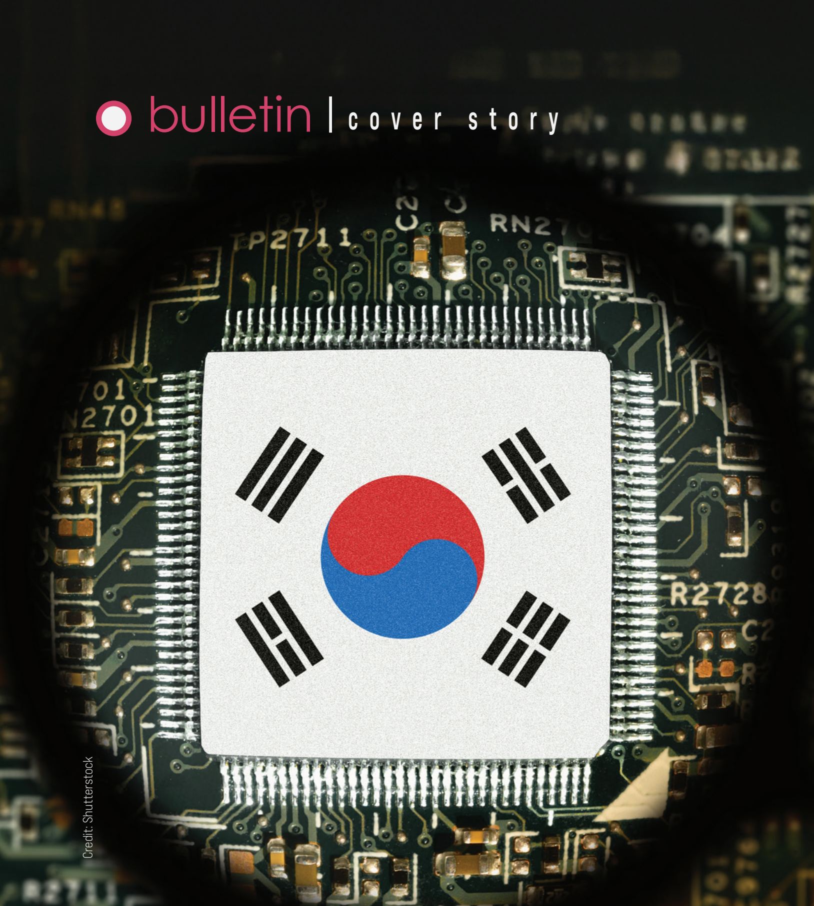
The researchers then dive into a review of the methods used to manufacture bioceramic scaffolds. First, they describe several traditional fabrication methods, including foam replica, gel or solvent casting, and freeze drying. These traditional methods often lead to irregular pore geometries, "resulting in regions with low pore interconnectivity, which compromises bioactivity, and high-stress concentration under load, which compromises mechanical properties," they write.

In contrast, additive manufacturing "addresses these issues by allowing for precise control of pore geometries," they write. They then describe various additive manufacturing techniques, including extrusion-based methods, selective laser melting and sintering, and stereolithography.

After overviewing all the manufacturing techniques, the researchers dive into describing shared parameters that impact porosity, including cooling rate, sintering time and temperature, and solid loading. They then explore the bulk and nanoceramic materials used for bioceramic scaffolds and discuss how porosity impacts mechanical strength in each case.

The researchers conclude that bioceramics have "a bright future" in bone healing applications. However, "more investigations on all different kinds of bioceramics are required to improve their properties so that their weakness becomes a treatable problem and make them more effective in bone repair," they write.

The open-access paper, published in *Journal of the European Ceramic Society*, is "Review on the strategies to improve the mechanical strength of highly porous bone bioceramic scaffolds" (DOI: 10.1016/j.jeurceramsoc.2023.09.003). ■



Credit: Shutterstock

Korea's ambitious intelligence

By Randy B. Hecht

A vast network of research institutes gives Korea strong R&D muscles to flex as artificial intelligence technologies and sustainability initiatives evolve globally.

The Republic of Korea's sovereign political history dates only to 1945, but its cultural and intellectual traditions span thousands of years.

Taehak, a Confucian educational institute, was founded in 372 CE, and by 992 CE, the Gukjagam (a national higher education institution) and local private schools called hyanggyo had been founded within the unified three kingdoms then known as Goryeo.[1]

Now, this long history of cultivating human intellect is taking a 21^{st}-century turn. The Korean government, in partnership with leading research institutes, is focusing domestic scientific endeavors on two major global transformations: the rise of artificial intelligence and the ongoing climate crisis.

Artificial intelligence

AI with national nuances

AI holds significant potential for revolutionizing the ceramics and materials industries in general, as outlined in "The synthetic data revolution: How AI is redefining quality control in ceramics manufacturing" (page 34). Achieving this potential, however, requires the coordinated efforts of academic, industrial, and governmental institutions to create AI systems that cater to each sector's unique needs.

On July 25, 2025, the Ministry of Science and ICT and the National Information Society Agency released details about the Performance Evaluation Dataset Construction Project.[2] The announcement noted: "Global big-tech companies have released a range of generative-AI services, yet most benchmark tests still rely on English-language metrics and do not adequately reflect the usage environment of Korean-language services."

The government therefore committed to investing 2.4 billion won (~US$1.7 million) "to construct high-quality performance-evaluation datasets that embody Korea's culture and social values while enabling an objective diagnosis of both domestic and overseas AI models."

This news followed the June 27, 2025, call for participants in developing Korea's Proprietary AI Foundation Model.[3] The Ministry of Science and ICT, National IT Industry Promotion Agency, National Information Society Agency, and Institute for Information & Communications Technology Planning & Evaluation jointly advocated for a "public–private collaboration to develop a globally influential Korean AI foundation model… aiming for ≥95% performance against leading global models."

Research institutes converge on AI

With these priorities in place, Korea's institutes are stepping up their efforts to attract and deploy the talent needed to give the country a global competitive advantage in AI.

KAIST

The Korea Advanced Institute of Science and Technology was founded in 1971 under the Korea Advanced Institute of Science Act,[4] which defined its mission as

- "To train advanced science and technology talent with in-depth theoretical knowledge and practical application skills," and
- "To conduct basic/applied research for national mid/long-term R&D projects and to advance Korea's science and technology prowess."

Today, it comprises five colleges, seven schools, and 13 graduate schools with a total faculty and staff of more than 1,500. It is also home to nearly 200 centers, institutes, and laboratories, including the Research Center for Next-Generation Metal-Supported Protonic Ceramic Fuel Cells, KAIST-Hansol Center for Advanced Materials and Devices, Center for Advanced Materials Discovery Towards 3D Displays, Quantum Materials Research Center, Global Bio-integrated Materials Center, Soft Nanomaterials Lab, and Center for Functionally Antagonistic Nano-Engineering: Creative Research Initiative.

On June 16, 2025, KAIST announced the launch of the Innovation-Core (InnoCORE) Research Group. This new venture, which was organized in cooperation with the Ministry of Science and ICT, Daegu Gyeongbuk Institute of Science & Technology, Gwangju Institute of Science & Technology, and Ulsan National Institute of Science and Technology, aims to "foster core research personnel who will lead innovation in the field of AI convergence," a KAIST statement says,[5] "to prevent brain drain of domestic talent and attract excellent overseas talent amidst the accelerating global competition for AI talent."

KAIST operates research groups focused on hyper-scale language model innovation, AI-based intelligent design-manufacturing integration, AI innovation drug development, and AI-transformed aerospace systems. Additional groups (including some led by partner institutes) are intended to "promote global collaborative convergence research" in bio-integrated physical AI, intelligent hydrogen technology innovation, and AI-space solar power research.

To meet one of its initial goals of recruiting "up to 200 world-class postdoctoral researchers," InnoCORE Research Group held job fairs during June 2025 at Northeastern University's Egan Research Center in Boston, New York University's Metrotech campus in Brooklyn, and the Korea Innovation Center in Silicon Valley.

KIMS

With its mission of contributing to industrial advancement, Korea Institute of Materials Science engages in processing technology for ceramics, metallurgy, surface-related materials, composites, and materials convergence as well as R&D for material verification and authorization and certification of components. It carries out those activities through research divisions dedicated to extreme materials, lightweight materials, nanomaterials, composites and convergence materials, energy and environment materials, advanced bio and healthcare materials, materials processing, and materials data and analysis research.

On June 30, 2025, KIMS announced that it is setting up an autonomous "self-driving laboratory" in which experiments can be conducted by AI.

"When a researcher inputs the desired material properties, the AI identifies the most efficient experimental conditions, and a robot automatically carries out the experiments," the announcement says.[6] "The results are then analyzed by the AI and used to guide the next set of experiments."

This move is seen as reducing the amount of time and cost needed to develop new materials, but KIMS sees advantages beyond an accelerated pace of R&D.

"By continuously accumulating and analyzing experimental data, the AI is able to learn autonomously, eventually enabling sophisticated experimental design," the announcement says. The design is intended to provide "a fully automated, end-to-end research environment in Korea" that KIMS can advance "by developing a digital twin laboratory, integrating multimodal AI models, and releasing large-scale materials datasets."

Sustainability

Expansion of eco-friendly national policies

Korea's adoption and implementation of carbon-neutral policies has been slower than that of other developed nations, and it remains the second-highest coal polluter among G20 countries after Australia.[7] Government efforts to increase acceptance of green practices and technologies picked up in 2021 with the enactment of the "Framework Act on Carbon Neutrality and Green Growth for Coping with Climate Crisis."[8]

The Korean government announced several new policies in the first half of 2025 aimed at improving the country's energy efficiency and reducing carbon emissions. In February, the Korean government finalized its 11th Basic Plan for Long-Term

Electricity Supply and Demand.[9] The plan is expected to pave the way for Korea's green energy transition in association with the recently passed Energy Trifecta Bill,[10] which includes the National Grid Expansion, Special Offshore Wind Power, and High-Level Waste Management bills.

In April, the Ministry of Science and ICT announced a strategic plan to advance carbon capture and utilization (CCU) technologies.[11] During the launch event, the Ministry also unveiled the Action Plan for Advancing Carbon Capture and Utilization Technologies and Industries, which outlines a science and technology-driven approach to accelerating the transition toward a carbon-neutral society.

Learn more about recent initiatives to achieve carbon neutrality in specific sectors in the sidebar "Efforts in the cement and glass industries to reduce carbon emissions."

Green technology developments at research institutes

Many Korean institutes are focusing R&D efforts on environmentally friendly technologies, such as those that improve the energy efficiency of industrial and residential systems, reduce carbon emissions, and combat waste. The developments described below offer a glimpse into the types of research taking place.

Smart windows that selectively reflect heat and light

On June 20, 2025, KAIST reported that one of its research teams had developed an electrochromic smart window technology that operates in three modes depending on voltage control.[12] In contrast to traditional metal deposition smart windows, this window effectively suppresses the glare phenomenon caused by external reflected light. It can also actively control the transmittance of both visible and near-infrared light, thus "presenting a truly smart window platform that comprehensively considers not only active indoor thermal control but also the visual safety of pedestrians," Professor Hong Chul Moon of KAIST says in the announcement.

Building-integrated photovoltaic technology

On May 29, 2025, KIMS announced a joint venture with Korea Southern Power Co., Ltd. for the development of building-integrated photovoltaic technology to be integrated into building exteriors.[13]

"By embedding solar modules into architectural elements such as roofs, exterior walls, and windows, the system not only generates electricity but also functions as a part of the building envelope," the announcement notes.

Efforts in the cement and glass industries to reduce carbon emissions

Report contributed by Haejin Hwang, president of the Korean Ceramic Society

Special thanks to Woo Sung Yum, Hyeong Jun Kim, and Sung-Min Lee of KICET for their assistance.

Cement

The Korean cement industry has long served as a key partner in the nation's construction infrastructure. In October 2022, research funding totaling approximately US$215 million was approved for the 2023–2030 period, launching the "Cement Industry Carbon Neutrality Program" with participation from all domestic cement producers. This program, which aims to cut CO_2 emissions by 12% compared to current levels and achieve full carbon neutrality by 2050, focuses on three main strategies:

Credit: Lotte Engineering & Construction

Seoul-based Lotte Engineering & Construction developed carbon dioxide reaction-hardening cement that is now in use at various construction sites.

- Replacing carbonate-based raw materials with noncarbonate alternatives.
- Substituting fossil fuels with alternatives, such as waste synthetic resins.
- Re-mineralizing CO_2 emissions for reuse in cement products.

Technologies are being developed to replace limestone—the primary raw material for cement—with noncarbonate sources, and blended cements using a variety of inorganic materials are being promoted to reduce limestone consumption. However, Korea currently has fewer types of blended cement compared to Europe or the U.S., and related legal standards are underdeveloped, prompting efforts to establish new national standards.

About 30% of CO_2 emissions during cement manufacturing come from fuel combustion. To address this source of emissions, research is underway to replace coal with waste plastics and other alternatives, creating a circular, eco-friendly energy ecosystem. Still, using waste plastics introduces challenges such as chlorine bypass dust generation and changes in cement chloride content, requiring updates to national standards.

Efforts are also underway to recycle CO_2 within the cement industry, including CO_2 reaction-hardening cement, mineral carbonation of chlorine bypass dust, and carbonation of construction materials. Institutional frameworks to support these efforts are in development.

Glass

In the glass industry, national projects for carbon reduction are equally active. The goal is to secure technologies that will reduce annual CO_2 emissions by 350,000 tons by 2030 and a total of 3.92 million tons by 2050. The approach centers on three areas:

- Reduce about 25% of CO_2 emissions through noncarbonate raw materials.
- Increase recycled glass usage and improve melting efficiency via pretreatment.
- Enhance process efficiency and reduce emissions through digital manufacturing, with a goal of up to 5% energy savings.

Oxy-fuel combustion technology, unlike conventional air-based melting, maximizes combustion efficiency and heat generation, significantly reducing fuel consumption. When combined with hybrid heating that integrates electricity, precise temperature control becomes possible, targeting up to 50% CO_2 reduction. Development is also underway for hydrogen-based combustion burners and next-generation glass melting furnaces, with design-to-simulation R&D in progress.

Other product-level efforts include lightweighting glass bottles and commercializing vacuum and quadruple glazing for energy-efficient windows. These innovations are expected to make a meaningful contribution to the glass industry's 2050 carbon neutrality goal. ■

MARKET SNAPSHOT

Made for foreign trade: Korea's export excellence meets economic uncertainty

By Randy B. Hecht

The Republic of Korea is home to Asia's fourth-largest economy, behind China, India, and Japan and just ahead of Indonesia. But in February 2025, the government's Korea.net site reported that the country's 2024 per capita gross domestic product was estimated to have exceeded that of Japan and Taiwan, according to data published by the Ministry of Economy and Finance, Bank of Korea, and Statistics Korea.[a]

It has been a bumpy ride since then. The country's GDP contracted by 0.2% in the first quarter of 2025 but rallied with second-quarter growth of 0.6%. *The Wall Street Journal* credited "resilient exports and policy support, as the central bank delivered monetary easing and the government stepped up fiscal stimulus" for the rebound.[b] But the CIA World Factbook notes that while Korea's manufacturing sector, led by the semiconductor and automotive industries, remains strong, the country must contend with "slow growth amid declining construction investment, export risks, and recent political instability" in addition to an aging workforce.[c]

The country's population was nearly 52,082,000 in 2024, and its labor force numbered more than 29,713,000. Women represent 43.8% of the workforce.

Credit: Efired, Shutterstock

An export-driven economy

Korea's 2024 export volume was about $835.14 billion, up from $769.24 billion in 2023. Leading export commodities include integrated circuits, cars, refined petroleum, plastics, and machine parts. Its largest export partners are China, the U.S., Hong Kong, Japan, and Taiwan. Major natural resources include coal, tungsten, graphite, molybdenum, and lead, and the country has strong hydropower potential.

Import volume was estimated at $758.72 billion for 2024, essentially on par with $758.41 billion in 2023. Integrated circuits, natural gas, crude petroleum, machinery, and cars are Korea's leading import commodities, and its largest import partners are China, the U.S., Japan, Germany, and Australia.

New AI legal framework

In December 2024, the Korean government passed the Act on the Development of Artificial Intelligence and Establishment of Trust, known as the AI Basic Act, which is slated to take effect in January 2026. The law establishes a comprehensive AI regulatory framework, and the U.S. Department of Commerce International Trade Association calls it "a pivotal development for U.S. companies operating in or entering the Korean Artificial Intelligence market."[d]

It further elaborates that "The act establishes legal grounds for establishing a national AI control tower, an AI safety institute, and various governmental initiatives in R&D, standardization, and policies. The legislation also mandates separate initiatives to support the national AI infrastructures, including training data and data centers, and fostering SMEs [small and medium-sized enterprises], startups, and talent in the AI field. More importantly, the act assigns transparency and safety responsibilities to businesses that develop and deploy 'high impact' AI and generative AI."[d]

The regulatory environment

Companies interested in exploring Korean market opportunities may need support in meeting regulatory and compliance requirements. The organizations below offer such resources.

The Korea Testing & Research Institute "completes over a half million tests and certification requests per year for over 30,000 businesses" and has "a global partner network connecting 180 overseas organizations in 40 countries." Website: https://www.ktr.or.kr/eng/main/index.do

The Korean Testing Certification Institute has a five-decade history of supporting "clients in the fields of machinery, electricity, electronics, lighting, renewable energy, chemistry, and medicine." It also offers "product quality test and evaluation service" for such industries as machinery, metallurgy, electrical/electronics, lighting, chemistry, environment, and construction. Website: https://www.ktc.re.kr/web_eunited

Korea Testing Laboratory describes itself as "Korea's only public comprehensive testing and certification organization" and states that it "studies evaluation methods for technological performance and safety in order to contribute to the successful establishment of the Fourth Industrial Revolution technologies." Website: https://www.ktl.re.kr/eng/main.do

Further trade resources

The U.S. Department of Commerce International Trade Administration's South Korea Country Commercial Guide provides guidance on everything from doing business in the country to the digital economy.[e] An overview of the status of the U.S.–Korea Free Trade Agreement is available at https://www.trade.gov/us-korea-free-trade-agreement.

Further resources include the U.S.–Korea Business Council (https://bit.ly/us-korea-business-council), the American Chamber of Commerce in Korea (https://www.amchamkorea.org), and the Korean Chamber of Commerce and Industry in the USA (https://kocham.org).

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Intellectual property sharing in Korea

Report contributed by Haejin Hwang, president of the Korean Ceramic Society

Special thanks to Woo Sung Yum, Hyeong Jun Kim, and Sung-Min Lee of KICET for their assistance.

In Korea, intellectual property (IP) generated through government-funded research projects is, in principle, owned by the university or national research institute that carried out the work. This setup ensures transparent management and fair use of publicly funded R&D outcomes.

For projects fully funded by a company, the resulting IP generally belongs to the company. In the case of joint research, patents are shared according to agreed contribution levels, often split 50:50 between the university and the company.

If a company wishes to use a jointly owned patent, it must enter into a technology transfer agreement, which can take the form of equity purchase of patent rights, granting of nonexclusive licenses, or assignment of exclusive licenses under specific conditions. Most cases involve granting nonexclusive licenses, but exclusivity is possible when justified.

Korea's system provides substantial inventor compensation for technology transfer. Typically, 50–60% of technology transfer income is distributed to the inventors to incentivize innovation and industrial application. In cases where only one domestic company can utilize a patent, the patent may be sold outright at an appraised value, with proceeds again prioritizing inventor compensation and the remainder allocated to the institution for reinvestment in R&D.

Credit: Jeonbuk National University

Scientists performing experiments at the Semiconductor Physics Research Center at Jeonbuk National University (Jeonju, Korea).

To enhance the effectiveness of technology transfer, more universities and research institutes now operate technology licensing offices, with internal rules allowing up to 10% of transfer revenues as additional incentives for contributors. Yet the globalization of research collaborations has introduced challenges, as differing national IP ownership rules can complicate joint projects.

A polymer cyclicality breakthrough

On March 6, 2025, Korean Institute of Science and Technology (KIST) announced that a research team in its Convergence Research Center for Solutions to Electromagnetic Interference in Future-mobility had developed a new polymeric material with self-healing capabilities and high recyclability.[14] The material can selectively depolymerize into monomers upon disposal, even when mixed with conventional plastics, and the recovered monomers can then be used to synthesize polymers with properties matching those developed from raw materials.

To learn more about how the intellectual property rights of government-funded innovations at research institutions are handled, read the sidebar "Intellectual property sharing in Korea."

Ceramics research

A century-plus of ceramic technology

When it comes to shepherding ceramic innovations into the marketplace, the Korea Institute of Ceramic Engineering & Technology (KICET) specializes in the testing, evaluation, and certification of ceramic materials. Its origin traces to 1912, when the Central Testing Laboratory, a government organization, established its Ceramics Department. As of 2019, however, it has operated as a research and development-oriented institution under the Ministry of Trade, Industry, and Energy.

"Its mission includes research and development of cutting-edge new materials in the ceramics field, as well as testing, analysis and evaluation, corporate support, and ceramic industry policy support," the website states.[15] "It is the only specialized ceramic research institute in Korea that has contributed to the development of national industries through innovation in ceramic technology."

Its fields of research include optoelectronic materials, energy and environment materials, mechanical structural materials, biomaterials, nanocomposite materials, traditional ceramic materials, and ceramic process technology.

Current areas of focus at KICET include the Aerospace Ceramic Fiber Convergence Material Utilization Commercialization Support Project,[16] now in its second year. The project supports small and medium-sized enterprises in the production and commercialization of aerospace prototypes using ceramic fiber composite materials.

Committed to instituting innovation

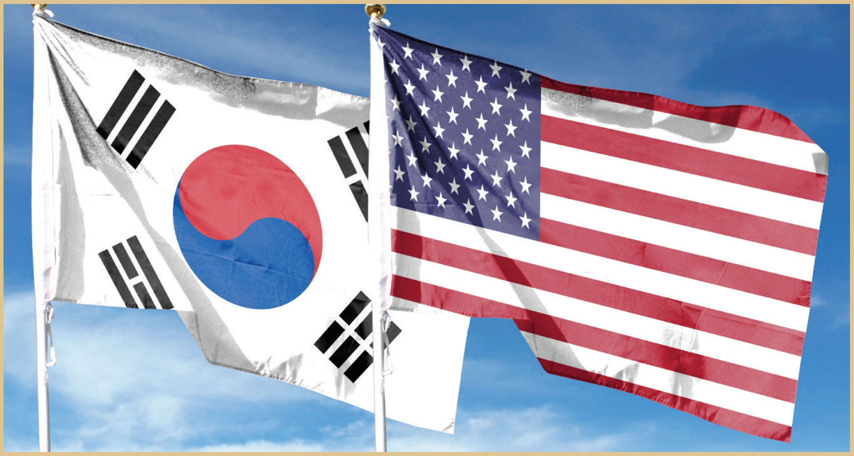
The research institutes mentioned in the preceding sections are but a few of the many organizations working to advance Korea's scientific endeavors. Additional Korean research institutes, as represented by members of the Korean Ceramic Society's Board of Directors, are listed below. A list of other ceramics-related associations, institutes, companies, and universities in Korea can be found in the directory (page 32).

- **Ulsan National Institute of Science and Technology** (UNIST) is a post-secondary institution that opened in 2009 and conducts all courses in English. Its research areas of focus include next-generation energy and advanced materials, including bio, energy, composite, and carbon materials. Website: https://www.unist.ac.kr
- **Korea Institute of Energy Research (KIER)** encompasses a Hydrogen Energy Institute, Renewable Energy Institute, Energy Efficiency Research Division, Climate Change Research Division, Jeju Global Research Center, R&D Strategy Division, and Energy AI & Computational Science Laboratory. Website: https://www.kier.re.kr/mps
- **Korea Evaluation Institute of Industrial Technology (KEIT)** describes itself as "a specialized organization for industrial technology R&D planning, evaluation, and management that works with the public and businesses, aims to proactively pursue the mission of 'technology-led innovative growth and a technology-based industrial powerhouse.'" Website: https://www.keit.re.kr
- **Korea Institute of Energy Technology (KENTECH)** describes itself as "committed to becoming a hub and open platform by hosting global energy research centers and energy start-ups" so that "participating stakeholders may share research resources and their achievements through the integrated efforts of future energy inventions and innovations." Website: https://www.kentech.ac.kr/main.do

CROSS-BORDER COLLABORATIONS

Three Korean organizations work to forge profitable ties to the US market

By Randy B. Hecht



Credit: Andy.LIU, Shutterstock

An unassuming three-story office building in the Washington, D.C., suburb of Vienna, Va., is home base for the Republic of Korea's networking activities with U.S. investors, businesses, universities, scientists, and engineers. Their interests extend from emulating U.S. institutions and practices to creating cross-border research and commercialization opportunities.

Korea–U.S. Science Cooperation Center

The nonprofit Korea–U.S. Science Cooperation Center (KUSCO) was established in 1997 to facilitate U.S.–Korean science and technology collaborations, expand global exchange programs, and provide support to U.S.-based Korean-American scientists and engineers.

One of its newest programs, the "Exploration of Innovative Practices in U.S. Universities," launched May 6–18, 2025, when KUSCO hosted 38 representatives of 18 Korean universities at the program's inaugural meeting. The agenda included a mix of lectures and field trips to the campuses of New York University, George Washington University, George Mason University, and City College of New York.

The event was "designed to help innovation managers from Korean universities gain insights into the innovation practices of American universities, fostering a practical understanding of university innovation systems, accomplishments, and methodologies," KUSCO stated in a press release.[a]

KUSCO also sponsors the US-Korea S&T Forum,[b] which is intended "to further empower the cooperation platform for scientists and engineers from both countries by focusing on any types of S&T filed seeking for the long-term collaboration between the U.S. and Korea."

That program serves as co-sponsor of the annual U.S.–Korea Forums on Nanotechnology. This year, the 19th Forum on "Nanotechnology: Sustainability in Semiconductor Manufacturing by Design and Neuromorphic & Quantum Sensors on a Chip" was held July 3–4, 2025, in Gyeonggi-do, Korea.

Korean American Scientists and Engineers Association

Among KUSCO's neighbors in that office building is the Korean-American Scientists and Engineers Association (KSEA), which was founded in 1971 to contribute to Korea's economic development through collaborations with the U.S. Its members include employees of IBM, Massachusetts Institute of Technology, Argonne National Laboratory, Rensselaer Polytech Institute, Boeing Research and Technology, Johns Hopkins University, Microsoft, Lockheed Martin, and Intel, among many others.

The organization's recent activities include two events held in Atlanta, Ga., from Aug. 5–6, 2025: the Scientists and Engineers Early Career Development (SEED) Workshop 2025 and the U.S.–Korea Conference 2025, which had the theme "Future US: Advancing Science and Technology to Benefit Humanity from Earth to Space."

KSEA's priorities include expanding internships within leading industries, joint research with public institutions, and startup partnerships, according to Jae Hyeon Ryu, who assumed the presidency of KSEA on July 1, 2025.

"We aim to play a pivotal role in fostering a U.S.–Korea Science and Technology Alliance by pursuing joint international collaborations, supported by government funding agencies such as the U.S. National Science Foundation and Korea's National Research Foundation," he says in his inaugural presidential announcement.[c] "These efforts will support both individual researchers and larger research ecosystems."

Korea Innovation Center

The Korea Innovation Center (KIC) team works from this office building and also maintains operations in Silicon Valley, Berlin (headquarters for European activities), and Beijing. A project of the Ministry of Science and ICT, the organization describes itself as "on a mission to create a global startup ecosystem throughout our four locations" and "discover and incubate promising Korean technology startups" that have the potential to do business in the U.S. market.[d]

Each year, more than 80 of those fledgling Korean companies participate in the Washington, D.C., branch's "Technology Exchange & Transfer" accelerating programs, which are designed to promote cross-border technology exchange and commercialization. With an eye to market entry, the program also assists in making connections with strategic advisors and the investment community.

In Silicon Valley, programs include the annual Deep Konnect event, which offers the opportunity for one-on-one meetings with local investors. Although artificial intelligence, software as a service, and digital health initiatives dominate its list of startups, KIC Silicon Valley has partnered with Anpoly, a Korean venture that develops technologies aimed at enhancing the performance of eco-friendly products by using nanocellulose materials made from discarded waste materials.

An additional information resource is the Washington, D.C.-based Korea Economic Institute, an agent of the Korea Institute for International Economic Policy (a public corporation established by the Korean government). The think tank's website at https://keia.org provides data and commentary regarding Korea's perspective on its trade relationship with the U.S.

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Korea's ambitious intelligence

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Directory

ASSOCIATIONS

Korean Ceramic Society

Seoul, http://eng.kcers.or.kr

The Korean Ceramic Society (KCerS) was founded in 1957 to help bridge academic advancements and industrial applications in the field of ceramics. According to its website, KCerS currently organizes its priorities around a four-point vision:

Strengthening the status of ceramics as a national strategic technology. In Korea, government ministries oversee roadmaps known as the Basic Plan for Science and Technology and the 12 National Strategic Technologies. These policy strategies focus on "core materials for advanced industry supply chains, and super-gap/neo-gap technologies," and KCerS advocates to ensure that ceramic materials and technologies are well represented.

Fostering young ceramists and expanding member participation. KCerS makes membership more accessible to the next generation by lowering barriers to engagement in its activities.

Strengthening international networks and enhancing academic standing. KCerS holds an annual joint symposium with the European Ceramic Society, and it also maintains a long-standing partnership with the Ceramic Society of Japan, co-hosting annual bilateral symposia to promote academic exchange. While there is no formal organizational partnership with The American Ceramic Society, KCerS organizes a dedicated symposium each year in cooperation with the ACerS International Korea Chapter.

Strengthening cooperation between industry, academia, and institutions. KCerS plans to "establish a collaborative platform between businesses, academia, and research institutes" and to "operate small research groups linked to the Materials and Components Technology Development Project to foster close collaboration between industry practitioners and researchers." Its plans also include collaborating with the Korea Institute of Technology Evaluation and Planning on a "platform that can contribute to the development of national strategic technologies."

Korea Cement Association

Seoul, http://www.cement.or.kr/english

The Korea Cement Association was established in 1963 and joined the World Cement Association and the World Cement and Concrete Association in 2020. In 2022, it established the Korea Cement New Materials Research Association, which was expanded last year to include 24 institutions from industry, universities, and research institutes who will be responsible for oversight and operation of the "Vision 2030 Project."

The Korea Cement Association publishes an annual chart- and graphic-driven report, *Cement in Korea*, and a PDF of the 2025 report is available in English at https://bit.ly/4mODIMh.

Korea Semiconductor Industry Association

Seongnam, https://www.ksia.or.kr

The contemporary Korea Semiconductor Industry Association (KSIA) emerged in 1991, when what was then Korea's Ministry of Commerce, Industry, and Energy approved the merger of the Semiconductor Equipment Association, Semiconductor Industry Association, and Semiconductor Research Association.

According to its website, KSIA's priorities include monitoring the opportunities and disruptions created by artificial intelligence; meeting global competition challenges; and contending with labor shortages, supply chain restructuring, and trade risks.

Along with the Ministry of Trade, Industry, and Energy, KSIA co-hosts SEDEX, Korea's only semiconductor exhibition featuring participants from all sectors of the semiconductor industry ecosystem.

INSTITUTES

Korea Advanced Institute of Science and Technology

Daejeon, https://www.kaist.ac.kr/en

Korea Evaluation Institute of Industrial Technology

Daegu, https://www.keit.re.kr/index.es?sid=a2

Korea Institute of Ceramic Engineering and Technology
Jinju, https://www.kicet.re.kr/main.web

Korea Institute of Energy Research
Daejeon, https://www.kier.re.kr/eng

Korea Institute of Energy Technology
Naju, https://www.kentech.ac.kr/main.do

Korea Institute of Machinery & Materials
Daejeon, https://www.kimm.re.kr/eng

Korea Institute of Materials Science
Changwon, https://www.kims.re.kr/?lang=en

Korea Institute of Science and Technology
Seoul, https://www.kist.re.kr/eng/index.do

Ulsan National Institute of Science and Technology
Ulsan, https://www.unist.ac.kr

COMPANIES

Asia Cement Co., Ltd.
Seoul, https://www.asiacement.co.kr

Daejoo Electronic Materials Co., Ltd.
Silheung, https://www.daejoo.co.kr/en/main

Dasan Solueta
Hwaseong, https://www.solueta.com/en

Dongwon Industries
Seoul, https://www.dongwon.com/en

Halla Cement Corp.
Gangneung, https://www.hallacement.co.kr/en

Hanil Holdings
Seoul, https://www.hanil.com/eng/main.do

Hankook Cement & Textile Co., Ltd.
Gwangju, http://www.hcnt.co.kr

JNTC Co., Ltd.
Hwaseong, https://thejntc.com/en/main.do

KCC Glass
Seoul, https://www.kccglass.co.kr/eng/main.do

Korea Circuit
Ansan, https://www.kcg.co.kr/eng/main.asp

Korea Testing Certification Institute
Gunpo, https://www.ktc.re.kr/web_eunited

Korea Testing Laboratory
Jinju, https://www.ktl.re.kr/eng/main.do

Korea Testing & Research Institute
Gwancheon, https://www.ktr.or.kr/eng/main/index.do

LX Glas Corp.
Seoul, https://www.lxglas.co.kr/en

Max Tech Fine Ceramics
Daegu, http://newceramic.com/HomeE

Samyung Trading Co., Ltd.
Seoul, http://www.samyung.co.kr/site

Shinceramic Co., Ltd.
Ansan, http://shinceramic.com/index.php?mid=default_en&ckattempt=1

Credit: KANNOI, Shutterstock

SK Hynix
Incheon, https://www.skhynix.com

Ssangyong Cement Co., Ltd.
Seoul, https://www.ssangyongcne.co.kr/main.do

Sungjin KM Co., Ltd.
Seoul, http://www.sungjinkm.com

UJL Inc.
Ansan, https://www.kcg.co.kr/eng/main.asp

WONIK QnC
Gumi, https://www.wonikqnc.com/en

UNIVERSITIES

Ajou University
Suwon, https://www.ajou.ac.kr/en/index.do

Changwon National University
Changwon, https://www.changwon.ac.kr/eng/main.do

Chosun University
Gwangju, https://eng.chosun.ac.kr/eng/index..do

Chungnam National University
Daejeon, https://plus.cnu.ac.kr/html/kr

Dankook University
Yongin, https://www.dankook.ac.kr/web/international

Gachon University
Seongnam, https://www.gachon.ac.kr/sites/eng/index..do

Gyeongsang National University
Jinju, https://www.gnu.ac.kr/eng/main.do

Hanyang University
Seoul, https://www.hanyang.ac.kr/web/eng

Inha University
Incheon, https://eng.inha.ac.kr/eng/index.do

Jeonbuk National University
Jeonju, https://www.jbnu.ac.kr/en/index.do

Kongju National University
Gongju, https://english.kongju.ac.kr/eng/index.do

Kookmin University
Seoul, https://english.kookmin.ac.kr

Korea Aerospace University
Goyang, https://kau.ac.kr/index/main.php

Korea University
Seoul, https://www.korea.edu/sites/en/index.do

Kyonggi University
Suwon, https://www.kyonggi.ac.kr/international_kgu/contents.do?key=7523

Kyungpook National University
Daegu, https://en.knu.ac.kr/main/main.htm

Pohang University of Science and Technology
Pohang, https://www.postech.ac.kr/kor/index.do

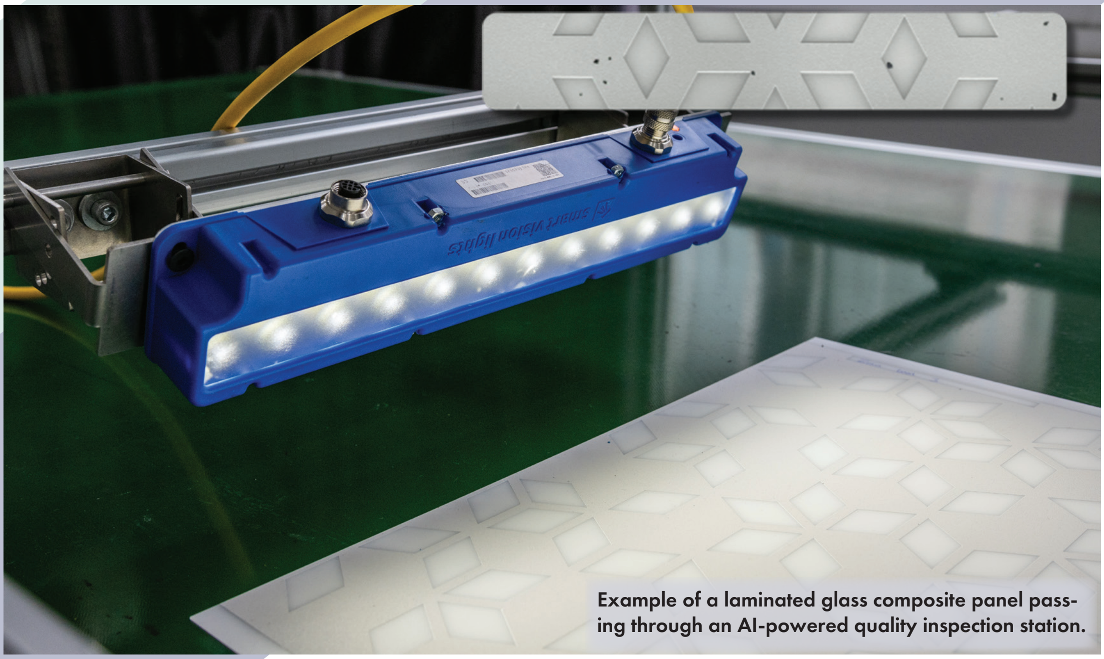
Sejong University
Seoul, https://en.sejong.ac.kr/eng/index.do

Seoul National University
Seoul, https://en.snu.ac.kr

Sungkyunkwan University
Seoul, https://www.skku.edu/eng/index.do

University of Seoul
Seoul, https://www.uos.ac.kr/eng/web/main

Yonsei University
Seoul, https://www.yonsei.ac.kr/en_sc/index.do



Example of a laminated glass composite panel passing through an AI-powered quality inspection station.

Credit: Zetamotion

The synthetic data revolution: How AI is redefining quality control in ceramics manufacturing

By Wilhelm Klein

The ceramics industry stands at the brink of a fundamental shift in how quality control is conceived, implemented, and scaled.

For decades, the promise of artificial intelligence-powered inspection systems was held back by a persistent obstacle: the scarcity of high-quality data. This bottleneck made it difficult for ceramics manufacturers to realize the full potential of advanced machine learning, particularly because product variations are abundant while defects tend to be rare, subtle, and highly variable due to the nature of ceramic materials and processes.

Over the last several years, AI has delivered an array of headline-grabbing advances: language models drafting complex documents, AI agents pushing to the forefront of many business activities, and predictive algorithms forecasting customer behavior months in advance. Yet if you speak with manufacturing executives privately, you will hear a rather sobering reality on the shop floor.

U.S. research and advisory firm Gartner reports that more than 80% of AI pilot projects never evolve into production systems that reliably create business value.[1] In many companies, this gap gets labeled a "change management issue." In data science teams, it is often called the last mile problem—the hard work of turning an experimental model into a trusted, repeatable process on the shop floor.

Last mile problem: Why ceramics makes AI harder

In ceramics manufacturing, this last mile is especially difficult to bridge. Unlike industries where enormous data volumes are readily available, defect detection for ceramics requires carefully curated datasets: images of both flawless products and a broad range of defect types, all captured in real-world conditions and consistently annotated.

Collecting this data takes time—often many months—because defects are sporadic, unpredictable, and heavily influenced by kiln temperature, humidity, and raw material composition. Even when images are gathered, labeling them correctly demands expert judgment, particularly for aesthetic criteria such as glaze smoothness or acceptable variations in color. This work is both expensive and inherently subjective.

Most AI initiatives that stall out do so because three constraints converge:

- **Insufficient data.** Relevant examples are too few or arrive too slowly. Rare edge cases are missing altogether, privacy regulations limit access to needed records, and manual labeling cannot keep pace. As a result, model accuracy stagnates and trust declines.
- **Limited time.** Leadership often expects usable results in a matter of weeks, while assembling and preparing datasets on an industrial scale typically takes months. By the time the model starts to show promise, the project window has already closed.

- **Lack of available expertise.** The specialists who understand subtle defect criteria are already stretched thin. When their time is unavailable for labeling or review, backlogs grow, experiments stall, and enthusiasm wanes.

These challenges help explain why 57% of manufacturing leaders cite poor data quality as the main barrier to scaling AI successfully, according to *MIT Technology Review Insights*.[2] The issue is not only technical—it is organizational and operational as well.

Emergence of synthetic data solutions

Synthetic data is emerging as a way to bypass much of the uncertainty and delay inherent in real-world data collection. By generating realistic training images computationally, these datasets provide both the quantity and diversity needed to train more accurate models while ensuring consistent standards for labeling and defect classification (Figure 1).

As many leaders in the AI space have pointed out, relying solely on real-world data is no longer sufficient for advanced AI systems. Research institutions such as Fraunhofer IPM[3] also share this view, seeing synthetic generation as a practical route to accelerate development, tighten quality standards, and finally close the gap between prototypes and production.

Synthetic data generation represents a paradigm shift in how training datasets are created for ceramic quality control applications. Rather than waiting for defects to occur naturally during firing cycles, ceramic manufacturers can now generate thousands of labeled examples computationally. This approach leverages advanced computer graphics techniques, originally developed for entertainment and visualization, to create photorealistic images of ceramic products with precisely controlled defects.

The process typically begins with high-resolution scans of as-close-to-perfect-as-possible products, which serve as the foundation for synthetic variations. Advanced rendering algorithms then introduce controlled defects—glaze crawling, pinholing, crazing, dimensional variations, color deviations, and surface texture irregularities—at specific locations and severities. Because these defects are generated digitally, every pixel in the resulting images can be precisely labeled, eliminating the need for manual annotation.

Several companies have emerged to provide synthetic data solutions for ceramics manufacturing applications. Zetamotion, a multinational quality control company based in the U.K., has developed an AI-empowered platform called Spectron™ that can generate comprehensive datasets from a single product scan. Their approach emphasizes not just the generation of training data but also the creation of visual references that help ceramic manufacturing teams achieve consensus on quality standards—a particularly important consideration given the subjective nature of many ceramic quality judgments.

Beyond data generation: The consensus challenge

While synthetic data solves the technical challenge of AI training, it also addresses a more fundamental problem in ceramic manufacturing: the lack of consensus on what constitutes acceptable quality. This issue has plagued producers for

Credit: Zetamotion

Figure 1. By simulating thousands of photorealistic flaw variations, manufacturers can train AI models faster and with greater consistency than manual methods allow.

generations, leading to inconsistent decisions, wasted resources, and damaged customer relationships.

Ask any production manager or quality engineer, and you will hear the same story: one team flags a glaze inconsistency as a critical defect, while another considers it acceptable variation. Without a shared definition, inspection becomes subjective and reactive, often resulting in debates long after production is complete.

Synthetic data platforms help tackle this challenge by generating comprehensive visual references across the entire quality spectrum. Instead of relying on sporadic real-world examples, teams can review synthetic images of every defect type and severity, using them as objective anchors for quality discussions.

But the benefits do not stop with training data. Modern AI inspection systems also include feedback loops and reporting dashboards that make defect consensus an ongoing process. As operators validate or override AI decisions, their input is logged and analyzed, creating a transparent record of what was accepted or rejected—and why.

Zetamotion, for example, has built this capability into its platform. Its AI-powered inspection combines synthetic data generation with DefCon, their defect consensus tool, enabling manufacturers to collect input from operators, suppliers, and customers in one place. With a clear dashboard and audit trails, teams can align on definitions, refine acceptance criteria over time, and avoid disputes.

In other words, synthetic data does not just train AI to detect defects—it enables defect consensus, turning subjective opinions into shared standards. When everyone is working from the same playbook—and you have the data to prove it—you eliminate confusion and deliver consistent quality that customers trust.

Case study: Aviation glass implementation

The practical impact of synthetic data-driven quality control in ceramics-adjacent industries is perhaps best illustrated through real-world implementations. Aviation Glass, a European supplier of aircraft interior components that shares many characteristics with advanced ceramics manufacturing, faced mounting pressure to scale their inspection processes while maintaining the stringent quality standards required by aerospace applications.

The company's traditional manual inspection process was thorough but time-intensive, requiring more than 20 minutes per panel. This approach worked well for smaller production volumes but became increasingly untenable as demand grew. More critically, the company faced questions of consistency across different inspectors and shifts, leading to occasional disagreements about quality decisions—a challenge that resonates strongly with ceramic manufacturers dealing with subjective aesthetic judgments.

Aviation Glass partnered with Zetamotion to implement a synthetic data–driven inspection system. The process began with high-resolution scanning of perfect panels, followed by the generation of thousands of synthetic variations representing common defects including scratches, bubbles, and inclusions—defect types that parallel those found in ceramic manufacturing such as glaze defects, surface irregularities, and structural flaws.

The implementation involved more than just technology deployment. The company's most experienced inspectors, along with representatives from key customers, participated in structured consensus sessions where they reviewed synthetic examples and established clear acceptance criteria for different defect types and severities.

The results were quantifiable and significant. Inspection time dropped from more than 20 minutes per panel to approximately 20 seconds, representing a 60-fold improvement in efficiency. The system processed more than 4,500 panels, assessing more than 700,000 potential anomalies with 99.99% detection accuracy. Perhaps most importantly, the company achieved a 5% improvement in yield by eliminating unnecessary rejections based on inconsistent standards.

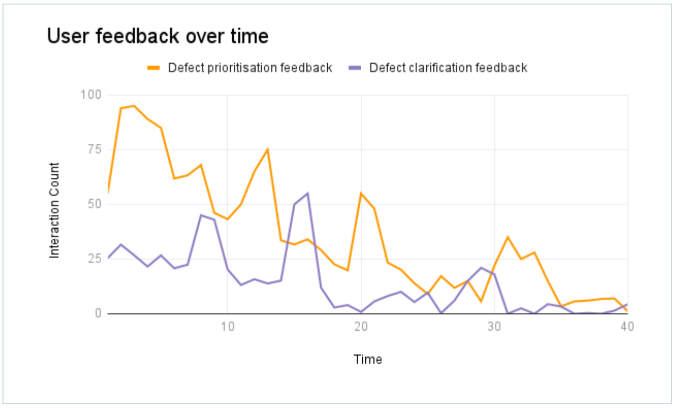
Jaap Wiersema, managing director of Aviation Glass, emphasizes the broader impact:

"The platform's efficiency and precision have not only enhanced our inspection capabilities but also provided us with actionable insights that drive continuous improvement. We've saved more than 1,200 hours annually, but the real value is in the consistency and traceability."

Challenges and limitations

Despite its promise, synthetic data adoption in ceramics manufacturing faces several industry-specific challenges. The initial investment in platform development and implementation can be substantial, particularly for smaller ceramic manufacturers operating on tight margins. The technology also requires significant computational resources, though costs continue to decline as hardware becomes more accessible and cloud-based solutions become available.

The quality of synthetic data depends heavily on the accuracy of the underlying models used to generate ceramic-specific defects. If these models do not accurately represent real-world ceramic defect characteristics—such as the complex interactions



Credit: Zetamotion

Figure 2. As time progressed, Spectron™ incorporated operator feedback and expertise, decreasing the need for human clarification while boosting automated confidence.

between clay bodies and glazes, or the effects of firing atmosphere on ceramic properties—the resulting AI systems may perform poorly in production environments.

Perhaps most critically, successful implementation depends on selecting the right technology partner. Many vendors offer synthetic data solutions, but few provide the comprehensive support necessary for successful deployment in ceramics manufacturing environments. Too often, companies deliver a technical solution without understanding the complexities of ceramic production processes, regulatory requirements, or the specific challenges of scaling quality control across different product lines. Wilhelm E. J. Klein, CEO of Zetamotion, emphasizes this point:

"The right tools are important, but they're only part of the equation. You need partners who are attuned to your workflows, your regulatory challenges, and the tempo of your innovation."

The most successful ceramic manufacturers partner with providers who offer not just technology but guarantee ongoing support throughout the implementation journey. This support includes understanding the nuances of ceramic manufacturing processes—from raw material variability to firing complexities—and providing guidance on how to adapt quality standards to leverage synthetic data effectively.

There are also concerns about over-reliance on synthetic data in ceramics applications. While these systems can generate comprehensive training datasets, they may miss subtle variations that occur in real ceramic manufacturing environments. Most successful implementations combine synthetic data with ongoing collection of real-world examples to ensure continued accuracy and relevance to actual production conditions.

Looking ahead: The future of quality control

As synthetic data becomes more accessible and integrated into digital twin ecosystems, one might assume that human input will fade from the equation. In reality, the opposite is true. Even the most advanced systems depend on human expertise to ensure quality standards are meaningful, adaptable, and aligned with real-world conditions.

While AI can simulate defect scenarios and automate routine decisions with precision, final judgment still often relies on the intuition and experience of skilled operators—particularly in edge cases where visual or structural anomalies defy easy classification.

These situations are where Human-in-the-Loop (HITL) systems play a crucial role.[4] By combining the consistency of AI with human oversight, HITL frameworks ensure both reliability and contextual intelligence. AI handles repetitive or attention-intensive tasks while human input guides corrections, verifies outputs, and shapes the evolving definition of "quality" itself—especially as new materials and product variants are introduced.

As an example of HITL, Figure 2 shows how Zetamotion's Spectron platform steadily reduced its reliance on operator clarification feedback over time while strengthening prioritization confidence—clear evidence of how human expertise is captured and reinforced within the system.

HITL also plays a vital role in long-term resilience. With one in three U.K. manufacturing workers now over 50,[5] there is a growing risk of losing decades of tacit knowledge. HITL systems capture operator input as structured feedback, feeding it back into the AI to refine decision-making and preserve institutional expertise. This collaborative model does not just improve outcomes today—it safeguards them for the future.

Conclusion

The synthetic data revolution in ceramics manufacturing quality control represents more than a technological advancement—it signals a fundamental shift in how quality is conceived, defined, and maintained within the ceramics industry. By addressing both the technical challenges of AI training and the human challenges of consensus-building around subjective quality standards, synthetic data platforms are enabling ceramic manufacturers to achieve levels of consistency and traceability that were previously unattainable.

The success of implementations such as Aviation Glass demonstrates that this technology is not merely theoretical but practically effective across industries with similar challenges to ceramics manufacturing. The combination of synthetic data generation, AI-powered inspection, and Human-in-the-Loop validation creates quality control systems that are both scalable and nuanced, capable of handling the complex quality judgments that characterize ceramic manufacturing.

As the ceramics industry continues to evolve toward higher performance requirements and increasingly demanding customer specifications, the need for systematic approaches to quality control will only intensify.

The future of ceramics quality control lies not in choosing between traditional human expertise and artificial intelligence but in finding ways to amplify ceramic manufacturing knowledge through technology and the right partner. Synthetic data serves as the bridge between these two worlds, creating quality systems that are both efficient and trustworthy while also scalable and precise. Those who choose wisely will gain significant competitive advantages in an increasingly demanding marketplace.

Zetamotion : Founding and future goals

Wilhelm Klein

CEO of Zetamotion

Founded in 2019, U.K.-based Zetamotion emerged from a pivotal "lightbulb moment" when the founders were working with a large, traditional manufacturer in North America. In tackling the manufacturer's request for an artificial intelligence-powered computer vision system to automate quality control, they realized a critical gap in the market: Most vision systems failed when faced with the complexity and variability of real-world products. This realization inspired them to apply their deep technological expertise toward a solution.

Zetamotion's flagship AI-powered quality control platform, Spectron™, delivers 99.99% accuracy without requiring advanced AI expertise, large datasets, manual labeling, or lengthy retraining. Spectron can be deployed in under 24 hours and seamlessly integrates with a wide range of sensors and hardware, helping reduce false positives and achieve results that typically take traditional solutions several months to match.

With a growing global presence, Zetamotion supports manufacturers and automation partners across industries such as aerospace, automotive, glass, metal, electronics, and packaging. Over the next five years, the company plans to expand into new manufacturing verticals, continue advancing its platform capabilities, and further reduce waste and inefficiencies in production lines. Zetamotion's ultimate vision is to make perfect quality control achievable for every manufacturer—improving profitability, reducing environmental impact, and setting a new global standard for manufacturing excellence.

Learn more about the company at https://zetamotion.com. ■

About the author

Wilhelm Klein is CEO of Zetamotion (Dartmouth, U.K.). Contact Klein at contact@zetamotion.com.

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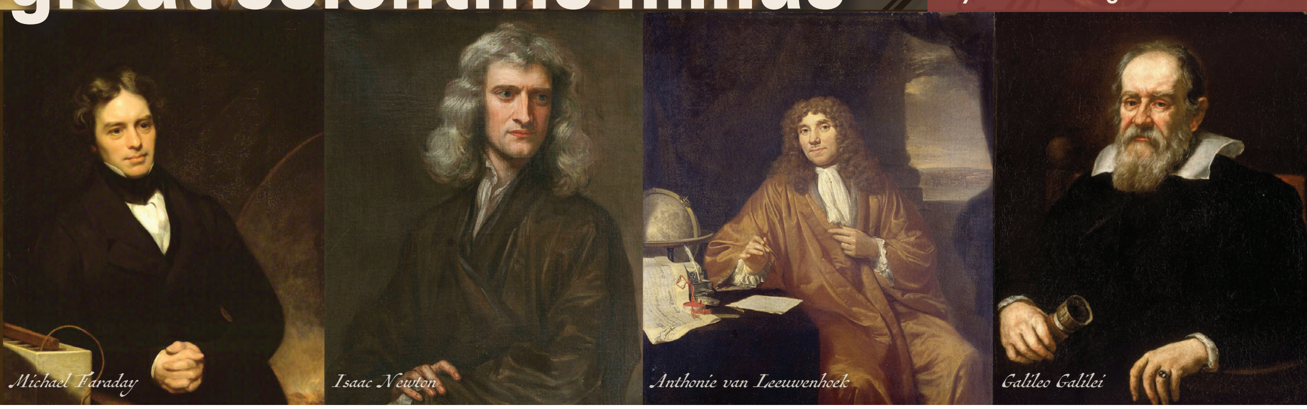
On the shoulders of giants: Glass developments by great scientific minds

By Mario Affatigato



Credit: Public-domain portraits from Wikimedia

Glass has fascinated artisans and scientists throughout history, with some great scientific minds in astronomy, microbiology, and physics dabbling in this material.

It is commonly accepted that the scientific study of glass did not begin in earnest until the 19th century with the pioneering work of Otto Schott.

Although this statement is strictly correct—the work had to wait for the formal development of physics and chemistry—it is also understood that glass had been studied for centuries beforehand. From the empirical work of the glass masters of Murano, Italy, to the reinvention of *Rubinglas* by German alchemist Johann Kunckel, glass had been studied by many artisans and early scientists. In this article, however, I will focus on how glass fascinated some of the great scientific minds of the past five centuries, with the selection made at my discretion.

Galileo and van Leeuwenhoek: Lenses for astronomy and microbiology

Galileo Galilei, the forefather of physics and engineering, had the advantage of spending many years of his early scientific career at the Università di Padua (1592–1610), only about 30 miles from the islands of Venice.[1] This proximity allowed him to secure high-quality glass from Murano, which he then polished into lenses for increasingly better telescopes.

On display at the Museo Galileo in Florence, Italy, is a personal shopping list Galileo wrote in 1609 on the back of an envelope before a trip to Venice.[2] Alongside sugar, white beans, and slippers, and raisins, he includes "polished German glass," "felt and a rubbing mirror," "Tripoli powder," and many other ingredients necessary for lens creation—more than half the list! With instruction from local artisans who made spectacles and mirrors, Galileo used these ingredients to quickly grind and polish lenses that attained telescope magnifications five times better than any other available in Europe.

Five decades later, Antonie van Leeuwenhoek was developing some of the first microscopes in Delft, Holland.[3] Using a secret technique in which a soda-lime glass whisker was flamed into a small lens of high curvature,[4] he could better see the fine threads in his draper shop. He also polished larger lenses of lower magnifications to confuse competitors about his fabrication methods. Soon afterward, van Leeuwenhoek created the field of microbiology and became a scientific sensation in Europe.[5]

Newton: Fundamentals of glass optics

Grinding and polishing glass was also nothing new to the great Isaac Newton. Although he was able to find glass and even prisms at the local university markets, he was intimately familiar with the process of "polishing Glass with Sand, Putty, or Tripoly."[6] This knowledge allowed Newton to develop a keen physical understanding of what might be happening as light traversed a glass piece.

As Feynman notes in his book QED: *The Strange Theory of Light and Matter*,[7] Newton was trying to explain why glass only reflects part of the light incident upon it (4% per surface at normal incidence). A proposed explanation assumed that glass was not unlike Swiss cheese, containing holes in its volume. The idea was that light was transmitted only if it went through the "holes," and reflected if light hit the glassy matter. But Newton knew that polishing made the glass more transparent. In his book *Opticks*,[6] he wrote:

"For in polishing Glass with Sand, Putty, or Tripoly, it is not to be imagined that those Substances can, by grating and fretting the Glass, bring all their Surfaces to an accurate Polish; so that all their Surfaces shall be truly plain…The smaller the Particles of those Substances are, the smaller will be the Scratches by which they continually fret and wear away the Glass until it be polish'd…bringing its roughness to a very fine Grain, so that the Scratches and Frettings of the Surface become too small to be visible. And therefore if Light were reflected by impinging upon the solid parts of the Glass, it would be scatter'd as much by the most polish'd Glass as by the roughest."

–Isaac Newton, *Opticks*, pp. 265–266

Regarding Newton's most famous optical experiment, there is much discussion about where exactly it took place and the glass prism he used.[8] This uncertainty is partly due to the multiple versions of the experiments and the different years when they occurred. One possible interpretation holds that Newton started experimenting with prisms at Trinity College but made the definitive experiments back at his home in Woolsthorpe-by-Colsterworth. His 60° prisms were purchased locally, likely made of soda-lime glass with the incorporation of some lead oxide (accounting for the higher-than-normal index of 1.55). As shown in Figure 1, the elongated prisms of this period were quite a bit different in shape than those found in modern physics labs.

Figure 1. Soda lime silicate prism from the same time period as Newton's optical research work. Sample currently held at the British Museum.

Figure 2. Glass working materials from Faraday's laboratory, held at the museum of the Royal Institution.

Faraday: Improvement of optical glass

Continuing our historical trip, Michael Faraday was another of the great experimental giants who spent an inordinate—and perhaps unwanted—amount of time studying glass.[9] By 1824, Faraday was already a Fellow of the Royal Society and an independent scientist. He was yet to carry out his world-changing research on electricity, however, and he remained morally obligated to his mentor, Sir Humphry Davy.

In 1824, the famous Board of Longitude was still meeting, even though its primary mission had been fulfilled in the 1770s by the creation of Harrison's marine chronometer. The Board was one of the few government sources for research, distributing monies from the Admiralty and Parliament, and it paid for the Secretary of the Royal Society. Its membership included the President of the Royal Society (Sir Humphry Davy, in 1824), and it had survived this long partly due to its role in preparing the yearly Nautical Almanac.

Rumors of the Board's demise were widespread, and Davy was desperate to not have this event occur during his presidency. He therefore proposed a new research project of interest to the Admiralty: the improvement of optical glass. The argument was that such an improvement would improve telescopes and, therefore, navigation.

The actual glassmaking work was contracted to the firm of Pellatt and Green. But an experimental subcommittee was formed, and Faraday was appointed to it. As part of his duties to the Royal Institution, he was also hired to conduct chemical analysis of the glass produced by the firm.

None of these duties were outside Faraday's job description, and the Royal Institution was always hungry for funding. But his role in the subcommittee became a significant time drain, as the firm was three miles from the Royal Institution, and the glass production lacked good supervision.

By 1827, the results had been quite disappointing, but the Joint Committee decided that the project's success would require bringing it in-house. To the Royal Institution. Under Michael Faraday. The funding to the Royal Institution made this contract impossible to refuse, and—after purchasing a furnace and other equipment (Figure 2)—Faraday spent approximately 46% of the next two years working on the glass project, or nearly 337 days. He was released from this obligation only after the abolition of the Board of Longitude (1828) and the passing of Davy (1829).

The newfound freedom allowed Faraday to dedicate himself to new research pursuits in electricity, for which he would become world-famous. He initially regretted the time spent on glass. But by 1845, his friend Giovan Battista Amici had put his glass work into practice by making achromatic microscopes, and this innovation reenergized his interest.

Soon after, and upon a suggestion by a young William Maxwell, Faraday experimented on a high-index lead borosilicate glass and discovered the magneto-optical effect that now bears his name. Afterwards, his attitude toward his early work mollified. After being asked to include a reprint of his glass paper in a new collection of articles (1858), he wrote: "The use of glass manufactured as described here has since become so important in diamagnetic and magneto-optical researches, that I deem the paper worthy of insertion at full length in this collection."[9]

Many other scientists studied glass or used it as an enabling agent in their work. A lack of space forbids me from giving a full account, but the work of Bavarian glassmaker and researcher Joseph Fraunhofer—who invented the diffraction grating and used it to analyze the solar spectrum—should be mentioned.[10]

Glass: The core of scientific research

The Scientific Revolution would have suffered greatly without this protean material, and the arrival of the modern world as we know it would have been delayed and inevitably altered. I can think of no better ending to this brief article than to quote Alan Macfarlane and Gerry Martin, who write in an essay in *Science*:[11]

"We randomly picked 20 famous experiments that changed our world—Thomson's discovery of electrons, Faraday's work on electricity, and Newton's splitting of white light into its component colors with a prism, for example—and found that 15 of them could not have been performed without glass tools."

About the author

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Jonathon Foreman
ACerS journals managing editor

Engineering and processing of semiconductor materials

With many leading electronics manufacturers based in the country, it is only natural that the Republic of Korea has many researchers investigating the functional and structural properties of semiconductor materials as well as developing and refining fabrication methods to improve device manufacturing and reduce production costs. Recent articles published in the ACerS journals showcase some of these advances.

In the article "Performance variation with pristine and doped high-*k* materials via atomic layer deposition,"[1] Eun Su Jung et al. review the use of atomic layer deposition for fabricating semiconductor devices. Briefly, in atomic layer deposition, very thin films are formed by cyclic deposition of chemical reactants as atomic-level monolayers on substrates. The reactions are activated by thermal energy or plasma enhancement. This method provides precise control of film thickness and uniformity.

Jung et al. describe the fabrication processes and resulting properties of thin films fabricated from hafnia, titania, and zirconia, both pure and doped with metals such as yttrium, aluminum, tantalum, and barium, along with potential applications of these wide-ranging materials. For example, niobium-doped titania shows promise as a transparent conducting oxide. The authors suggest areas of future research including doping schemes to enhance functional properties such as ferroelectricity.

Along similar lines, Keum et al.[2] demonstrate the ability to control crystal growth orientations for bismuth titanium iron oxide and thus material properties by adjusting the substrate temperature during pulsed laser deposition. Lower temperatures favored *a*-axis growth, resulting in enhanced ferroelectric properties. Growth in the *c*-axis direction is favored at high temperatures, and the material's ferromagnetic properties are enhanced.

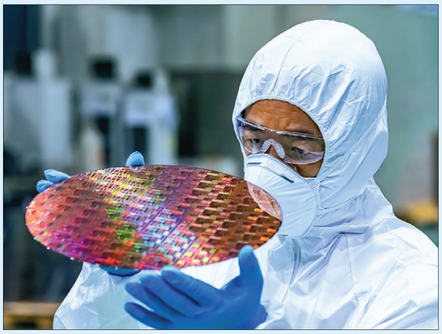
Plasma processing methods such as the activation mentioned previously are widely used in chip fabrication. Unfortunately, the materials comprising plasma equipment are susceptible to etching by plasma, which can lead to contamination and part failure. Yttria is highly resistant to plasma etching, but it is difficult and expensive to work with.

Yttrium aluminum garnet (YAG) is more readily used in part fabrication while being nearly as resistant to plasma etching as yttria. Unfortunately, due to its porosity, grain size and surface roughness, YAG etching generates higher levels of contamination from relatively larger debris particles. From their YAG sintering optimization studies, Zhao et al.[3] found that YAG doped with 0.3 wt.% tetraethyl orthosilicate shows high densification and reduced surface roughness after etching with minimal effect on etching resistance.

Silicon carbide is another material of high interest for electronics. It is being explored as a functional material for LEDs and power electronics. It is also used as a substrate and for manufacturing components, including focus rings and wafer carriers.

Much like yttria, silicon carbide is notoriously difficult to sinter, and the dense pieces are difficult to machine. Oh et al.[4] mention that decreasing the electrical resistivity of silicon carbide can lead to a greater ability to process the material into useful shapes via electrical discharge machining. They found that adding 10 wt.% carbon to silicon carbide with boron carbide as a sintering aid provided a good balance of sinterability and mechanical, thermal, and electrical properties. They attribute reduced resistivity to the carbon network exceeding the percolation threshold.

Anwar et al.[5] performed a similar study on sintering silicon carbide with additives aimed at reducing electrical resistivity. They added kaolin and various metals and sintered at relatively low temperatures. They found reduced electrical resistivity, attributing it to the formation of metal silicides during sintering.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As all sectors come to rely more on electronically driven technologies, the need to optimize semiconductor design and fabrication becomes increasingly important.

These few examples are but a few of the studies on the engineering and processing of semiconductor materials available in ACerS journals. Visit the ACerS journals homepage at https://ceramics.onlinelibrary.wiley.com to find and read more.

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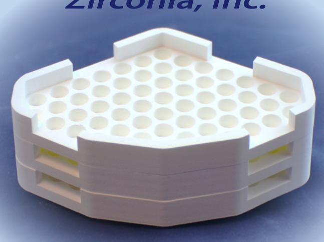

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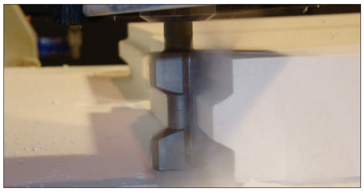

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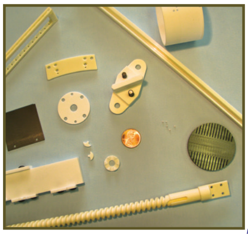

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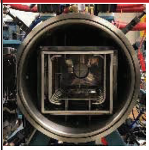

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By Dipta Pal

Guest columnist

Toward a carbon-neutral country: Industrial decarbonization in Korea

Among the various approaches to mitigate carbon emissions and achieve carbon neutrality, the concept of carbon capture, utilization, and storage (CCUS) has seen renewed interest in recent years (Figure 1).[1]

The core idea behind CCUS is to capture carbon dioxide before it is released into the atmosphere and either utilize it in industrial processes or store it safely underground. With increasing awareness of climate change and rising industrial emissions, scientists and policymakers around the world are investing more attention and resources into supporting CCUS projects.

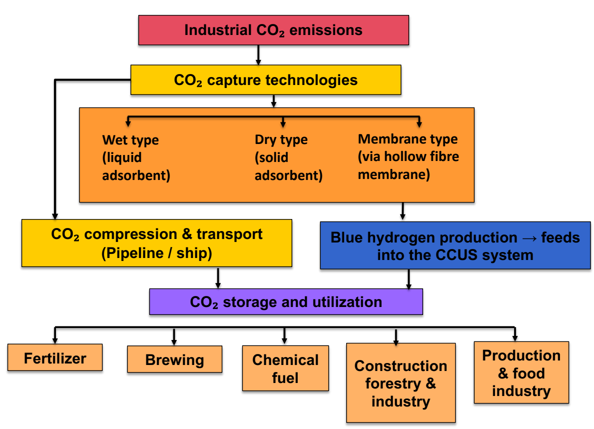
According to a 2023 report,[2] the Republic of Korea emitted approximately 624 million metric tons of CO_2 that year, ranking it among the world's top carbon emitters. The Korean government is working to change those statistics by committing to increase the capture capacity of CO_2 to 4.8 million metric tons annually by 2030.[3] It launched substantial investments and research projects to develop industrial CCUS hubs and incentivize companies to adopt low-carbon technologies. Additionally, it enacted the CCUS Act in 2024 to streamline regulatory procedures and provide financial support for CCUS deployment.[4]

One major CCUS project currently underway in Korea is the Donghae CCUS Hub,[5] which aims to store more than 1.2 million metric tons of CO_2 per year by 2028. This project, led by Korea National Oil Corporation, involves storing CO_2 at the depleted Donghae-1 gas field, which was Korea's first discovered source of offshore oil production in 1998 (it officially ceased production in 2021). Hyundai Engineering & Construction was contracted to conduct the preliminary front-end engineering and design for the project.

In Korea, CCUS technology serves as a cornerstone for the development of blue hydrogen, which is produced from natural gas. One pilot project for blue hydrogen production was conducted by a consortium of 12 organizations under the leadership of Hyundai Engineering & Construction, and it focused on developing various types of CCUS technologies.[6] Meanwhile, some major companies, including SK E&S and Korea Midland Power, are leading the Boryeong Blue Hydrogen Production Project—one of the largest initiatives of its kind globally.[7]

Reuse options for captured CO_2 include the production of liquid CO_2 and polymer production, among other chemicals. Carbonco, a subsidiary of DL E&C, provides a solution for this CCUS technology.[8] Another application of stored CO_2 is enhanced oil recovery, a technique that involves injecting CO_2 into oil–gas reservoirs to enhance recovery rates.[9]

Although achieving carbon neutrality remains a major challenge, Korea is positioning itself as a key innovator in offering global solutions to climate change.



Credit: Dipta Pal

Figure 1. Overview of carbon capture, storage, and utilization technologies.

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