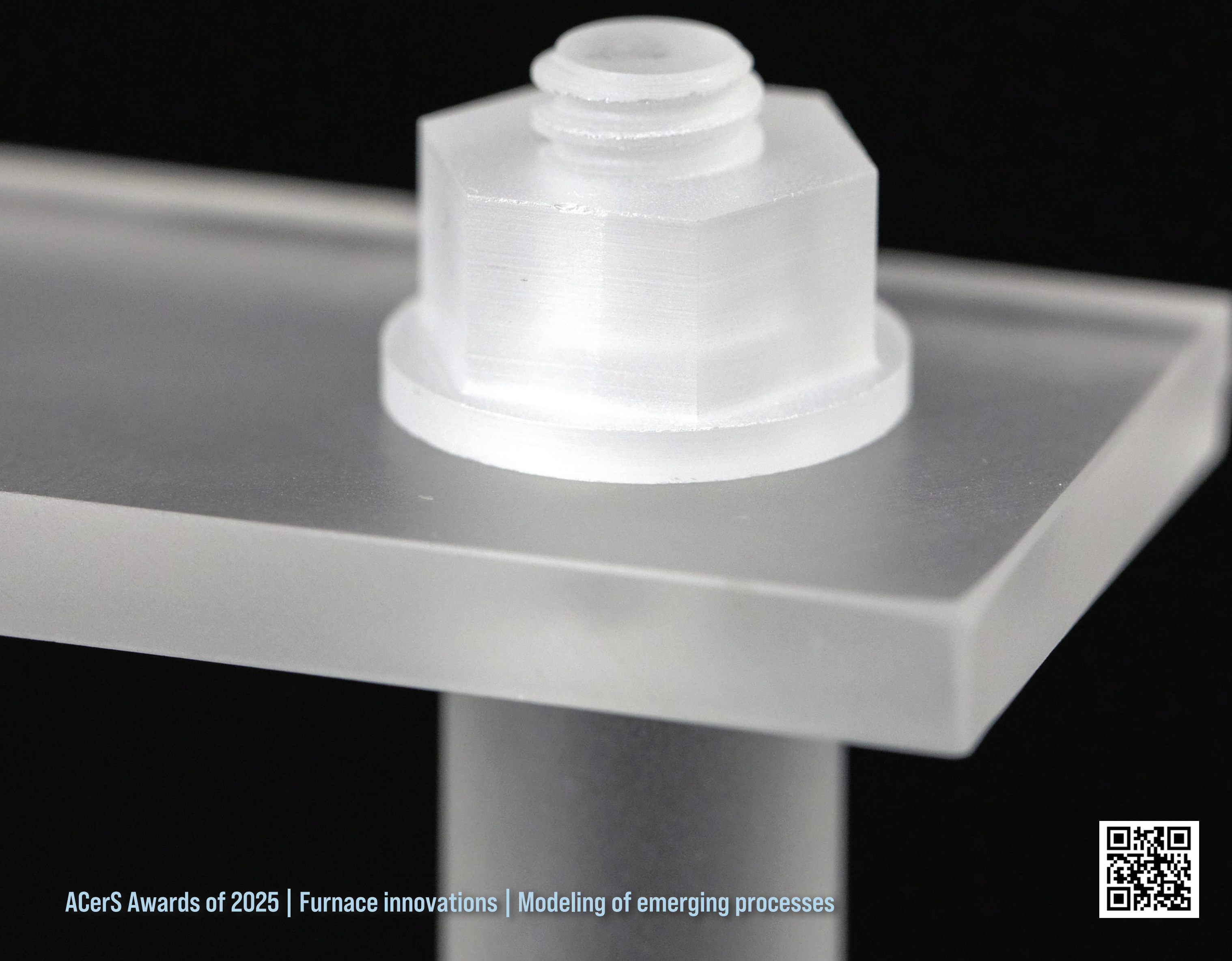
AMERICAN CERAMIC SOCIETY

bulletin

emerging ceramics & glass technology

SEPTEMBER 2025

Novel processing techniques and technologies for materials manufacturing



ACerS Awards of 2025 | Furnace innovations | Modeling of emerging processes

HARROP

INDUSTRIAL KILNS · SINCE 1919 · COLUMBUS, OHIO

HELPING YOU POWER THE FUTURE

INDUSTRIAL KILNS

- Elevator Kiln
- Rotary Tube
- Pusher Plate
- Shuttle Kiln
- Tunnel Kiln
- Box Kiln

TOLL FIRING & TESTING

- Product Development
- Material Characterization
- Technical Consulting
- Production Scale-Up
- From Single Firings to Multi-Month Tolling Campaigns

Your kiln needs are unique, and, for more than a century, Harrop has responded with applied engineered solutions to meet your exact firing requirements.

WWW.HARROPUSA.COM

contents

September 2025 • Vol.104 No.7

feature articles

departments

industry

columns

meetings

resources

Cover image
Example of a ¼–20 thread that was machined in post-fired sapphire. *Credit: INSACO*

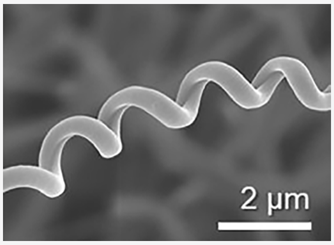
AMERICAN CERAMIC SOCIETY
bulletin

online
www.ceramics.org

September 2025 • Vol.104 No.7

http://bit.ly/acerstwitter http://bit.ly/acerslink http://bit.ly/acersfb

As seen on *Ceramic Tech Today*...



Credit: Dong et al., *ACS Nano* (CC BY 4.0)

Ceramic nanofibers and springs unlocked with coaxial electrospinning

Conventional electrospinning of sol–gel ceramic solutions places limitations on the composition and structural integrity of the resulting fiber. University of Oxford researchers showed that uniform, flexible ceramic nanofibers and springs can be created using the modified technique of coaxial electrospinning.

Read more at https://ceramics.org/coaxial-electrospinning

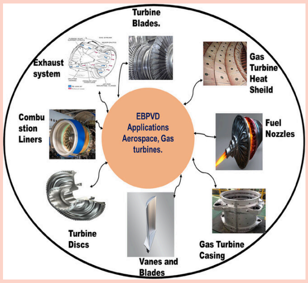
Also see our ACerS journals...

Nanostructured thermal barrier coatings via magnetron sputtering: A review of enhanced performance and durability
By S. F. Altaf, A. Rahman, and M. F. Wani
International Journal of Ceramic Engineering & Science

Challenges and opportunities for increase sustainability and energy efficiency in ceramic tile industry
By C. L. Alves, J. de Oliveira Martins Müller, A. de Noni Jr., et al.
International Journal of Applied Ceramic Technology

Commercially viable manufacturing of high-entropy carbide feedstocks
By K. Kaufmann, J. Vecchio, and K. S. Vecchio
International Journal of Ceramic Engineering & Science

Additive manufacturing of high-density silicon carbide ceramics through post-processing spark plasma sintering
By J. Amodeo and E. Bourasseau
International Journal of Applied Ceramic Technology



Credit: Altaf et al., *IJCES*

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

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

American Ceramic Society Bulletin is the membership magazine of The American Ceramic Society. It covers news and activities of the Society and its members and provides the most current information concerning all aspects of ceramic science and technology, including R&D, manufacturing, engineering, and marketing. *American Ceramic Society Bulletin* is published monthly, except for February, July, and November. Subscription included with The American Ceramic Society membership. Institutional subscription rates can be found online at www.ceramics.org or by contacting customer service at customerservice@ceramics.org.

POSTMASTER: Please send address changes to American Ceramic Society Bulletin, 470 Olde Worthington Road, Suite 200, Westerville, OH 43082-8985. Periodical postage paid at Westerville, Ohio, and additional mailing offices. Allow six weeks for address changes.

American Ceramic Society Bulletin (ISSN No. 0002-7812). ©2025. Printed in the United States of America.

ACSBA7, Vol. 104, No. 7, pp. 1–56. All feature articles are covered in Current Contents.

news & trends

New floatovoltaic installations continue globally as studies investigate possible challenges

Since their invention in the 19th century, photovoltaic panels have improved significantly in terms of conversion efficiency, from only about 1% to around 20%. These improvements have allowed photovoltaic panels to steadily gain in popularity over the past few decades as a relatively affordable alternative to fossil fuels.

But as solar technology becomes more popular, one continual challenge is figuring out where to install these systems. With efficiencies just over 20%, many photovoltaic panels are needed to convert enough sunlight to fulfill electricity demands, and these panels require large, flat areas for installation.

Floating photovoltaics, or floatovoltaics, are photovoltaic panels that are installed on top of bodies of water rather than land, and they may offer a solution to finding long-term homes for solar panels. In the past five years, many new developments have taken place in the floatovoltaics field.

Growth of floatovoltaics around the world

In November 2024, China's CHN Energy went online with the world's largest open sea floatovoltaic system, boasting 1 gigawatt (GW) of power generation in Shandong Province. Coincidentally, China is also a leading country in the implementation of floatovoltaic systems.

In early 2024, Singapore-based Ciel & Terre and HEXA Renewables completed the launch of a coastal floatovoltaic system in Taiwan. The system will help power an estimated 74,000 Taiwanese households while also helping the country reach its goals of 20 GW renewable energy capacity by 2025.

Southeast Asian countries such as Thailand, Indonesia, and the Philippines are also anticipated to make waves in the floatovoltaic industry. The Laguna Lake in the Philippines has the potential to house floatovoltaics on a large scale, and construction plans are underway for 2025.

Floatovoltaics can also work well with existing structures such as hydropower plants, like in Thailand, where the Sirindhorn dam floating solar farm combines both solar and hydropower to generate 45 MW of electricity. The project is part of a series of hydropower solar farms by the Generating Authority of Thailand, which aims to help propel Thailand toward total carbon neutrality by 2050.

Indonesia also launched one of the world's largest floating solar panel systems in 2023 at the Cirata reservoir, southeast of Jakarta. The system works in tandem with a hydropower plant and has plans to be expanded to help propel Indonesia toward even more renewable energy goals.

Credit: CHN Energy

In November 2024, China's CHN Energy went online with the world's largest open sea floatovoltaic system. The system, which boasts 1 gigawatt of power generation, combines fish farming with solar power generation to enhance use of the marine area.

As far as domestic developments go, a few large floating solar projects have debuted in the U.S., although there are still many opportunities for floatovoltaics to make waves. For example, Healdsburg, Calif., saw a large floatovoltaic system go live in 2021, with an estimate of 8% of the city's power needs being met by the project.

In 2023, the Canoe Brook Reservoir in Short Hills, N.J., unveiled an 8.9 MW array of floating solar panels. The power generated is estimated to bring electricity to 1,400 homes in the area while also working with the local water treatment plant. Other projects are underway in Cohoes, N.Y., and Fort Liberty, N.C.

Although none of the floatovoltaic projects in the U.S generate more than 10 MW of electricity on their own, a new open-access study by National Renewable Energy Laboratory researchers outlines the potential for floatovoltaics in federally controlled reservoirs. The study estimates that utilizing these reservoirs could generate anywhere from 861 to 1,042 GW direct current, which would cover more than half of the U.S.'s needs for a decarbonized grid—no warehouse roofs required.

The open-access paper on federal floatovoltaic systems, published in *Science Direct*, is "Floating photovoltaic technical potential: A novel geospatial approach on federally controlled reservoirs in the United States" (DOI: 10.1016/j.solener.2024.113177).

Downsides of floatovoltaic systems

Despite their potential, floatovoltaics still come with a myriad of concerns, from anchoring issues to maintenance safety and unpredictable weather scenarios. Additionally, a recent open-access study reveals the potentially negative effects on carbon emissions that floatovoltaic systems may have when installed on smaller bodies of water.

Researchers at Cornell University conducted the study, which found that installing floatovoltaic systems on smaller bodies of water, specifically ponds, impacted greenhouse gas emissions in those aquatic ecosystems. After installing floatovoltaics, the ponds showed higher dissolved CO2 and CH4 concentrations, lower temperatures, and severely low levels of oxygen. These outcomes can negatively impact freshwater biodiversity, among other sustainability issues.

In light of these findings, "A holistic understanding of the ecological and biogeochemical impacts of FPV [floating photovoltaic] deployment is needed, and these impacts should be considered not only for the waterbody in which FPV is deployed but also in the broader context of trade-offs of shifting energy production from land to water," the researchers write.

Despite these challenges, overall, floatovoltaic systems remain a promising technology in the U.S. and beyond, offering a way to preserve agricultural or populated land while also making strides toward a clean energy future.

The open-access paper on downsides of floatovoltaic systems, published in *Environmental Science & Technology*, is "Immediate effect of floating solar energy deployment on greenhouse gas dynamics in ponds" (DOI: 10.1021/acs.est.4c06363). ■

Labor economics: Skill level determines relationship between wages and automation innovation

Ever since the U.S. government set the first federal minimum wage in 1938, heated debate repeatedly surrounds the decision of whether or not to raise the minimum wage.

Supporters argue that raising the federal minimum wage is a clear way to build the economic security of workers and their families. Opponents argue that the benefits of higher wages are voided by an increase in the price of consumer goods as companies attempt to maintain their profit margin.

The veracity of these arguments remains a topic of debate. But a new open-access paper by several Swiss economists suggests that the concern that higher wages may result in reduced employment opportunities is valid when it comes to jobs with the potential for automation.

Automation is the use of various machines and control systems to perform tasks with minimal human input. While automation can benefit workers by taking over risky or dangerous job functions, if certain low-skill positions are automated, some workers may face unemployment if there are no opportunities to upskill or reskill.

Economists have theorized that higher wages drive innovation in automation technology as companies seek cost-saving measures to expensive labor. The new open-access paper provides the first strong empirical evidence to support this idea.

To conduct this study, the Swiss economists combined two distinct datasets: a newly developed dataset of automation patents and a macroeconomic dataset covering 41 countries. From this data, they calculated wage levels and analyzed how wage fluctuations drive automation innovation.

The economists found that higher wages for low-skilled workers incentivized firms to invest in automation innovation to reduce their production costs. On the other hand, higher wages for high-skilled workers, such as those who operate and install automation machinery, reduced automation innovation because it makes implementing automation more expensive.

To provide more support for these findings, the economists analyzed past labor market reforms and their impact on innovation trends, specifically the Hartz employment reforms in Germany. These reforms, implemented between 2003 and 2005, aimed to bring down the unemployment rate by, among other things, creating part-time job opportunities with a low threshold and minimum salary.

The economists found that the introduction of low-wage jobs during the Hartz reforms led to a decline in automation innovation among firms exposed to the German market. This discovery supports their findings regarding the relationship between skill level, wages, and automation innovation.

They conclude the paper by stating future research could adapt their classification method to patents for emerging automation technologies, such as artificial intelligence, to determine its relationship to wages.

The open-access paper, published in *Journal of Political Economy*, is “Induced automation innovation: Evidence from firm-level patent data” (DOI: 10.1086/734778). ■

news & trends

Corporate Partner news

Chiz Bros acquires Advanced Material Science

Chiz Bros, a solutions provider for the refractory and high-temperature application industries, recently acquired Advanced Material Science, a thermal and electrical insulation material distributor. According to Mark Rhoa, Jr., vice president of Chiz Bros, the acquisition will help Chiz Bros expand its offerings for induction insulation. Read more: https://hub.chizbros.com/insights

Elkem signs power purchase agreement with NTE in Norway

Elkem entered into a power purchase agreement with NTE Energy based in Norway. The agreement, which has a contract volume of 300 GWh/year, will support long-term operations at Elkem's plant in Salten in northern Norway while they aim to reach net-zero CO_2 emissions by 2050. Read more: https://www.elkem.com/media

Nabaltec achieves platinum status in Best Managed Companies Award

As a seven-time recipient of the Best Managed Companies Award, Nabaltec has now achieved platinum status. Johannes Heckmann, CEO of Nabaltec AG, says in a press release that this status "honors the sustainable orientation of Nabaltec on an international level." Read more: https://www.nabaltec.de/en/press/press-releases

Resonac and Tohoku University collaborate on semiconductor materials research

Japan-based Resonac and Tohoku University are conducting joint research on producing silicon carbide semiconductor materials from silicon sludge and carbon dioxide. If the project is successful, the CO_2 reduction effect per 100 tons of silicon carbide powder is estimated to reach the equivalent of 110 tons of CO_2. Read more: https://am.resonac.com ■

Global markets for laser systems, components, and materials

The global market for laser systems, components, and materials films was valued at $21.0 billion in 2024 and is expected to grow at a compound annual growth rate (CAGR) of 7.7% to reach $30.4 billion by the end of 2029.

The growth of industrial automation and smart manufacturing technologies is driving the adoption of laser technologies, which offer high precision, reduced wastage of materials, and enhanced efficiency of industrial processes. The rapid growth in electronics is spurring the laser technology market along as well, as lasers are required for annealing, dicing, and micro-drilling semiconductor wafers.

The global laser systems market is segmented into four types:

- **Solid-state lasers** use a solid material as their gain medium, such as a crystal or glass infused with rare earth elements. Among different types, fiber lasers are the most popular due to their high efficiency, excellent beam quality, and versatility for industrial and scientific applications. One recent innovation is the development of advanced ultrashort pulse solid-state lasers, which are increasingly used in applications such as glass and organic light-emitting diode display manufacturing.
- **Semiconductor lasers**, also called diode lasers, generate light by electrically exciting semiconductor materials. These lasers offer the advantages of fast modulation, high efficiency, and compact form, which make them suitable for large-scale deployments in various industry verticals.
- **Gas lasers** use a gaseous substance as the gain medium. CO_2 lasers are mainly used in materials processing because they can cut and engrave nonmetallic materials. Excimer lasers are popular in semiconductor lithography and ophthalmic procedures, while helium–neon lasers are usually used in laboratory applications.
- **Liquid lasers** use dye solutions as the gain medium. As they can generate tunable wavelengths, these lasers are used in several niche applications, such as isotope separation. Future developments are expected to be focused on reducing the toxic environmental impact of the dyes used in these systems.

For emerging laser technologies, extreme ultraviolet lithography is one of the most critical breakthroughs in the semiconductor industry that enables the fabrication of very small (<2 nm) transistors to manufacture integrated circuits. Meanwhile, mid-infrared lasers are finding use in environmental monitoring and medical diagnostics.

The industrial sector is the biggest user of laser technology mainly because of its widespread use in activities such as cutting, welding, engraving, drilling, and 3D printing. However, lasers are increasingly used in surgeries, skin treatments, eye care, and cancer treatment due to femtosecond and picosecond lasers making medical treatments more precise (Table 1).

Table 1. Global market for laser systems, components, and materials, by end use, through 2029 ($ millions)

End use	2024	2025	2029	CAGR % (2024–2029)
Industrial	6,393.4	6,546.1	8,471.2	5.8
Semiconductor and electronics	4,145.1	4,471.7	6,990.6	11.0
Medical and aesthetics	3,124.2	3,324.0	4,899.2	9.4
Telecommunications	2,457.2	2,593.2	3,684.2	8.4
Defense and surveillance	1,708.1	1,775.5	2,303.9	6.2
Instrumentation and scientific research	1,278.0	1,319.0	1,605.3	4.7
Automotive	1,075.1	1,127.8	1,516.9	7.1
Others	852.3	864.7	976.9	2.8
Total	21,033.4	22,022.0	30,448.2	7.7

In 2023, the Asia-Pacific region held the largest share of the global laser technology market, accounting for 51.9%. The region's continued growth is primarily driven by consistent adoption and innovation in the semiconductor and industrial sectors. However, Canada and Mexico are emerging as key markets for semiconductor laser manufacturing and photonics research.

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 markets for laser systems, components, and materials," BCC Research Report PHO002D, April 2025. https://bit.ly/April-2025-lasers ■

50 YEARS NUTEC GROUP

Interview with Daniel Llaguno

Thermal processing equipment developments for a decarbonized future

In recent years, there has been a strong, industry-wide focus on decarbonization and emissions reduction, which is driving the adoption of electric kilns and hybrid systems that combine electricity with gas or alternative fuels. For processes where carbon-based fuels remain necessary, technologies such as low-NO_x combustion, regenerative thermal oxidizers, and even carbon capture systems are expected to become standard components.

NUTEC Group is a Mexico-based manufacturer of high-temperature insulation materials and engineered thermal equipment celebrating its 50th anniversary this year. Through its decades of operation, NUTEC Group stands ready to meet the evolving needs of the thermal processing industry.

In an interview with *Bulletin* editor Lisa McDonald, NUTEC Group CEO Daniel Llaguno discusses the company's history and its plans for the next 50 years of innovation.

Q: Can you provide a brief history of how NUTEC Group started?

A: NUTEC was founded in 1975. At that time, there was a gas shortage in Mexico, so it was projected that combustion equipment and industrial furnaces would need to be retrofitted to fuel oil instead. Businessman Genaro Cueva Sr. saw this situation as an opportunity, and he reached out to North American Mfg. Co. (Cleveland, Ohio) to obtain a manufacturing license for burners and combustion equipment. While the conversion to fuel oil never happened, Cueva continued with his business plan, resulting in the creation of NUTEC as (initially) a manufacturer of combustion equipment.

Of course, almost every company that uses combustion equipment needs high-temperature insulation as well. In 1986, Cueva oversaw the construction of the first ceramic fiber manufacturing facility in Mexico. Then, in 1990, NUTEC Industrial was born to expand the company's product offerings to industrial furnaces. In 2000, it was renamed NUTEC Bickley after the acquisition of Bickley Furnaces Inc. out of Philadelphia, Pa.

Through acquisitions and organic growth, NUTEC Group now has two divisions—Fibers and Industrial Kilns, Furnaces & Ovens—with eight manufacturing plants in four countries. Its products and services are sold globally in more than 50 countries.

Types of thermal processing equipment

Kilns typically operate in the range of 800–1,800°C. They are designed for processes such as sintering, vitrification, or glazing. Kilns can be either batch type—such as shuttle and elevator kilns—or continuous, such as tunnel kilns and roller hearth kilns.

Ovens generally operate at 200–600°C and are primarily used for drying, curing, or preheating. They are usually air-heated and can also be configured as batch systems—such as walk-in ovens—or continuous systems, such as mesh belt or rotary ovens.

Q: In the past 50 years, what were the main innovations in the design and construction of thermal processing equipment for ceramics?

A: Fiber insulation has largely replaced traditional refractory bricks in applications operating below 1,600°C, offering improved energy efficiency and faster thermal cycling. In addition, heat recuperation technologies have been widely adopted to reduce fuel consumption and lower emissions. More recently, there has been a growing shift toward electric heating elements as a means to eliminate the use of natural gas entirely.

In terms of digital control and automation, programmable logic controllers and supervisory control and data acquisition systems have largely replaced manual and analog controls, providing more precise and consistent operation. More recently, the adoption of predictive control algorithms and Industry 4.0 technologies has significantly enhanced process reliability, traceability, and efficiency.

Q: What innovations has NUTEC Group contributed to thermal processing equipment design?

A: NUTEC has actively supported the industry's transition to more energy-efficient insulation systems through, notably, our Jointless® insulation system. This system seamlessly integrates the kiln roof and exhaust flue, thus eliminating joints that often lead to maintenance issues.

Regarding thermal processing equipment, the Carbell® kiln, which minimizes heat leaks and air infiltration, is widely adopted across the ceramics sector with more than 400 units installed worldwide. Meanwhile, our IMPS® pulse firing technology is recognized for delivering excellent temperature uniformity while simultaneously reducing fuel consumption. Also, our recently introduced ecombustion® helps minimize fuel usage at the source rather than relying solely on heat recovery.

Q: What projects or initiatives has NUTEC Group launched to prepare for the next 50 years of innovation?

A: We recently completed the design and commissioning of several electric tunnel kilns, shuttle kilns, and ovens that all operate exclusively on electricity. For ceramic processes emitting volatile organic compounds, we now offer regenerative thermal oxidizers as a standard solution to ensure more efficient and environmentally compliant exhaust treatment. Within our Fibers Division, we have focused on the development of high-temperature fibers with low biopersistence, aligning with stricter health and safety standards.

Learn more about NUTEC Group at https://gruponutec.com. ■

By David Holthaus
Industry reporter

Materials businesses and researchers explore the commercial frontiers of space

It has been said that space is the final frontier, but for some businesses, space is the new marketplace.

Businesses are leveraging the microgravity environment of space for research, product development, and innovation, as the weightlessness of space loosens the bonds of gravity, enabling processes and experiments that are not possible on the terra firma of Earth. The environment has proven useful for materials science enterprises interested in pursuing purer alloys, glasses, and ceramics.

Investigating manufacturing processes in space is not new: Experiments have been conducted on the International Space Station (ISS) for more than two decades, and they took place on the space shuttle before that. But the potential for commercial use of space for microgravity processing has grown in recent years.

In early 2024, a NASA-supported investigation called “Production of Flawless Space Fiber” used the ISS to demonstrate a manufacturing technology developed to improve the quality and length of optical fiber produced in space (Figure 1). Optical fibers are widely used in medicine, defense, cybersecurity, and telecommunications. Previous research in simulated microgravity had shown that fibers produced in microgravity could be higher quality than those made in normal gravity, resulting in greater capacity and purity, and the ISS provided a platform to investigate their commercial production.

The preliminary results are promising, NASA says on its website.[1] The project manufactured more than seven miles of fiber and demonstrated that the results are repeatable. Seven of the runs exceeded 2,200 feet, demonstrating for the first time that commercial lengths of fiber can be produced in space.

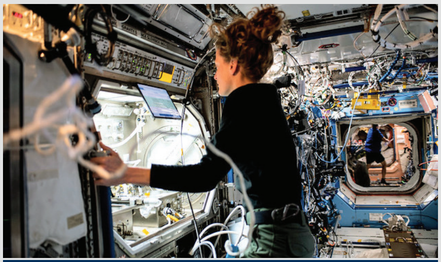


Figure 1. NASA astronaut Loral O’Hara works on an optical fibers project in the Microgravity Science Glovebox of the ISS.

The technology demonstrated in the investigation was developed by Flawless Photonics, a company whose U.S. headquarters are in Reno, Nev., and which specializes in manufacturing optical glasses, fibers, and components in microgravity. The company’s Luxembourg facility has developed fibers known as ZBLAN, a glass alloy made of zirconium, barium, lanthanum, sodium, and aluminum fluorides. These materials can transmit a much broader spectrum of light, meaning it can send much more data compared to traditional silica-based fibers over the same distance, NASA says.[1]

But ZBLAN is difficult to make on Earth. When the fiber is made in gravity-influenced environments, crystals form that will disrupt signals and render the fiber brittle. Crystals grow more slowly in microgravity, so the fibers can be cooled before crystals have a chance to form. Microgravity hinders crystallization because it removes buoyancy and the movement of the glass ingredients that are the starting point for crystals to grow. The glass produced in microgravity is 10 to 100 times more transparent than typical glass found in homes, the company said in an interview with the Luxembourg Space Agency.[2]

The ISS has also served as the platform for experiments run by Materials Development Inc., a materials science and research firm based in Evanston, Ill. The company provides instruments for containerless processing of materials.

MDI has conducted experiments on the space station using the Japanese Aerospace Exploration Agency furnace, in collaboration with NASA, levitating materials in microgravity.

“In microgravity, you don’t have any buoyancy, so there’s essentially no convection,” explains Rick Weber, MDI’s founder and president, in a podcast.[3] “That allows one to measure transport properties in a supercooled liquid. And that’s a very challenging thing to do.”

On the ISS, MDI has experimented with rare earth titanates and aluminates, studying how their properties change over a range of temperatures.

Pharmaceutical development is another area where space provides commercial opportunities. One study sponsored by Rahway, N.J.-based Merck worked to grow a more uniform crystalline form of the company’s anti-cancer drug Keytruda. The results of that study could lead to a version of the drug that can be given via injection in a doctor’s office, potentially making it more convenient and less costly for patients.

Varda Space Industries, Inc., is an El Segundo, Calif.-based “microgravity-enabled life sciences company,” according to its website. In May 2025, it announced the successful completion of its third mission into low-Earth orbit using a small capsule that reentered Earth’s atmosphere and landed on a test range in Australia. The capsule carried an inertial measurement unit (IMU), which are electronics developed by the U.S. Air Force that can measure an object’s motion, orientation, and velocity. Commercial IMUs can be inaccurate at high-speed conditions, and Varda’s capsule tested the devices at speeds exceeding Mach 25, or 25 times the speed of sound, advancing research into high hypersonic technologies.

The successful reentry came 11 weeks after the completion of the company's second mission. That capsule carried research the company said will expand its pharmaceutical processing capacity and capability. The capsule also carried a spectrometer built by the Air Force Research Laboratory and employed a heat shield developed in collaboration with NASA's Ames Research Center.

Like other space-oriented firms, Varda is capitalizing on the reduced cost of space launches, hitching a ride on a SpaceX mission that hosted dozens of other payloads. Varda wants to accelerate research into space commercialization with more frequent experiments.

"High-cadence, routine operations are our goal," Vice President for Mission Management Brandi Sippel said in a news release.[4] "We are looking forward to the day when sending capsules into orbit and back to Earth is seen as routine."

Varda's research will "continue building a thriving foundation for economic expansion to low Earth orbit," CEO Will Bruey said in a news release.[5]

Visualizing, designing, and scaling materials and products that are produced in microgravity is the business of G-Space, a Sunnyvale-Calif.-based startup.

"G-space is the only software-first platform for designing products that you manufacture in microgravity," says founder and president Ioana Cozmuta in an interview. The company provides data, analysis, and software tools for researchers and commercial businesses startups, enabling them to quantify improvements that occur during microgravity processing. That improves decision making, Cozmuta says.

"We also have tools that can tell you what the difficulties are in taking that to market, and what the potential market is that you can reach with that material," she says.

Looking ahead, more companies will make commercial investments in the space manufacturing arena, Cozmuta says. The cost of processing materials in space will require that, in return, the product is superior or unique enough to justify a high price point, can be produced in sufficient volume, or can reduce energy costs or greenhouse gas emissions to make the effort worthwhile.

About the author

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

References

[1]"Optical fiber production," NASA. Published 25 March 2025. https://bit.ly/4lDctHI

[2]"Flawless photonics: Pioneering space fiber production in Luxembourg," Luxembourg Space Agency. Published 31 May 2025. https://bit.ly/4o9ZaQL

[3]"Materials research for space and in space: Rick Weber," Ceramic Tech Chat. Published 10 Aug. 2022. https://bit.ly/3TIYbZK

[4]"Varda announces third mission launch, the company's second launch this year," Varda Space Industries. Published 15 March 2025. https://bit.ly/3UgCQHa

[5]"Varda Space Industries makes history with the first successful commercial space reentry in Australia," Varda Space Industries. Published 28 Feb. 2025. https://bit.ly/4kLdzjj

*All references verified as of July 16, 2025. ■

SOCIETY DIVISION SECTION CHAPTER **NEWS**

FOR MORE INFORMATION:

ceramics.org/spotlight

Louis J. Trostel Jr., DLM, 1927–2025

Louis J. Trostel Jr. died on April 7, 2025, at the age of 97. He was an ACerS Fellow (1969) and Distinguished Life Member (2010).

Originally from Baltimore, Md., Trostel received his B.S., M.S., and Ph.D. degrees in ceramic engineering from The Ohio State University. He worked at The Ohio State Research Foundation from 1950 to 1955 and then joined the Norton Company Advanced Ceramics Group, where he worked as a research manager until retiring to establish his technical consulting practice.

Throughout his life, Trostel played a critical role in the advancement and development of refractory ceramic materials. He authored or coauthored more than 27 technical papers on the properties and testing of refractories, and he was awarded three U.S. and six foreign patents.

Trostel had long-standing involvement with the Unified International Technical Conference on Refractories (UNITECR). He served as program chair and proceedings editor of the first UNITECR in 1989, and he continued to serve as a Board member or advisor to the Board at numerous subsequent meetings. In 1993, he was elected a UNITECR Distinguished Life Member.

Trostel became a member of ACerS in 1949, and he became actively involved with both the Refractories Ceramics Division (RCD) and New England Section. He served as RCD chair from 1985 to 1986, and he was an RCD trustee on the ACerS Board from 1993 to 2002; he continued to serve RCD as a counselor until 2022. In 1955, Trostel joined the New England Section, serving in various officer positions, including chair. He was also active on the ACerS Publications and Nomenclature Committees.

Trostel received various awards throughout his life that recognized his work in refractories. For example, in 1982, he received the F.H. Norton Award of Distinguished New England Ceramist. In 1996, the ACerS St. Louis Section (now the Greater Missouri Section) awarded him the T. J. Planje Refractories Award. In 2008, The Refractories Institute awarded him the William T. Tredennick Award. In 2010, he presented the ACerS/NICE Arthur L. Friedburg Memorial Lecture at ACerS Annual Meeting at MS&T.

Trostel also received recognition for his involvement in supporting the next generation of materials engineers. In 2011, the town of Princeton, Mass., where Trostel moved after taking the job at Norton Co. in Worcester, Mass., awarded him the Outstanding Citizen Award for his four decades of volunteer work with the science seminar program at Wachusett Regional High School and his 10 years of service on the Princeton Cemetery Commission.

In addition to his involvement in ACerS, Trostel was a Fellow of ASTM and was a member of its Committee C8 on Refractories and its subcommittees since 1959, serving as chair for many years. He was also a member of the International Organization for Standardization's Technical Committee TC-33 for Refractories since 1985. Furthermore, he was a member of Sigma Xi, Tau Beta Pi, and Keramos.

Trostel leaves behind many close colleagues and friends, including Dana Goski, vice president of research and development at Allied Mineral Products, who recalls the impact his "extraordinary career" had on ACerS and the larger refractories world.

"Alongside his beloved wife, Mary, who was a constant and cherished presence at ACerS functions and industry meetings, they helped cultivate a sense of family and community that enriched the professional lives of countless colleagues. Lou was a sage voice of experience I could rely on for leadership advice, delivered with a dose of clever humor," she says.

Trostel was preceded in death by his father, Louis Trostel Sr., also an ACerS DLM (1966) and past president in 1942. His wife, Mary, passed away on May 10, 2025. They were married for 71 years. ■

Welcome new ACerS Corporate Partner

ACerS is pleased to welcome its newest Corporate Partner:

EPIC™
ADVANCED MATERIALS

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

Amit Bandyopadhyay appointed next editor-in-chief of ACT

Amit Bandyopadhyay is now editor-in-chief of the *International Journal of Applied Ceramic Technology (ACT)*.

Bandyopadhyay is the Boeing Distinguished Chair Professor in the School of Mechanical and Materials Engineering at Washington State University in Pullman, Wash. He brings to the position substantial editorial leadership experience, having served as an editor for many materials journals, including being a co-equal editor of *ACT* prior to becoming editor-in-chief.

Bandopadhyay joined The American Ceramic Society in 1992 while pursuing his Ph.D. research in silicon nitride ceramics for structural applications at the University of Texas at Arlington. While his research currently focuses on additive manufacturing of advanced materials with a special emphasis on ceramics, metals, and composites, Bandyopadhyay has researched and published in structural, piezoelectric, sensor, and bioceramics areas.

Bandopadhyay's plans for *ACT* include bringing in papers from different areas of applied ceramics and establishing several special issues in areas vital for the growth of applied ceramics research. He also plans to increase engagement with the advanced ceramics community, for example, by developing a robust social media presence for the journal.

Operationally, Bandopadhyay plans to further reduce the review time for each *ACT* manuscript while maintaining the high quality of the reviews. Each submission will be evaluated more critically to fit *ACT*'s aims and scope during pre-review screening. Papers of high quality but with unclear significance and impact on applied ceramics will be given the opportunity to address these issues and resubmit or to transfer to the *International Journal of Ceramic Engineering & Science*.

Bandyopadhyay along with the entire ACerS journals team thank Professor Young-Wook Kim, the outgoing editor-in-chief, for his leadership. During Kim's tenure, the journal's reputation, submissions, and published papers greatly increased. ■

more SOCIETY DIVISION SECTION CHAPTER NEWS

Greater Missouri Section/Refractory Ceramics Division 61st Annual Symposium planned for March 2026

The ACerS Greater Missouri Section and Refractory Ceramics Division will hold the 61st Annual Symposium on Refractories from March 31–April 1, 2026, in St. Louis, Mo., at the Hilton St. Louis Airport Hotel. A kickoff event will be held the evening of March 30, 2026. The theme of the 2026 Symposium will be “Refractories for Non-Ferrous Applications.” Co-program chairs are Dan Gower of Refractory Minerals and Kimberley Peterson of Christy Refractories. Questions? Contact Patty Smith at (573) 341-6265 or psmith@mst.edu. ■

ACerS Colorado Section members enjoy a day at the ballpark

The ACerS Colorado Section enjoyed an afternoon at the Colorado Rockies vs. Arizona Diamondbacks baseball game on June 22, 2025, at Coors Field in Denver, Colo. Section leaders reported the event as a success, with excellent attendance, good food and drink, and networking. ■

Members of the ACerS Colorado Section, with friends and family, enjoying the Colorado Rockies vs. Arizona Diamondbacks game.

Welcome New ACerS International Israel Chapter

Welcome to the newest ACerS International Chapter! The ACerS Board of Directors recently approved a petition to establish an ACerS International Chapter in Israel.

Chapter officers

Chair: **Gideon Grader**, Technion-Israel Institute of Technolgy

Chair-elect: **Wayne Kaplan**, Technion-Israel Institute of Technolgy

Secretary: **Maxim Sokol**, Tel Aviv University

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

ACerS International Spain Chapter plans conference entitled ‘New Horizons in Multifunctional Ceramic and Glass Materials’

The ACerS International Spain Chapter will hold a short conference titled “New Horizons in Multifunctional Ceramic and Glass Materials” the afternoon of Oct. 7, 2025, in the auditorium of the Spanish National Research Council office in Oviedo, Spain. The conference will conclude the following morning with a visit to the facilities of the Nanomaterials and Nanotechnology Research Center in Sotrondio, Spain. Be on the lookout for more details and the final program as they become available. ■

ACerS International United Kingdom Chapter helps deliver successful 'Fractography of Ceramics' training course

Members of the ACerS International United Kingdom Chapter who attended the training course on the fractography of ceramics.

The ACerS International United Kingdom Chapter worked with The Institute of Materials, Minerals & Mining to hold a training course on the fractography of ceramics at the Lucideon site in Stone, U.K., on June 12, 2025. The course was aimed at materials science students as well as early career researchers and engineers wishing to gain an understanding of how to use fractography to explore the limitations of brittle materials. The course combined lectures and practical demonstrations that covered fundamental principles of brittle fracture, practical aspects for studying cracks and fracture origins, practical sessions on flexural strength and participant components, and case studies dealing with component failures. ■

ACerS International Nordic Chapter members attend conference on inorganic materials chemistry

ACerS International Nordic Chapter members at the Nordic Conference on Inorganic Materials Chemistry.

The Nordic Conference on Inorganic Materials Chemistry was held June 3–5, 2025, at the Ångström Laboratory in Uppsala University, Sweden. The conference, which was sponsored by Uppsala University and the ACerS International Nordic Chapter, featured 38 invited talks by leading and early-career researchers from the Nordic countries and the near-Nordic countries of Germany, Belgium, Austria, and Italy. Researchers also came from countries farther away, such as the Republic of South Korea and the United States.

Some of the topics covered were fundamentals of solution processing and gas-phase growth of advanced materials, catalysis, photoactive materials, thermoelectrics, electroceramics, batteries, metal–organic frameworks, solar cells, next-generation nuclear fuel, and carbon capture and storage materials. Very engaged discussions took place after the talks, during the coffee breaks and during dinners.

Following the success of this conference, members of the ACerS International Nordic Chapter anticipate a second conference will take place again in the coming years. ■

more SOCIETY DIVISION SECTION CHAPTER NEWS

ACerS International Brazil Chapter members attend 69th Brazilian Ceramics Congress

At the 69th Brazilian Ceramics Congress in June 2025, members of the ACerS International Brazil Chapter ran an ACerS booth that served as a central hub for engagement, information, and international connection throughout the event. Booth volunteers promoted ACerS membership benefits; upcoming international events; and opportunities for publication, collaboration, and participation in global networks such as the Global Graduate Researcher Network. It also provided tailored guidance for Brazilian participants seeking deeper involvement with ACerS activities, reinforcing the Society's commitment to international scientific development.

ACerS International Brazil Chapter members at their booth during the 69th Brazilian Ceramics Congress.

The evening of the conference served as a meeting point between young and experienced ceramists, fostering mentorship and knowledge exchange in an informal atmosphere. Students, postgraduates, and recent graduates networked with leaders in the field, including ACerS members and representatives from the Brazilian ceramics community.

The ACerS International Brazil Chapter also presented awards to top-performing participants at the conference, offering one-year student memberships to recognize talent and encourage continued engagement with the global ceramics community.

Through these activities as well as reaffirming its collaboration with the Brazilian Ceramic Association, ACerS demonstrated its commitment to the international ceramics community. ■

The American Ceramic Society
ceramics.org

WEBINAR LIBRARY

CHECK OUT THESE RECENT ADDITIONS TO THE ACERS WEBINAR ARCHIVE:

FACTORS THAT AFFECT PHASE STABILITY AND PERFORMANCE OF HAFNIUM OXIDE FOR MEMORY APPLICATIONS
Original air date: April 25, 2025
Hosted by: ACerS Washington, D.C./Maryland/Virginia Section
Featured speaker: Jon Ihlefeld

FIELD ASSISTED SINTERING: INNOVATIVE APPROACHES AND BASIC MECHANISMS and DENSIFICATION OF SDC: ALKALI CARBONATE NANO-COMPOSITE ELECTROLYTES FOR SOFC APPLICATIONS BY COLD SINTERING PROCESS
Original air date: May 12, 2025
Hosted by: ACerS International Italy Chapter and ACerS International Türkiye Chapter
Featured speakers: Umberto Anselmi-Tamburin and Hüseyin Yilmaz

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

MEMBER HIGHLIGHTS

Volunteer Spotlight: L. K. Sharma and Bryce Switzer

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

L. K. Sharma is chief executive officer of Mahamana Ceramic Development Organization (New Delhi, India), as well as a visiting professor at several colleges and universities in India. He also serves as an advisor for both state governments and private ceramic industries.

Sharma received his postgraduate degree in materials technology and doctorate in ceramic engineering from Indian Institute of Technology (IIT) Banaras Hindu University (now IIT Varanasi). He previously served in roles at Grindwell Norton Ltd. (plant head), Algrain Ceramique Corp. (general manager), and Central Glass & Ceramic Research Institute (chief scientist).

Sharma champions sustainable development, cluster transformation, and skill-based education in ceramics. He believes that ceramic science is as much about people and purpose as it is about products and processes.

An active ACerS member since 1991, Sharma is the founding chair of the ACerS International India Chapter. In 2023, Chapter growth allowed ACerS to approve the establishment of two separate India Chapters (Northeast and Southwest), and Sharma currently serves as chairperson of the ACerS International Northeast India Chapter.

Besides Chapter involvement, Sharma has served in roles on both the ACerS Nomination Committee and the Engineering Ceramics Division Board, and he is a former chair of the Global Corporate Achievement Award Committee. In 2017, he organized awareness programs through the Ceramic and Glass Industry Foundation on ceramics and glass materials for students at Jamia Millia Islamia University in New Delhi, India. In March 2024, he organized the 4th Global Ceramics Leadership Roundtable at IIT Roorkee. He also helped coordinate the agreement that was signed between the Indian Ceramic Society and The American Ceramic Society in 2011.

In recognition of his global outreach and technical leadership, Sharma has been honored with the Global Star Award (2014), Global Ambassador designation (2015), Corporate Environment Achievement Award (2015), and ACerS Fellow (2024).

Bryce Switzer is business unit sales manager for Vibrantz Technologies LLC in Marion, Ark. He received his business marketing degree from the University of Arkansas at Little Rock and has been in the clay brick business since 1997.

Switzer currently volunteers for The National Brick Research Center, providing presentations on "Brick Coloring" for the Clemson University short courses offered every spring and fall. He previously worked with the Brick Industry Association as a volunteer member for both the Membership Committee and for the Architectural Design Committee. He also worked with the Greater Little Rock Home Builders Association and the Arkansas Chapter of the American Institute of Architects. After spending nearly 30 years in the clay brick industry and seeing many of his colleagues now retiring, Switzer is working with several people within the industry to develop a program to identify and retain a new generation of "Brick Makers."

Switzer has spent the past four years as an officer of the ACerS Structural Clay Products Division. He has been a member of both the Structural Clay Products Division and the ACerS Southwest Section since 2015.

We extend our deep appreciation to Sharma and Switzer for their service to our Society! ■

FOR MORE INFORMATION:

ceramics.org/membership

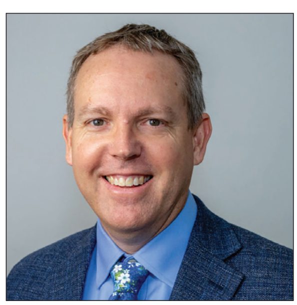
more MEMBER HIGHLIGHTS

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.

Arun Varshneya, FACerS, DLM, Alfred University Emeritus Professor of glass science, and his wife, **Darshana Varshneya**, will financially support the biennial University Conference on Glass series as well as an annual lecture on glass at Alfred University. The University Conference on Glass is hosted on a rotational basis by four institutions: Alfred University, Missouri University of Science and Technology, Rensselaer Polytechnic Institute, and The Pennsylvania State University. Funding will support the conference at all four host institutions.

Olivier Guillon, FACerS, professor at RWTH Aachen University, was appointed chief executive officer of the Luxembourg Institute of Science and Technology (LIST), effective Sept. 1, 2025. LIST is a research and technology organization active in the fields of information technology, materials, space resources, and the environment. Guillon was chosen for this role thanks to his expertise in the field of energy materials and experience as director of the Institute of Energy Materials and Devices at Forschungszentrum Jülich.



Bryan Huey, FACerS, was selected as the next Blacutt–Underwood Head of the School of Materials Engineering at Purdue University. He comes to Purdue after a two-decade career at the University of Connecticut. Huey assumed his new duties on Aug. 15, 2025. ■

IN MEMORIAM

Clarence "Larry" D. Bell

H. Kent Bowen

Diane Folz

Jim McGuffin-Cawley

Carlo Pantano

CGIF CERAMIC AND GLASS INDUSTRY FOUNDATION

Student voices, congressional ears: Highlights from the 2025 Material Advantage Congressional Visits Day

The 2025 Material Advantage Congressional Visits Day (CVD) brought 36 students from 16 universities to Washington, D.C., for two days of science advocacy, professional development, and connection with peers and policymakers.

Hosted by the Material Advantage student program, CVD is an annual event that gives students in materials science and engineering the chance to engage with policymakers and their staff on Capitol Hill to advocate for federal funding of research in materials science and related fields.

This year's event kicked off with an opening reception and training session at the Credit Union House on April 2. Students heard from professionals working at the intersection of science and policy, including Alessandra Zimmerman, senior manager of R&D policy at the American Association for the Advancement of Science (AAAS); Adriana Bankston, federal science policy advocate currently serving as the first-ever AAAS/ASGCT Congressional Policy Fellow; and Mark Feuer DiTusa, who currently works in the office of Senator Chris Coons (D-DE) to improve policy in workforce, biomanufacturing, and education. The speakers provided valuable insights on the federal budget, careers in science policy, and the importance of student advocacy. Students also had time to practice their talking points and make final preparations for their scheduled meetings on the Hill the next day.

On April 3, the university students participated in congressional visits throughout the day. They shared personal experiences, emphasized the impact of federal research funding on their education and career goals, and brought visibility to the materials science and engineering community. Many participants teamed up with students from other universities in their state or district to visit offices together.

The impact of the experience extended beyond the policy discussions themselves, as explained by Marlena Alexander, a student at the University of Tennessee.

"Being surrounded by students equally as passionate about materials science and engineering as I am was so empowering. Not only was I able to talk about the importance of materials research in our lives, but I had the opportunity to learn from my peers, make new friends, and better understand how our federal government works. I left the event feeling more confident in my ability to advocate for what I believe in," she says.

a) University students take a picture inside the office of U.S. Representative Paul D. Tonko (D-NY).

b) From left: Zane Smith, Patrick Angelino, Staffer Andrew Guffee, Grace Chrisman, and Marlena Alexander following their meeting with the staff of Senator Marsha Blackburn (R-TN).

c) Students from the University of Virginia posing outside the U.S. Capitol Building.

The Ceramic and Glass Industry Foundation and the Material Advantage partners—ACerS, AIST, ASM International, and TMS—thank all the students who participated and represented their universities and the broader materials community with professionalism and enthusiasm.

To learn about how you can support more student opportunities such as the Material Advantage Congressional Visits Day, visit foundation.ceramics.org or contact foundation@ceramics.org. ■

research briefs

Preserving traditions and legacies: Ceramic and glass technologies on the UNESCO Intangible Cultural Heritage Lists

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) was founded in the midst of World War II, as the Allied Nations recognized that rebuilding the education systems of warring nations would be a foundational step toward ensuring lasting peace. Since the 1940s, UNESCO's mission has grown to encompass scientific collaborations and preservation of intangible cultural heritage.

Intangible cultural heritage is defined as traditions or cultural expressions inherited from ancestors. These skills have been passed down for generations, and now their existence is threatened.

Since 2008, the UNESCO Intergovernmental Committee for the Safeguarding of the Intangible Cultural Heritage have published Lists of the Intangible Cultural Heritage of Humanity. Over the last decade, numerous ceramic and glass technologies have made the lists.

Clay production

In south-central Vietnam, the Chăm ethnic minority people use their feet to mix clay and sand in specific proportions to produce their unglazed pottery. In Zlakusa, Serbia, local clay is mixed with calcite in varying percentages depending on the size and purpose of the finished product. In Bisalhaes, Portugal, an unglazed black pottery has been produced for centuries by firing the clay objects in outdoor pits. In northern Peru, the wise women of the indigenous Awajún people have safeguarded their pottery-making techniques for centuries.

Decorating

The women of Sejnane, Tunisia, produce cookware, utensils, and other handmade pottery objects for the home that they decorate with traditional designs and colors. In the Carpathian region of Ukraine, the decorative themes on local pottery are painted in green and yellow mineral glazes that are sourced locally. The decorative glazing techniques of Türkiye's çini makers have been perfected through generations. Ceramic artists in Uzbekistan traditionally learn the skill from their grandparents, and each lineage may have their own characteristic style. Mexican talavera pottery involves techniques originally brought from Spain by the conquistadors but made exuberantly their own in the last 500 years.

Sculpting

Not all pottery is made into vessels for cooking or eating. Estremoz, Portugal, is famous for its clay figures that are uniquely decorated on specific themes. The handmade tableware and figurines of Chile's mestizo culture has been produced by women for generations, but it is under threat as the clay mining areas are converted to farmland.


Credit: Becky Stewart

Example of blown glass-bead ornaments from Czechia.

Glass production

Artisans in Czechia, Finland, France, Germany, Hungary, and Spain have all been recognized for their knowledge, craft, and skills of handmade glass production, a centuries-old practice that has shaped specific terminologies, festive cultures, and religious functions. However, traditional Syrian glassblowers, also recognized on the lists, are considered to have the longest history with glassmaking.

The glass beads from southern France and northern Italy represent a range of creative practices and can offer insights into ancient trade networks. Meanwhile, the blown glass beads from Czechia are considered a key cultural element of the Giant and Jizera Mountain regions in North Bohemia, where the creation of Christmas ornaments using these beads appear in folk tales about Krakonoš, the legendary ruler of the mountains.

View all the Lists of the Intangible Cultural Heritage of Humanity at https://ich.unesco.org/en/lists. ■

Materials in the news

Semiconductors get magnetic boost with new method

Researchers led by the University of California, Los Angeles developed a method to produce semiconductor materials containing up to 50% magnetic atoms, whereas current methods are often limited to a concentration of magnetic atoms no greater than 5%. Their technique involves alternately stacking together atomically thin sheets of the semiconducting materials and self-organized layers of magnetic atoms. This layered architecture allows each component to retain its ordered arrangements and intrinsic properties while giving rise to new collective behaviors. For more information, visit https://newsroom.ucla.edu.

Model predicts long-term effects of nuclear waste on underground disposal systems

Researchers from Massachusetts Institute of Technology, Lawrence Berkeley National Laboratory, and the University of Orléans showed that simulations of underground nuclear waste interactions aligned well with experimental results from a research facility in Switzerland. The simulation software, called CrunchODiTi, was developed from established software known as CrunchFlow and accounts for electrostatic effects. The new model could now replace older models that have been used to conduct safety and performance assessments of underground geological repositories. For more information, visit https://news.mit.edu. ■

ceramics in energy

Expanding opportunities in the subsurface for hydrogen sourcing and storage

The use of hydrogen fuel in industrial operations has made great strides in recent years, but using hydrogen is only one aspect of establishing a hydrogen economy. We also need ways to efficiently produce, transport, and store hydrogen at scale to facilitate its widespread adoption.

Researchers offer insights into locating naturally formed subsurface hydrogen

In May 2025, researchers at the University of Oxford, as well as Durham University and the University of Toronto, published a review paper that explores the possibility of sourcing clean hydrogen from Earth's crust.

According to the article, three key ingredients determine whether hydrogen will accumulate naturally: a source rock, water within the source rock, and conditions for the hydrogen to remain trapped within the geological structure after the water–rock reaction.

That last ingredient is essential when it comes to extracting geologic hydrogen. Over the past billion years, Earth's crust is estimated to have generated volumes of hydrogen with energy equivalent to 170,000 years' worth of the oil we use today. However, much of this hydrogen may have already been lost to evaporation, absorption, or chemical or biological processes beneath the crust.

In the new study, the researchers note that helium may serve as a tool for understanding the regional release mechanisms and flux of hydrogen.

"Formed in crystalline systems through radioactive decay, helium (^4He) is often co-produced with hydrogen from the same source rock region. In contrast, helium is not consumed by chemical or biological processing and provides a clear resolvable signal in near-surface crustal fluids. With similar physical characteristics, such as solubility and diffusivity, helium provides a relevant proxy for understanding hydrogen source–rock retention, expulsion, and transport efficiencies," they write.

However, the researchers caution that geologic hydrogen should not be considered an abundant resource—Earth does not provide hydrogen in response to human environmental needs, after all, but at its own pace over millions of years.

The review article, published in *Nature Reviews Earth & Environment*, is "Natural hydrogen resource accumulation in the continental crust" (DOI: 10.1038/s43017-025-00670-1).

DOE program lays foundation for large-scale hydrogen storage

The U.S. Department of Energy is funding research on hydrogen storage through a multiyear study called the Subsurface Hydrogen Assessment, Storage, and Technology Acceleration (SHASTA).

As explained in a Lawrence Livermore National Laboratory press release, naturally occurring, underground reservoirs make attractive locations for hydrogen storage thanks to their enormous volume and intrinsic layers of security. However, currently only salt dome structures or caverns are assessed for safe, large-volume underground hydrogen storage.

SHASTA was launched in 2021 to determine the viability, safety, and reliability of storing pure hydrogen or hydrogen–natural gas blends in different types of underground environments. To answer these questions, SHASTA relied on the expertise of researchers from four DOE national laboratories: National Energy Technology Laboratory, Pacific Northwest National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories.

In April 2024, the researchers presented the culmination of their findings during the Office of Resource Sustainability Program Review Meeting in Pittsburgh, Pa. They shared evidence for using non-salt-based subsurface environments for storage, such as porous subsurface rock found in depleted oil and natural gas reservoirs. They also described an overarching methodology for assessing hydrogen storage suitability.

Because of these successes, DOE's Office of Fossil Energy and Carbon Management announced that it would extend SHASTA into 2025, with "the potential of further extension to address unmet needs," as reported in the SHASTA 2024 technical workshop summary. ■

Honoring the ACerS

Over its long history, The American Ceramic Society has established a tradition of awards to recognize its members' outstanding contributions and accomplishments and to create career benchmarks for aspiring young scientists, engineers, and business leaders. The most prestigious of ACerS awards is Distinguished Life Member designation, a recognition bestowed upon only two or three members each year.

In 2025, two individuals will receive DLM honors: John E. Marra and Subhash H. Risbud. The Society will elevate 12 members to Fellow and recognize many more outstanding members with various Society and Class awards during the ACerS Annual Honor and Awards Banquet Reception on Sept. 29, 2025.

2025 DISTINGUISHED LIFE MEMBERS

John E. Marra

Growing up in rural New York, it may seem unusual that John Marra and his four brothers all pursued careers in the science and mathematics field, especially considering their father was a Latin and English teacher. But with Alfred University only about 100 miles away from their hometown, Marra says it was a natural spot to gravitate toward.

"Alfred drew us all in," he says. "Three of the five Marra boys graduated with ceramic engineering degrees from Alfred."

Marra first joined The American Ceramic Society as a student member through Alfred University. After earning his B.S. in ceramic engineering and B.A. in chemistry, Marra then went on to receive his Ph.D. in ceramic engineering from The Ohio State University.

During graduate school, Marra ended up connecting with Tom Rankin, a distinguished and active member in ACerS. Rankin helped create the Nuclear Division of ACerS in the 1960s, which had a big impact on the Society as well as Marra's personal life.

"I don't think any of us that started out in ceramics or materials think that we're going to end up in nuclear," Marra says. "But for me, it kind of just happened and then again it was that Ohio State connection."

Marra ended up working at Savannah River National Laboratory (SRNL) as an associate laboratory director, later moving to the U.S. Department of Energy (DOE) in 2015 as a senior technical advisor and then chief engineer of the DOE Office of Environmental Management. Until recently, he served as chief technology officer at the DOE, a position in which he had technical responsibilities across DOE's Environmental Management Mission.

Although he started out doing ceramics-related research at SRNL, Marra also explored other materials and even took on a managerial role. He remembers managing a group of electrical engineers at one point in his career and learning to lean on those around him for guidance.

"I always wanted to rely on the folks around me that had the experience or a different type of experience and take that on board, and that was certainly something that was valuable within my term as president of The American Ceramic Society," Marra says.

During Marra's time as ACerS president from 2004 to 2005, he strengthened the new environmental component of the renamed Nuclear & Environmental Technology Division (1994), but he gives credit to the younger ACerS members who have continued his progress.

"They expanded it to the Energy and Materials Systems Division [2020], which I think was just a natural and very smart evolution," he says. "The thing that I've always found about ACerS is the willingness to progress but not lose the important heritage and legacy, and also the opportunity to listen to some of the younger folks that are coming in."

Marra is also known for leading the Society into a partnership with the Materials Science and Technology (MS&T) technical meeting and exhibition, which still takes place in tandem with the ACerS Annual Meeting today.

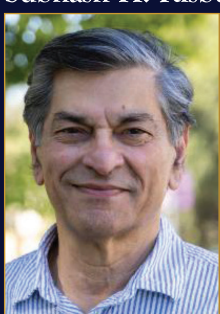
Marra recalls many positive memories in the Society, from squeezing into shared dorm rooms with other graduate students at the annual meeting to forming friendships with people such as Ted Besmann, who once "saved" Marra during a presentation that involved hefty computer code questions.

Marra would like to express his gratitude toward Randy Johnson, David Pye, Arun Varshneya, Dennis Ready, Katherine Faber, Jim McGuffin-Cawley, Eric Kriedler, Bill Lee, and Tom Rankin, among others, for serving as instrumental figures throughout his life and career.

"ACerS been a highlight of my professional career," he says. "But the friendships that I've made have also been a highlight of my personal journey."

Awards Class of 2025

Subhash H. Risbud



Almost every scientist can point to a specific person or experience that sparked their interest in the field. For Subhash Risbud, his inspiration was a literal spark.

"In my very early years, I went to the just-started, first-ever Delhi Public School in India, which didn't have a building yet, so our classes and all of us were in tents. During the hot summers of Delhi, a spark from fans on the wooden poles would sometimes start a fire. We would rush out and play firefighters, using a garden hose," he recounts.

Even at that young age, Risbud noticed the cloth and wood caught fire quickly, but the metallic fan was not affected. This observation sparked his interest in studying metallurgy, and he was selected to attend the Indian Institute of Technology in Bombay (now Mumbai).

During his fifth year at the institute, Risbud did a project on crystal growth from the vapor phase using sealed glass tubes. This project fueled a passion for ceramic and glass materials, and he pursued this newfound interest at the University of California, Berkeley, where he conducted his M.S. thesis under the guidance of Richard M. Fulrath.

"Fulrath was a kind, wonderful man who vividly showed me melting and hot pressing. I would stand by and watch him hot press glass–alumina composite powders into disks or pour glass melts out all by himself," Risbud says.

During this time, Risbud also got to know Joseph Pask and Alan Searcy, who along with Fulrath made up the world-famous "Berkeley Ceramics Trio," Risbud says.

After his M.S. degree, Risbud worked as a crystal grower at Stanford University in Bob Feigelson's laboratory and then worked on the manufacture of alumina substrates at WESGO company (now GTE-Sylvania). He returned to UC Berkeley, where he got his Ph.D. in 1976 working under the guidance of Pask on glass immiscibility and mullite crystallization.

Following graduation, Risbud accepted professorships at the University of Nebraska, Lehigh University, the University of Illinois Urbana-Champaign, and the Optical Science Center at the University of Arizona. Returning to California in 1990 as a professor at UC Davis, Risbud is now Distinguished Professor Emeritus of Materials Science and Engineering and a member of the graduate programs in the chemical engineering and mechanical & aeronautical engineering departments.

Over the course of his career, Risbud and his students authored more than 300 publications as well as secured six patents on projects ranging from semiconductors to biomedicine. He is grateful to Brian Leeners, CEO of Homerun Resources in Canada, for encouraging his students with frequent advice delivered via Zoom talks, as well as supplies of ceramic powders from Brazil and his generous gift funds.

The core philosophy underlying Risbud's work is that joy and happy, healthy interactions with your colleagues must come before anything else.

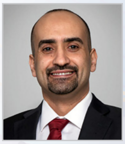
"I tell all my students, 'The project matters, but your happiness comes first.' Close your eyes and just tell me what you are happiest doing, and we'll find out together how to reach the best support mechanisms that are available," he says.

Risbud first joined ACerS as a student at UC Berkeley, and for more than 50 years, he served on Society award committees and chaired numerous technical sessions. His efforts in the lab, classroom, and Society have been recognized through awards and honors, including the James Mueller Award (2025), the W.D. Kingery Award (2020), the Outstanding Educator Award (1998), Fellow (1989), and the Ross Coffin Purdy Award (1979).

Among his many friends, Risbud wants to say a special thank-you to ACerS Fellow James Shackelford and ACerS Distinguished Life Member Zuhair Munir, the two people who helped him move to UC Davis.

"Zuhair, Jim, and all my other friends and mentors have shaped my career and enriched my life in more ways than I can imagine," he says. ■

The 2025 Class of Fellows



Amjad Almansour is a materials research engineer in the Ceramic and Polymer Composites Branch of the Materials and Structures Division at NASA Glenn Research Center. He received his B.S., M.S., and Ph.D. in mechanical engineering from Mu'tah University in Jordan, the University of Dayton, and the University of Akron, respectively. He has been an ACerS member since 2012 and is currently chair-elect of the Engineering Ceramics Division. Almansour has been the lead organizer of several symposiums at ICACC, PACRIM, the 14th International Conference on Ceramic Materials and Components for Energy and Environmental Systems, and the National Space and Missile Materials Symposium. He has served as chair of the ACerS Award Committee; secretary, treasurer, and vice-chair of ECD; and program chair of ICACC 2025. He has received the ECD Global Young Investigator Award, ACerS Global Star Award, Richard M. Fulrath Award, and Global Ambassador Award.

Yajie Chen is a distinguished research fellow at Rogers Corporation. He received a B.Eng. in magnetic materials and devices from Huazhong University of Science and Technology, China, followed by a Ph.D. in condensed matter physics from Soochow University, China. He has been an ACerS member since 2007 and belongs to the Electronics, Basic Science, and Engineering Ceramics Divisions. Chen actively contributes to ACerS through his participation in annual conferences, invited talks, and his role as an author and reviewer for ACerS journals. Additionally, he serves as a mentor in the ACerS Student Mentor Program, exemplifying his commitment to fostering the next generation of professionals in the field.

Armin Feldhoff is extraordinary professor at Leibniz University Hannover, Germany. He received a diploma in physics from the University of Münster, Germany, and his Ph.D. from Martin-Luther University Halle-Wittenberg, Germany. He has been an ACerS member since 2017 and belongs to the Energy Materials and Systems Division, as well as the Basic Science and Engineering Ceramics Divisions. He was the inaugural chair of EMSD (2020–2021). Feldhoff has served as associate editor of both *Energy Harvesting & Systems* and *Journal of Electronic Materials*. Since 2023, he has been an associate editor of *Journal of the American Ceramic Society*. In 2022, he received the ACerS D.T. Rankin Award and has been recognized as an ACerS Global Ambassador.

Yumi Ikuhara is principal researcher in the Nanostructures Research Laboratory at the Japan Fine Ceramics Center (JFCC), Japan. She received her B.S. in pharmaceutical sciences from Gifu Pharmaceutical University, Japan, her M.S. in materials science and engineering from Case Western Reserve University, and her Ph.D. from Kyoto University. She has been an active ACerS member since 1998 and belongs to the Basic Science and Energy Materials and Systems Divisions. Ikuhara is a Fellow and director of The Ceramic Society of Japan.

Mihails Kusnezoff is head of the Department of Materials and Components at Fraunhofer Institute for Ceramic Technologies and Systems, Germany. He received his M.S. in solid-state physics from the University of Latvia. He has been an active member of ACerS since 2012 and belongs to the Engineering Ceramics Division. Kusnezoff has been a leading organizer of the annual Symposium S3 on Solid Oxide Cells at ICACC for the last 13 years. He is co-editor of *International Journal of Applied Ceramic Technology* and received a Certificate of Appreciation as ACerS Journal Reviewer in 2020. He has also received the ECD Global Star and ACerS Global Ambassador Awards.

Gregory Morscher is professor of mechanical engineering at the University of Akron. He received his B.S. in ceramic engineering from The Ohio State University and his M.S. and Ph.D. in materials science and engineering from Case Western Reserve University. He has been an ACerS member since 1987 and belongs to the Engineering Ceramics Division. Morscher has served on the Richard M. Fulrath Committee since 2023, and he previously served as vice chair (2013–2014) and chair (2015–2016) of the Ceramics Committee of ASME IGTI as well as conference organizing chair for HTCMC8 and advisory committee for HTCMC9 through 11. He received the ACerS Richard M. Fulrath Award in 2005.

K.T. Ramesh is the Alonzo G. Decker, Jr., Professor of Science and Engineering at Johns Hopkins University and interim co-director of the Johns Hopkins Data Science and AI Institute. He received his B.E. from Bangalore University and his M.Sc. in applied mathematics and Ph.D. in engineering from Brown University. He has been an ACerS member since 2005 and belongs to the Engineering Ceramics and Refractory Ceramics Divisions. Ramesh's research and scholarship have been recognized through various major awards, and some of his work has been published in *Journal of the American Ceramic Society*.

The 2025 Class of Fellows (continued)

Wolfgang Rheinheimer is professor at the University of Stuttgart, Germany. He received his M.S. in industrial engineering and Ph.D. in mechanical engineering from Karlsruhe Institute of Technology, Germany. He has been an ACerS member since 2011 and belongs to the Basic Science, Electronics, and Engineering Ceramics Divisions. Rheinheimer previously served in the executive leadership of the Basic Science Division, including as chair (2021–2022). He also served as co-chair for the ACerS Electronic Materials and Applications Conference in 2020 and 2022. Rheinheimer has assisted in the organization of 26 symposia at a variety of international conferences.

Denise A. Silva is senior scientist at Oak Ridge National Laboratory. She received her B.S. and M.Sc. in civil engineering from the Federal University of Rio Grande do Sul, Brazil, and her Ph.D. in materials science from the Federal University of Santa Catarina, Brazil. She has been an ACerS member since 2011 and belongs to the Cements Division. Silva is a former secretary, chair-elect, and chair of the Cements Division and has co-chaired the 11^{th} and 12^{th} Advances in Cement-Based Materials conferences. She was recognized as an ACerS Global Ambassador in 2022.

Gurpreet Singh is Massey Neff professor in the mechanical and nuclear engineering department at Kansas State University. He received his B.S. in mechanical engineering from the College of Engineering Pune, India, and his M.S. and Ph.D. in mechanical engineering from the University of Colorado Boulder. He has been an ACerS member since 2019 and belongs to the Basic Science and Engineering Ceramics Divisions. Singh has organized or co-organized symposia and tracks for several ACerS-supported conferences, including the MS&T technical meeting and exhibition. He also co-founded the ACerS Technical Interest Group to advance polymer-derived ceramic materials, explore their emerging applications, and foster collaborative R&D opportunities. He previously served on the Editorial Advisory Board of the *ACerS Bulletin*, and he currently serves as an associate editor for *Journal of the American Ceramic Society*.

Federico Smeacetto is Full Professor of Materials Science and Technology at Politecnico di Torino, Italy. He received his M.S. in chemistry from the University of Torino and his Ph.D. in materials science from Politecnico di Torino. He has been an ACerS member since 2004 and currently serves as vice-chair of the Engineering Ceramics Division, as well as belongs to the Energy Materials and Systems Division. Since 2021, Smeacetto has served as associate editor of *International Journal of Applied Ceramic Technology*. He also served as co-organizer and organizer for Symposium 3, "International symposium on solid oxide fuel cells (SOFC): Materials, science and technology" at ICACC.

Wil V. Srubar, III is professor of civil and architectural engineering and materials science and engineering at the University of Colorado Boulder. Srubar received his B.S., M.S., and Ph.D. in civil and environmental engineering from Texas A&M University, The University of Texas at Austin, and Stanford University, respectively. He has been an ACerS member since 2016 and belongs to the Cements Division, as well as the Bioceramics and Engineering Ceramics Divisions. Srubar has held several leadership positions within the ACerS Cements Division, including secretary, chair-elect, and chair, and has served as conference chair of the 15^{th} Advances in Cement-based Materials Conference. He is the recipient of the 2023 ACerS Cements Division Early-Career Award and a 2020 NSF CAREER Award. ■

Visit https://ceramics.org/awards/society-fellows to learn more about the 2025 Fellows.

Society Awards

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

Carol Handwerker, FACerS, is the Reinhardt Schuhmann, Jr. Professor of Materials Engineering and professor of environmental and ecological engineering at Purdue University.

Her research areas include developing innovative and lead-free interconnect technologies for next-generation microelectronics, investigating sustainable materials and processes for thin film solar cells and other electronics, identifying and implementing strategies to move research and development into manufacturing and commercialization, and controlling interface properties to design microstructures in polycrystalline materials and thin films.

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

Jingyang Wang, FACerS, is Distinguished Professor of the Chinese Academy of Sciences and head of the Advanced Ceramics and Composites Division at Shenyang National Laboratory for Materials Science and the Institute of Metal Research.

His research interests focus on the fundamental exploration and technological development of ceramics. Specifically, he works on advancing the design, processing, evaluation, and application of advanced ceramics, ceramic matrix composites, and high-temperature thermal barrier and environmental barrier coating for extreme environmental applications.

RICHARD AND PATRICIA SPRIGGS PHASE EQUILIBRIA AWARD honors authors who made the most valuable contribution to phase stability relationships in ceramic-based systems literature in 2024.

"Analysis of slag chemistry in WEEE smelting using experimental and modelling study of the '$CuO_{0.5}$'–ZnO–FeO–$FeO_{1.5}$–CaO–SiO_2–$AlO_{1.5}$ system in equilibrium with Cu metal," *Ceramics International* 2024, **50**(15): 26513–26527.

Georgii Khartcyzov, The University of Queensland, Australia
Cora Kleeberg, Aurubis AG, Germany
Maksym Shevchenko, The University of Queensland, Australia
Denis Shishin, The University of Queensland, Australia
Evgueni Jak, The University of Queensland, Australia

ROSS COFFIN PURDY AWARD recognizes authors who made the most valuable contribution to ceramic technical literature in 2023.

"Lead-free Zr-doped ceria ceramics with low permittivity displaying giant electrostriction," *Nature Communications* 2023, **14**: 7371.

Maxim Varenik, Weizmann Institute of Science, Israel
Boyuan Xu, Brown University, Rhode Island
Junying Li, Stony Brook University, N.Y.
Elad Gaver, Weizmann Institute of Science, Israel
Ellen Wachtel, Weizmann Institute of Science, Israel
David Ehre, Weizmann Institute of Science, Israel
Prahlad K. Routh, Stony Brook University, N.Y.
Sergey Khodorov, Weizmann Institute of Science, Israel
Anatoly I. Frenkel, Stony Brook University, N.Y.
Yue Qi, Brown University, R.I.
Igor Lubomirsky, Weizmann Institute of Science, Israel

"High-entropy rare earth titanates with low thermal conductivity designed by lattice distortion," *Journal of the American Ceramic Society* 2023, **106**(10): 6279–6291.

Saisai Zhu, Zhengzhou University, China
Jinpeng Zhu, Zhengzhou University, China
Songbo Ye, Zhengzhou University, China
Kaijun Yang, Zhengzhou University, China
Mingliang Li, Zhengzhou University, China
Hailong Wang, Zhengzhou University, China
Jilin He, Zhengzhou University, China

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

Katelyn Kirchner is a glass process scientist at CelSian Inc. in Toledo, Ohio.

Her dissertation focused on the development of robust physics-based techniques to quantify the formation of structural fluctuations and evaluate structural adaptations during the industrial chemical strengthening process. Experimental and computational results revealed the pivotal role of nanometer-

Society Awards (continued)

sized voids, bonding fluctuations, and topographical fluctuations on the thermal behavior of bulk and thin silica films.

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

Naotaka Kondo is president and CEO of Toyo Tanso Co. Ltd., Japan.

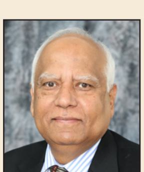
Kondo has directed the development of composite carbide, ceramic, and graphite materials for the metallurgy and semiconductor markets, while at the same time innovating manufacturing technology to timely launch products at the pace desired by the global market. His company, Toyo Tanso, is the first in the world to successfully industrialize mesoporous carbon, and this innovation is directing its business expansion.

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

Charmayne Lonergan is assistant professor at Missouri University of Science and Technology.

Lonergan previously co-chaired the ACerS Young Professionals Network and is now the Member Engagement liaison for the Glass & Optical Materials Division. She was vice chair of the International Commission on Glass Technical Committee on Waste Vitrification, a role that highlighted her dedication to addressing global challenges through innovative glass-based solutions. She is now on the executive board for the ACerS Energy Materials and Systems Division, is a member of the Education and Professional Development Council, and was recently named to the Board of the Ceramic and Glass Industry Foundation.

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



Mrityunjay Singh, DLM, FACerS, is chief scientist at Ohio Aerospace Institute.

Singh is globally recognized for his long-term and outstanding contributions to the science and technology of advanced materials and manufacturing technologies. His research has addressed both basic and applied questions and has been instrumental in establishing design, integration, and performance limits for single and multimaterials used in a wide variety of aerospace and ground-based applications. Singh is an ACerS past president and holds honorary fellowships and doctorates from numerous institutions. He is a recipient of nearly 100 national and international awards.

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

"Structural and thermodynamic investigations of $Zr(BH_4)_4$ and $Hf(BH_4)_4$ between 280 K and their decomposition temperatures," *New Journal of Chemistry* 2024, **48**(6): 2743–2754.

Authors: **Konrad Burkmann**, F. Habermann, E. Schumann, J. Kraus, B. Störr, H. Schmidt, E. Brendler, J. Seidel, K. Bohmhammel, J. Kortus, and F. Mertens

Konrad Burkmann is postdoctoral researcher in the Navrotsky Eyring Center for Materials of the Universe at Arizona State University.

Burkmann studies rare earth oxyphosphates and other rare earth ionic compounds to understand the materials' structures and thermodynamics. He aims to identify trends within these compounds that can be used to develop materials for high-tech applications, such as thermal barrier coatings. ■

ECerS-ACerS JOINT AWARD recognizes individuals who foster international cooperation between The American Ceramic Society and the European Ceramic Society, in demonstration of both organizations' commitment to work together to better serve the international ceramics community.

Pavol Šajgalík, FACerS, is president of the Slovak Academy of Sciences. He is a member of the European, American, and Japan Ceramic Societies, president of the Slovak Silicate Society, and member-elect of the World Academy of Ceramics. In 2015, he was awarded a Slovak State decoration, the Order of the Ľudovít Štúr of III. In 2013, he was awarded the Stuijts Award of ECerS and Bridge Building Award of ACerS.

ECerS-ACerS JOINT YOUNG PROFESSIONAL AWARD recognizes individuals who foster international cooperation between The American Ceramic Society and the European Ceramic Society, in demonstration of both organizations' commitment to work together to better serve the international ceramics community.

Antonia Ressler is postdoctoral research fellow in the engineering and natural sciences, materials science and environmental engineering department at Tampere University, Finland. She has served as a committee member of the Young Ceramists Network, and she is currently a committee member of the "Equity, Diversity, and Inclusion in the Ceramic Community" initiative of ECerS. She also shared her expertise by conducting a one-day workshop in collaboration with Soňa Hříbalová called "Navigating Global Research Careers: Young Researchers Sharing Their Experience." ■

Society Awards (continued)

DAVID W. RICHERSON EDUCATIONAL OUTREACH AWARD is given annually to honor up to two undergraduate or graduate student members of the ceramic and glass materials community who have made a significant impact in outreach to primary and secondary school students.

Nathaniel McIlwaine is a graduate researcher at The Pennsylvania State University. He has spent seven years with the ACerS President's Council of Student Advisors. He helped lead several outreach initiatives, including planning and running a STEM outreach workshop for Penn State graduate students, volunteering at the COSI Sci Fest in Columbus, Ohio, and extensive work with the Ceramic and Glass Industry Foundation Mini Materials Kits.

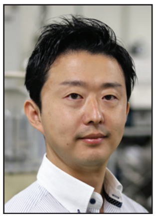
Paul Brune recently graduated from Missouri University of Science and Technology and is now a ceramic engineer at Kratos SREe in Birmingham, Ala. He traveled to local middle and high schools and met with young students in the classroom to share his passion for materials. He gave technical demonstrations on ultrahigh-temperature ceramics at summer camps for high school juniors and seniors in the Missouri area. ■

Richard M. Fulrath Symposium and Awards

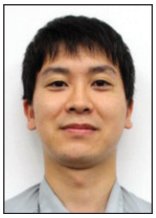
Promote technical and personal friendships between Japanese and U.S. ceramic engineers and scientists.

U.S. academic: **Lane Martin**, Rice University

U.S. industrial: **Nathan Orloff**, National Institute of Standards and Technology



Japanese academic: **Takashi Teranishi**, Okayama University



Japanese industrial: **Shota Daiki**, Tokuyama Corp.

Japanese industrial: **Satoshi Mori**, Niterra Co., Ltd.

Class Awards

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

Gregory S. Rohrer, FACerS, is the W.W. Mullins Professor of Materials Science and Engineering at Carnegie Mellon University. He received his B.S. in physics from Franklin and Marshall College and his Ph.D. in materials science and technology from the University of Pennsylvania.

During Rohrer's more than 30 years as a materials scientist and educator, he has influenced the education of more than 1,000 students at the undergraduate and graduate levels at Carnegie Mellon. He also created the first equity, diversity, and inclusion committee in the materials science and engineering department. As a member of the University Materials Council for more than a decade, Rohrer worked toward best practices in curriculum offerings and accreditation procedures for materials departments across the nation.

EPDC GREAVES-WALKER LIFETIME SERVICE AWARD is presented to an individual who has rendered outstanding service to the ceramic engineering profession and who, by life and career, has exemplified the aims, ideals and purpose of EPDC.

Eva Vogel, FACerS, is currently a part of the Lifelong Peer Learning Program in The Graduate Center at City University of New York. She received her B.S., M.S., and Ph.D. in chemical engineering and physical chemistry from Slovak Technical University.

Vogel is internationally recognized in the glass community for the demonstration of all-optical switching devices based on high optical nonlinearities. She was the first to identify tellurite glasses as ideal materials for fiber optic communications, and her research resulted in a patented tellurite glass host composition for the 1.3-mm optical fiber amplifier. ■

ACerS Award Lectures

EDWARD ORTON JR. MEMORIAL LECTURE

Tatsuki Ohji, DLM, FACerS, visiting professor, Yokohama National University and Nagoya Institute of Technology; emeritus research councilor, National Institute of Advanced Industrial Science and Technology, Japan

"Ceramics for structural applications—Overcoming the challenges of this formidable material"

Ohji's research interests include property characterizations of ceramics and related materials and their microstructural design for better performance.

ACERS FRONTIERS OF SCIENCE AND SOCIETY RUSTUM ROY LECTURE

Ungyu Paik, Distinguished Professor, Hanyang University, Republic of Korea

"Toward sustainable and high-energy lithium batteries: Materials and manufacturing at the energy frontier"

Paik's research interests center around the development of materials for next-generation energy devices and storage systems.

BASIC SCIENCE DIVISION ROBERT B. SOSMAN AWARD AND LECTURE

Sossina Haile, FACerS, Walter P. Murphy Professor, Northwestern University

"Interfacial defect chemistry of ceria"

Haile's research and development includes advanced energy conversion and storage technologies including fuel cells, electrolyzers, batteries and thermoelectric converters.

GLASS & OPTICAL MATERIALS DIVISION ALFRED R. COOPER AWARD SESSION

COOPER DISTINGUISHED LECTURE PRESENTATION

Morten M. Smedskjaer, professor of chemistry and bioscience, Aalborg University, Denmark

"Glass still breaks: Understanding crack initiation and growth"

2025 ALFRED R. COOPER YOUNG SCHOLAR AWARD NOMINEES

Jake Klucinec, University of Central Florida

"Optimization of the heat treatment protocol and metrology of Ge-As-Pb-Se glass"

Christopher S. E. Martin, Iowa State University

"Extending electrochemical impedance spectroscopy capabilities for non-Arrhenius and fast-ion-conduction studies of glassy-solid-state-electrolytes"

Kai Penner, University of Manitoba

"Connectivity of alteration layer in borosilicate glasses for applications in nuclear waste"

Wuqian Zhang, Swarthmore College

"Thermodynamic properties of Pt-Cu-P bulk metallic glasses"

Infrared curing of ceramic slurries consisting of ceramic powders and aluminum dihydrogen phosphate binder.

Additive manufacturing of porous ceramics: Direct processing through phosphate condensation and photonic irradiation

By Nicolas Somers, Eren Özmen, and Mark D. Losego

Ceramic materials offer many desirable properties: high thermal and chemical stability, strong mechanical properties, and biocompatibility, among others. Yet these properties can make it difficult to shape and sinter ceramics, especially components featuring complex geometries, such as hierarchical patterns and internal structures.

Additive manufacturing (AM) is seen as a transformative method to fabricate geometrically complex ceramic components through precise layer-by-layer deposition. But while research in ceramic AM has demonstrated significant potential to save time, materials, and energy, challenges in using these techniques remain.

For example, most ceramic AM processes still require long (up to several days) post-shaping thermal treatments at temperatures above 1,000°C to remove organic additives (debinding) and densify the ceramic part (sintering).[1] These treatments limit the rapid production of ceramic parts and, when conducted in a furnace, do not allow a tunable energy delivery for each layer.

These treatments also pose significant challenges for multimaterial fabrication, particularly during co-sintering. When materials with differing thermal expansion rates are processed together, mismatched shrinkage kinetics can lead to defects such as distortion, cracking, or delamination. These issues are especially common when co-sintering dissimilar materials, such as ceramics, metals, and glasses.

To mitigate such risks, it is generally necessary to use materials that sinter under similar thermal and atmospheric conditions. As a result, material selection for multimaterial components is highly restricted, limiting the design of advanced functionalities.

These constraints could be alleviated through layer-specific heating, enabling the integration of materials with varying thermal expansion and shrinkage behaviors into complex, multimaterial parts. This approach may also eliminate the need for prolonged high-temperature, post-processing treatments, which offers clear technological, economic, and environmental benefits.

Alternative heat sources and low-temperature chemical methods are both possible approaches to layer-specific heating of additively manufactured ceramics. Recent advancements in innovative sintering technologies—such as leveraging electric fields, rapid heating rates, pressure, or hydrothermal conditions—show great promise for integration with AM to produce high-performance ceramics efficiently.[1]

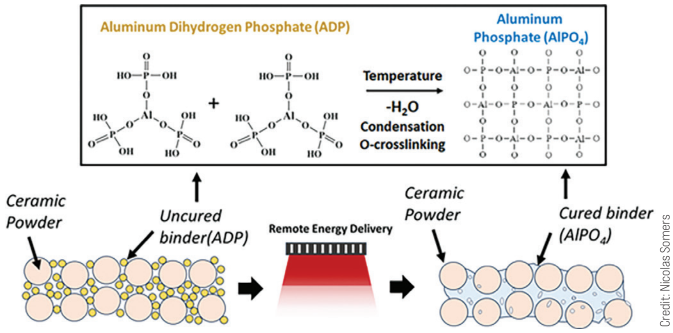


Figure 1. Overview of the condensation and crosslinking mechanism of aluminum dihydrogen phosphate as a binder. Its binding effect with ceramic particles is based on adhesion processes and on the same chemical phosphate crosslinks.

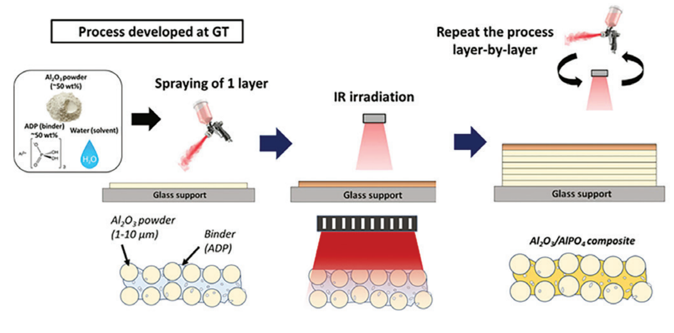


Figure 2. Schematic of the new synthesis process, which involves depositing a ceramic slurry through a high-volume, low-pressure spray gun followed by infrared curing of the sprayed layers. Adapted from Reference 16.

Amongst alternative heating routes, high-energy light irradiation—also called photonic curing or photonic sintering—has shown promise in densifying ceramic thin films (<1 μm thick)[2–6] and, more recently, thicker layers (tens of microns)[7–10] over sufficiently short timescales for use in AM.

Photonic curing uses high-intensity, short-duration light pulses (usually in the millisecond range) to selectively heat a material's surface or deposited layer without significantly heating the underlying substrate. Current technologies allow precise control over the shape, frequency, and other features of the emitted pulses, giving a lot of freedom to the photonic treatment for annealing thin films, sintering metal lines on temperature-sensitive substrates, reflowing solder, activating dopants, and improving the crystallinity of semiconductors, among other applications.

However, photonic curing faces the challenges of limited penetration depth, nonuniform sintering if energy absorption is not optimized, and the need for compatible inks and materials that absorb light efficiently, among other hindrances.

With funding from the U.S. Office of Naval Research, Mark Losego's group at Georgia Institute of Technology runs a project called "Exploration of new chemistries and processes for additive manufacturing of ceramics" (grant no. N00014-21-1-2258). Through this project, we aim to develop a new, single-step ceramic additive manufacturing process that does not require post-process pyrolysis or high-power lasers. To achieve this goal, we are developing new ceramic and preceramic chemistries that can achieve proper densification through liquid-phase sintering at low temperatures (<1,000°C).

A key point of this development process is the use of an inorganic binder that experiences consolidation reactions at temperatures low enough to minimize unwanted transformations of the main material. Aluminum dihydrogen phosphate ($Al(H_2PO_4)_3$, ADP) is a particularly attractive binder option due to the feasibility of creating chemically bonded phosphate ceramics (CBPCs)[11–13] by combining a layer-by-layer deposition process with light irradiation to trigger the binder consolidation and phosphate bonding with ceramic particles.[14–16]

CBPCs are composites that are obtained by dissolving an inorganic phosphate binder along with a dense ceramic powder in a solvent and subsequently reassembling the dissolved components into a new solid structure. This acid–base-type CBPC synthesis reaction usually takes place between an anion donor phosphate binder—such as phosphoric acid (H_3PO_4), diammonium hydrogen phosphate ($(NH_4)_2HPO_4$), or ADP—and a metal oxide, such as magnesium oxide or alumina. These systems undergo inorganic condensation polymerization reactions that form ceramic phosphate phases bound together by PO_4 tetrahedral linkages (Figure 1).

The formation of CBPCs occurs at low temperatures (<500°C). Thus, CBPCs have lower energy requirements than sintered ceramics while retaining high chemical resistance, high compressive strength, high abrasion resistance, biocompatibility, and good dimensional and thermal stability, often above 1,000°C. Additionally, the versatile chemistry of CBPCs allows functionality to be added to the final product, for example, corrosion resistance by doping with molybdate or chromate, self-healing capability by doping with cerium oxide, semiconductivity by doping with indium and its oxides, and thermochromism by doping with vanadium or chromium oxides.

Transposing this concept to an AM configuration represents a new route for ceramic AM, with opportunities for new functionalities and applications of multimaterial 3D structures. The new approach would remove the need for post-shaping thermal treatments thanks to the triggering of the reactive phosphate binder through infrared or visible light irradiation. The tailored heating of each layer along with the use of an efficient binder should offer new opportunities to combine materials with different thermal expansion coefficients and shrinkage kinetics into complex, multimaterial parts.

So far, our group has published four articles regarding the association of inorganic phosphate binders, photonic curing, and additive manufacturing.

Exploration of additively manufactured CBPCs

First article: Developing the infrared-driven curing process

Our first article introduced a fast, low-temperature, pressureless process to chemically bind ceramic parts with the help of infrared (IR) irradiation and phosphate binder condensation (Figure 2).[16]

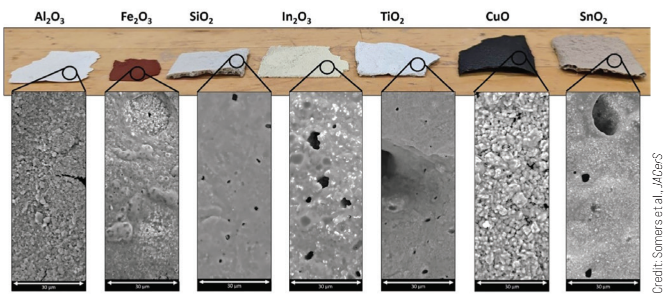


Figure 3. Photographs (top) and micrographs (bottom) of 20-layer, spray-cast, and infrared-irradiated ADP-bound ceramic sheets created from various oxide powders.[16]

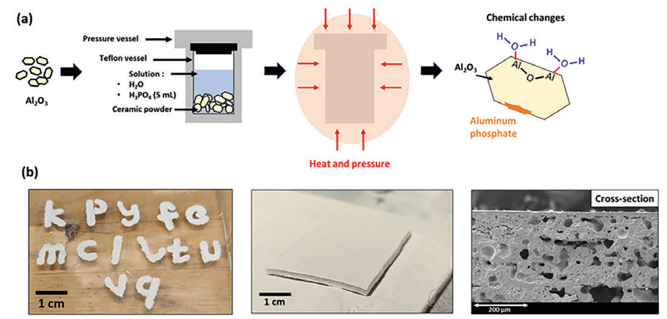


Figure 4. (a) Schematic of the hydrothermal treatment of alumina, which induced chemical changes at the surface of the particles. (b) Photographs and scanning electron microscopy micrographs of the H_3PO_4-treated powder that was shaped with spraying and infrared irradiation.

Ceramic components are synthesized from slurries of ceramic powders and ADP binders that are spray cast and irradiated with short-waved IR light capable of heating the system to 350°C. This irradiation is found to be sufficient to drive phosphate condensation, binding the ceramic powders together within a matter of seconds. The IR-irradiated components show an increase in density and Vickers hardness relative to uncured samples.

This approach allowed the production of free-standing ceramic sheets consisting of different oxide ceramics, such as alumina, iron oxide, silica, indium oxide, copper oxide, and tin oxide (Figure 3). These freestanding ceramic sheets were sufficiently robust to be handled, and they presented an important interconnected porosity that could find interesting applications in refractories, bone implants, electronics, and thermal barrier coatings, among other fields.

Second article: Optimization of printed parts

To optimize the properties of the printed parts, our second article investigated using hydrothermal treatments to modify the ceramic powder's surface chemistry to make it more reactive to the phosphate binder phase and, ideally, enhance mechanical strength and potentially density.[15] Specifically, we explored whether hydrothermal treatments could increase the number of hydroxyl and phosphate groups on the alumina powders (Figure 4a).

Alumina powders were pretreated in hydrothermal conditions with both water and phosphoric acid solution before slurry preparation and infrared irradiation. The effects of hydrothermal treatments on the powder's chemical reactions and the composite's final microstructure were assessed upon IR irradiation.

While water treatment did not induce any chemical changes, the presence of phosphoric acid led to the appearance of phosphate phases $Al(PO_3)_3$ and $AlPO_4$. Hydrothermal treatments in water and phosphoric acid solution were found to drive faster and more intense phosphate condensation reactions at lower temperatures, with a stronger effect in the presence of H_3PO_4 (condensation temperature of 150°C for the H_3PO_4-hydrothermal treated powder compared to 165°C for the untreated powder).

This improved reactivity of hydrothermally treated α-Al_2O_3 powders, especially in the presence of H_3PO_4, leads to a general decrease of porosity for 3D-printed parts compared to untreated alumina (Figure 4b). While further optimization is needed to reduce the final porosity, it is possible to rapidly print 3D parts using this method, demonstrating a possible pathway to a single-step ceramic AM process.

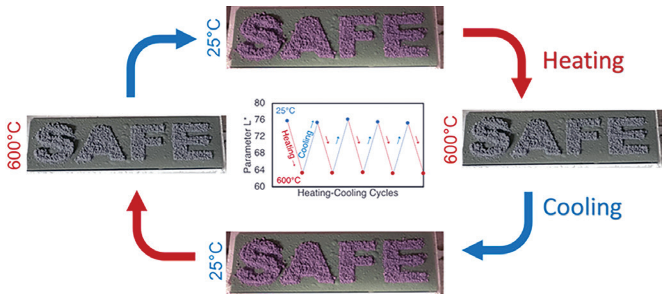
Third article: Creation of thermochromic sensor

Our third article involved manufacturing an inorganic, high-temperature (~600°C) thermochromic sensor made of a CBPC.[14] It showed the feasibility of fabricating CBPCs with reversible thermochromic properties using photonic annealing methods that follow a process flow consistent with additive manufacturing.

Phase analysis confirmed that the remote photonic energy can transform the ADP binder into an $AlPO_4$ ceramic phase that binds the thermochromic powders together. Interestingly, the quantity of energy needed to achieve "full conversion" of ADP to $AlPO_4$ is approximately the same for both IR irradiation and flash-lamp annealing (FLA), about 300 J/cm^2. However, FLA can deliver this energy in nearly two orders of magnitude less time due to being in the visible light spectrum, making it even more amenable for rapid prototyping.

The FLA system (PulseForge Invent) enabled easy adjustment of the photonic pulse sequence. We found that an initial sequence of low-energy pulses (10 flashes with 100 V or 1.1 J/cm^2 of lamp power, for a total energy of 11 J/cm^2) was important to first remove physically absorbed water prior to driving ceramization. This "drying step" was followed by higher energy pulses at a range of lamp voltages varying from 400 to 520 V, each with 30 repetitions, providing energy densities of 207, 279, 327, and 399 J/cm^2, respectively, paralleling those provided by the IR lamp. Because energy delivery was varied by lamp voltage, the duration of each FLA process could be kept constant at 48 seconds.

By understanding the thermochromic color changes of Cr:Al_2O_3 under varying conditions, we manufactured a simple, patterned thermochromic device to demonstrate the potential for this technology (Figure 5). Future work will need to optimize similar slurries for integration with higher resolution printing methods, such as inkjet printing and aerosol jet printing. Additionally, stacking of multiple layers and under-



Credit: Özmen et al., *Adv. Eng. Mater.* (CC BY-NC-ND 4.0)

Figure 5. Glass slides prepared with letters of 10 wt.% Cr:Al_2O_3–ADP (solid-state synthesis at 1,400°C) and surrounding media of 10 wt.% Cr:Al_2O_3–ADP (solid-state synthesis at 1,000°C). Color change of letters at 600°C makes them disappear within the background, warning users that it is no longer safe to touch. Adapted from Reference 14.

standing their interaction, both internally and in conjunction with the FLA method, will bring a new approach to rapid additive manufacturing.

Fourth article: Exploring the influence of binder:powder ratio

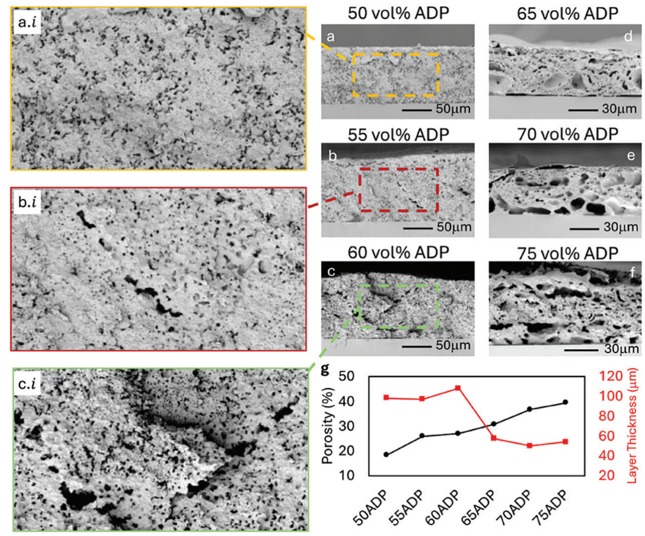
In our fourth article, we examined the influence of the ADP (binder):ceramic powder ratio and concentration, as well as the chemistry of optical absorber additives, on the overall density and microstructure of CBPC composite coatings composed of $AlPO_4$ and $Al2O_3$.[17] Our aim was to optimize the chemical composition, especially the ADP to alumina ratio, and the absorbance of the ceramic layers at wavelengths of the xenon lamp (400–800 nm), which significantly affect the bonding mechanisms, microstructure, and mechanical properties of the final ceramic parts.

This work showed that the ADP (binder):ceramic powder ratio affects the microstructure, porosity, and conversion efficiency in CBPC composites. The optimal ratio appears to be near 55 vol.% ADP to achieve layers that do not crack and convert all the ADP to the $AlPO_4$ phase (Figure 6). It is possible to convert 100-μm-thick, blade-cast layers into CBPC composites with an FLA pulse within 20 seconds. However, the photothermal conversion efficiency can be further enhanced by adding optical light absorbers to these CBPC slurries, lowering the necessary photonic energy density by more than 30%, from 300 to 220 J/cm^2 (Figure 7).

Of the light absorber additives tested here, a molecular liquid black dye was most interesting because it easily mixed with the slurry and provided good photothermal energy conversion. Future opportunities exist to further engineer this system for functional coatings or even extend to layer-by-layer printing for additive manufacturing.

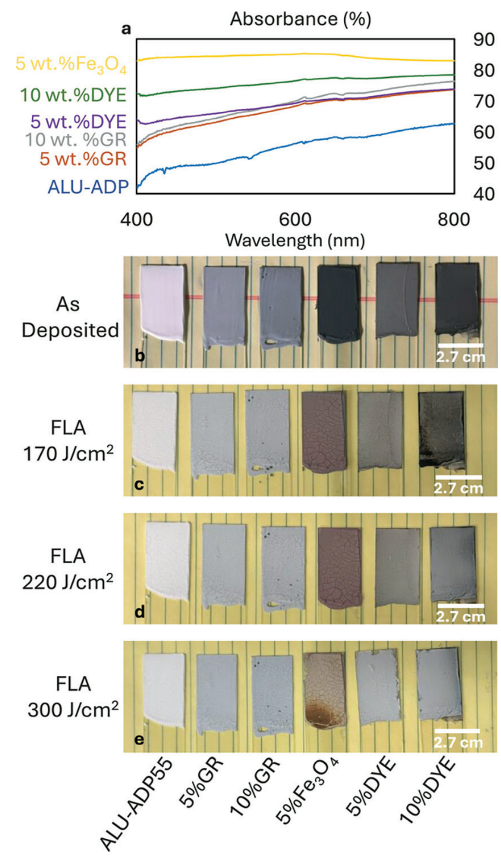
Perspectives for biomedical applications

Over the last two decades, the promise of patient-specific synthetic grafts for bone repair has been a strong driving force in the development of ceramic AM. Several bioceramics and bioactive glasses have been identified as suitable synthetic graft materials due to their biocompatibility, bioactivity and bioresorbability,[18] and efforts are underway to shape these materials



Credit: Özmen et al., *IJCES* (CC BY 4.0)

Figure 6. Cross-sectional scanning electron microscopy images of ADP–Al_2O_3 layers cured in a furnace at 400°C for two hours with ADP vol.% of (a) 50%, (b) 55%, (c) 60%, (d) 65%, (e) 70%, and (f) 75%. (g) Plotted change in porosity and cured layer thickness versus increasing ADP vol.%.[17]



Credit: Özmen et al., *IJCES* (CC BY 4.0)

Figure 7. (a) Absorbance spectra for as-cast ADP–Al_2O_3 layers without any optical absorbers (blue) and with 5 wt.% graphite (orange), 10 wt.% graphite (gray), 5 wt.% black iron oxide (yellow), 5 wt.% black liquid dye (purple), and 10 wt.% black liquid dye (green). (b–e) Photos of these same ADP55–Al_2O_3 layers without any optical absorber and with 5 and 10 wt.% graphite, 5 wt.% black iron oxide, and 5 and 10 wt.% dye.[17]

into complex architectures that interact with host cells to trigger a regenerative response, osteogenesis, and vascularization.[19,20]

However, translating the encouraging outcomes from academic research into the clinic remains a challenge: Worldwide, only three companies are currently commercializing ceramic 3D-printed implants.[21] As in traditional ceramic manufacturing, most ceramic AM processes still require long post-shaping thermal treatments at temperatures above 1,000°C. These treatments alter the physicochemical characteristics of the initial bioceramics and, therefore, their bioactivity and resorbability.

For example, bioresorption is usually faster for amorphous biomaterials than for crystallized ones. Ideally, the rate of bioresorbability of the implant should match the rate of tissue regeneration while keeping sufficient mechanical strength. Producing such gradually and fully resorbable bioceramic scaffolds with AM technologies is a challenge because the usual sintering treatments lead to high crystallinity of materials.

The tailored heating of each layer allowed by photonic curing could overcome these challenges with processing additively manufactured bioceramics and bioactive glasses.

The future of AM processing

Conventional sintering of additively manufactured multimaterial components can lead to structural defects such as distortion, cracks, and delaminations unless the selected materials have matching properties and can be sintered in the same temperature range and atmosphere. The new photonic curing approach developed at Georgia Tech could overcome these challenges, opening the door to the adoption of multimaterial AM in a broad range of potential applications in the biomedical field and beyond.

Acknowledgments

This research was supported by a grant from the U.S. Office of Naval Research (grant no. N00014-21-1-2258) under the direction of Antti Makinen. A portion of this work was also conducted in the Materials Innovation and Learning Laboratory, an open-access materials characterization facility supported by the School of Materials Science and Engineering and the College of Engineering at Georgia Tech. The flash lamp annealing equipment used in this study was purchased with an ONR-DURIP grant (grant no. N00014-23-1-2076).

About the authors

Nicolas Somers is postdoctoral researcher at the University of Liège, Belgium. Eren Özmen is postdoctoral researcher and Mark Losego is professor at Georgia Institute of Technology. Contact Losego at losego@gatech.edu.

References

[1]A. Zocca et al., "Additive manufacturing of ceramics: Issues, potentialities, and opportunities," *Journal of the American Ceramic Society* 2015, **98**(7): 1983–2001.

[2]K. Mallikarjuna et al., "Photonic drying/annealing: Effect of oven/visible light/infrared light/flash-lamp drying/annealing on WO_3 for electrochromic smart windows," *ACS Sustain Chem Eng* 2021, **9**(43): 14559–14568.

[3]M. Hösel, and F. C. Krebs, "Large-scale roll-to-roll photonic sintering of flexo printed silver nanoparticle electrodes," *J. Mater. Chem.* 2012, **22**(31): 15683–15688.

[4]M. Trzaskowska, V. Vivcharenko, and A. Przekora, "The impact of hydroxyapatite sintering temperature on its microstructural, mechanical, and biological properties," *International Journal of Molecular Sciences* 2023, **24**(6): 5083.

[5]Y. H. Son et al., "Application of flash-light sintering method to flexible inkjet printing using anti-oxidant copper nanoparticles," *Thin Solid Films* 2018, **656**: 61–67.

[6]E. B. Secor et al., "Rapid and versatile photonic annealing of graphene inks for flexible printed electronics," *Advanced Materials* 2015, **27**(42): 6683–6688.

[7]E. Gilshtein et al., "Millisecond photonic sintering of iron oxide doped alumina ceramic coatings," *Scientific Reports* 2021, **11**: 3536.

[8]L. Porz et al., "Blacklight sintering of ceramics," *Mater. Horiz.* 2022, **9**(6): 1717–1726.

[9]M. Scherer et al., "Blacklight sintering of $BaTiO_3$ ceramics," *J. Eur. Ceram. Soc.* 2023, **43**(12): 5406–5411.

[10]E. Gilshtein et al., "Photonic sintering of oxide ceramic films: Effect of colored Fe_xO_y nanoparticle pigments," *Ceramics* 2022, **5**(3): 351–361.

[11]A. S. Wagh, "Recent progress in chemically bonded phosphate ceramics," *ISRN Ceramics* 2013, **2013**: 983731.

[12]A. S. Wagh, "Chapter 2: Chemically bonded phosphate ceramics," in *Chemically Bonded Phosphate Ceramics* (2nd edition). Elsevier, 2016. pp. 17–34.

[13]S. Y. Jeong, and A. S. Wagh, "Cementing the gap between ceramics, cements, and polymers," *Materials Technology* 2003, **18**(3): 162–168.

[14]E. Özmen, N. Somers, and M. D. Losego, "Rapid, direct fabrication of thermochromic ceramic composite sensors via flash lamp annealing," *Adv. Eng. Mater.* 2024, **26**(11): 2400323.

[15]N. Somers, E. Özmen, and M. D. Losego, "Hydrothermal treatment of alumina powders to alter the low-temperature binding of chemically bonded phosphate ceramic composites via infrared irradiation," *J. Mater. Sci.* 2024, **59**: 4089–4101.

[16]N. Somers et al., "Infrared irradiation to drive phosphate condensation as a route to direct additive manufacturing of oxide ceramics," *Journal of the American Ceramic Society* 2023, **107**(1): 36–46.

[17]E. Özmen and M. D. Losego, "Effects of the concentration of inorganic binders and optical absorbers on the phase formation and microstructure of flash-lamp-annealed chemically bonded phosphate ceramic composites," *International Journal of Ceramic Engineering & Science* 2025, **7**(4): e70019.

[18]H. Qu et al., "Biomaterials for bone tissue engineering scaffolds: A review," *RSC Adv* 2019, **9**(45): 26252–26262.

[19]D. Han, and H. Lee, "Recent advances in multi-material additive manufacturing: methods and applications," *Current Opinion in Chemical Engineering* 2020, **28**: 158–166.

[20]T. Moritz and S. Maleksaeedi, "Chapter 4: Additive manufacturing of ceramic components," in *Additive Manufacturing: Materials, Processes, Quantifications and Applications*. Elsevier, 2018. pp. 105–161.

[21]P. Chocholata, V. Kulda, and V. Babuska, "Fabrication of scaffolds for bone-tissue regeneration," *Materials* 2019, **12**(4): 568. ■


The American Ceramic Society
ceramics.org
ACerS SPRING MEETING
APRIL 12–16, 2026
HYATT REGENCY BELLEVUE
ON SEATTLE'S EASTSIDE
BELLEVUE, WASH., USA

Understanding the dispersion behavior of nonaqueous mediums

By Keith J. DeCarlo and William M. Carty

Credit: Shutterstock

Water has been an integral component of ceramics processing for millennia, imparting clay with just the right plasticity to be coiled, pinched, thrown, and rolled into traditional pottery forms.

With the emergence of new advanced ceramic materials and technologies, however, commercial processing of ceramics using nonaqueous mediums is becoming more common. This trend is driven by drawbacks associated with processing in water, including the tendency of water to chemically react with certain powders, the inability to dissolve specific (i.e., nonpolar) additives, and the medium's volatility (i.e., evaporation over time).[1,2]

In this article, we will explore the current mediums used for nonaqueous suspension processing and identify gaps in knowledge involving the dispersion mechanisms of these various mixtures.

Nonaqueous suspension mediums: Common materials and ambiguous mechanisms

Nonaqueous suspension mediums are traditionally used in tape casting,[1,2] a processing method with roots in the early 20th century used to create thin, uniform layers of materials. But these mediums are finding increasing use in ceramic additive manufacturing techniques as well, such as stereolithography.

In many cases, multiple organic mediums are mixed to control the volatility of the bulk suspending medium and prevent extremely fast evaporation, which can result in a hard shell developing during drying.[1,3] The organic mediums must be miscible (able to form a homogeneous mixture) and are sometimes azeotropic, i.e., the composition of the evaporative vapor has the same composition as the liquid mixture, thus preventing preferential evaporation.

Manufacturers know that the type of mixture will affect the suspension and drying properties, but it is currently unclear how the medium mixture affects the rheological properties

Table 1. Nonaqueous systems that are frequently used in ceramics processing, as found in References 1–12.

Medium(s)	Corresponding powder system
Acetone	Various
Benzene	Various
Butanol/Isopropanol/Xylenes/Nitropropane	Various
Ethanol	Al_2O_3, $BaTiO_3$
2-butanone (MEK)	Various
MEK/Anhydrous ethanol	Various
MEK/95% Ethanol	Various titanates
MEK/Methanol	Various
MEK/Methanol/Butanol	Glass-ceramics
MEK/Acetone	Al_2O_3-SiO_2-B_2O_3
MEK/Toluene	Glass-ceramics
1,1,1 trichloroethane (TCE)	MgO
TCE/95% ethanol	Al_2O_3
Toluene	Various
Toluene/95% ethanol	Various
Toluene/Methanol	$BaTiO_3$
Xylenes/Anhydrous ethanol	Al_2O_3

of the colloidal suspension and, subsequently, the properties of the final product.[1,4] Many nonaqueous suspension systems have been tested, with the most common mediums including ethanol and 2-butanone (Table 1).[1–12]

Although several industries utilize nonaqueous processing techniques, our ability to predict colloidal suspension stability remains limited. This lack of knowledge is due in part to many companies keeping their specific mixtures a trade secret, so it is unknown which additives are commonly introduced to induce dispersion. Some of the dispersants that are known to have been proposed and tested for nonaqueous systems are given in Table 2.[2,5,10–13] A consensus on the dispersion mechanism has not been reached, and it is speculated that both steric (separation of the colloids using a physical barrier) and electrostatic mechanisms may be operative.[1]

Table 2. Frequently used dispersants in nonaqueous processing, as found in References 2, 5, and 10–13.

Dispersant
Benzene sulfonic acid
Dibutyl amine
Ethoxylates
Glycerol trioleate
Menhaden fish oil
Phosphate esters
Triglycerides

Determining colloidal stability in nonaqueous mediums

DLVO theory

The first step to understanding the dispersion behavior of nonaqueous suspensions is to evaluate the validity of the Derjaguin–Landau–Verwey–Overbeek (DLVO) theory, which models the electrostatic interactions between colloidal particles (i.e., particles that are small enough that thermal forces dominate over gravitational forces). This theory was first developed in 1941 by Derjaguin and Landau, and then in 1948, Verwey and Overbeek independently arrived at the same result.[14,15]

DLVO theory models the total interaction potential between two colloidal particles as a function of separation distance by balancing the repulsive and attractive forces acting upon those particles. The repulsive force is created by interacting electrical double layers, formed due to surface interactions of the colloid with the medium. The attractive potential between colloidal particles, i.e., the van der Waals attractive force, forms due to dipole interactions.

Difficulties in solving the DLVO equations have resulted in the use of a "shortcut," which involves researchers only considering the repulsive force or the attractive force to predict colloidal stability. To further simplify the equations, the values that correlate to these forces are approximated.

For example, ζ-potential, which correlates solely to the repulsive force in DLVO theory, has been commonly used as the benchmark to predict dispersion, with a large measured ζ-potential resulting in dispersion. This assumption even led to an ASTM standard (now abandoned) that defined the minimum ζ-potential needed for dispersion.[16] However, while the ASTM standard was applicable to some aqueous systems, some nonaqueous mediums with large measured ζ-potential values did not result in dispersion.

Similarly, the Pugh approximation is commonly used to quickly estimate the Hamaker constant, which correlates solely to the attractive force in DLVO theory. The Pugh approximation only requires the relative static permittivity of the components rather than a complete dielectric dispersion representation of the species,[17] significantly reducing both the data required to calculate the Hamaker constant and the time to perform the calculation. While this approximation works well for colloidal particles suspended in an aqueous medium, it has differing results when applied to colloids suspended in nonaqueous mediums.

Based on these unreliable results, various research groups proposed that DLVO theory is invalid for nonaqueous mediums. However, we hypothesized that the problem may lay with the approximated values—if force values are calculated directly, it may still be possible to use the "shortcut" (consider only repulsive or attractive forces) to accurately predict the dispersion behavior of nonaqueous mediums. We explored this hypothesis by calculating the Hamaker constant as the sole predictor of colloidal stability in nonaqueous mediums.

Measured Hamaker constants in nonaqueous mediums

As stated earlier, the Hamaker constant is a physical constant that directly correlates to the attractive potential between colloids in a specific medium. We calculated Hamaker constants for a variety of alumina/medium pairs using the Lifshitz equation with the Ninham-Parsegian dielectric dispersion oscillator model to test the applicability of using the "shortcut" DLVO theory to determine the viscosity of alumina suspensions.[18–20]

For calculation of the Hamaker constants, the complex permittivity on a real frequency basis from zero to infinity for alumina and the suspending medium must be known.[18] Unfortunately, the permittivity information required is not readily available for either alumina or the suspension mediums; therefore, a method developed by Ninham and Parsegian was utilized to deduce the characteristic absorption frequencies and strengths. This treatment models the complex permittivity using a Debye relaxation for the microwave region and a Lorentz electron dispersion term for infrared through ultraviolet regions of the electromagnetic spectrum.[8]

The results of the Hamaker constant calculations are reported in Table 3. Polyethylene glycol 200 (PEG 200) had the lowest Hamaker constant, meaning it would induce the smallest attractive potential between alumina particles compared to the other suspension mediums, including water. It is assumed that a larger Hamaker constant would mean greater attractive forces and thus higher suspension viscosity. To confirm this assumption, we measured the viscosity of alumina suspended in the various nonaqueous mediums.

Table 3. Calculated Hamaker constants for alumina powders in various mediums at 298 K.

Suspending medium	Hamaker constant (10^{-20} J at 298 K)
Polyethylene glycol (PEG) 200	2.63
Octanoic acid	3.30
2-Butanone (MEK)	3.72
Water	3.75
Ethanol	4.06
Toluene	4.13
Heptane	4.14
Isopropanol (IPA)	4.29
Sec-Butanol	4.43
Methanol	4.53
Acetone	4.72
Vacuum or air	15.3

Viscosity measurements

The viscosity of alumina suspended in each of the dozen nonaqueous mediums was measured using a strain-controlled ARES-RFS rheometer with parallel plate geometry (nominal gap of approximately 10^3 times larger than the particle size). Each suspension prepared had a total volume of 30 mL and was 20 vol.% solids. Prior to the measurement, each suspension was ultrasonicated for one minute while submerged in an ice bath to reduce vaporization of the solvent.

Each viscosity measurement required 10 mL of suspension, which was taken from the bulk suspension after ultrasonication. A shear-rate sweep starting at 10 s^{-1} to 0.1 s^{-1} was used with a pre-shear step of three seconds at 10 s^{-1}. The measurement time varied based on the time to reach a steady-state viscosity, and the geometry of the plates varied based on the viscosity of the suspension being tested. For low-viscosity suspensions, a 50 mm plate was used; for high-viscosity suspensions, a 25 mm plate was used. A temperature of 298 K was maintained using a Peltier heater and water bath. The resulting data was analyzed using instrument software and a spreadsheet.

Because the viscosity of the suspension mediums varied widely over several orders of magnitude, specific viscosity was used to describe the suspension viscosity rather than just the measured viscosity; this decision allowed all suspensions to be evaluated on an equivalent basis. Specific viscosity is defined as:

$$\eta_{specific} = \frac{\eta_{1.0}}{\eta_{medium}} \quad (1)$$

where η_{medium} is the intrinsic viscosity of the suspending medium and $\eta_{1.0}$ is the viscosity of the suspension at 1.0 s^{-1}.

The viscosity of all suspending mediums tested can be described as Newtonian (i.e., shear-rate independent). Based on previous research,[21] the specific viscosity stability cutoff value was defined as 1.1×10^4, with suspensions possessing values below this cutoff defined as stable (Table 4).

Table 4. Specific viscosity at a shear rate of 1.0 s^{-1} for each suspension tested. Italics indicate stable suspensions, as defined based on Reference 21.

Suspending medium	Specific viscosity ($\times 10^3$)
Poly(ethylene glycol) 200	*0.48*
Sec-Butanol	*9.5*
Isopropanol (IPA)	*31*
Octanoic acid	*37*
Ethanol	*88*
Water	140
Methanol	160
Heptane	310
Toluene	740
2-Butanone (MEK)	760
Acetone	5,500

Previous work has demonstrated that steric effects become significant when molecules in the suspension have a chain length that equals or exceeds that of six carbon atoms, and steric effects becomes the primary dispersion mechanism for molecules with a chain length greater than 11 carbon atoms.[22,23]

The PEG 200, octanoic acid, and heptane mediums tested exceed the determined critical chain length, and therefore dispersion cannot be considered as purely electrostatic in nature. However, in the case of octanoic acid and heptane, the primary mechanism is still electrostatic. Meanwhile, the chain length of PEG 200 exceeds 11 atoms, resulting in steric effects being the primary mechanism for PEG 200.

Toluene was not included in the group of mediums in which steric effects become significant because it is an aromatic compound. Because it is aromatic, the molecule is shorter than the aliphatic analogue (heptane) and therefore does not exceed the predicted critical molecule length.

Determining the stabilizing mechanisms

We empirically determined that the specific viscosity of the suspension, as a function of the shear thinning exponent, can be used to determine the stabilizing mechanism.

Figure 1 demonstrates that within 95% confidence, almost all suspension mediums follow a trend. It is hypothesized that the significant dispersion mechanism for the mediums within the 95% confidence band of the trend line is an electrostatic mechanism; mediums that fall outside the defined electrostatic band are hypothesized to include other significant forces that are not electrostatic in nature.

These hypotheses are backed by the science explained in the previous section. For example, toluene falls within the 95% confidence band, which suggests it does not demonstrate any stabilization mechanisms other than electrostatic forces. This finding matches with the fact that toluene has a shorter molecular chain length. Meanwhile, heptane and octanoic acid, which have longer chain lengths, are found just outside the electrostatic band, demonstrating that forces from other stabilization mechanisms are significant. PEG 200, which has the longest chain length, is found the farthest outside the electrostatic band, suggesting that for this material, the primary mechanism for dispersion is not electrostatic.

Eliminating the suspending mediums that are not 100% electrostatic—and comparing the results to the Hamaker constant calculations—demonstrated there is poor correlation between suspension stability and the Hamaker constant alone (Figure 2). This finding indicates that when comparing different suspending mediums and the same colloid—in this case, alumina—both the attractive and repulsive forces in DLVO theory must be considered.

The future of nonaqueous medium modeling

This study indicates that only evaluating the attractive force in DLVO theory is not sufficient to predict suspension stability in nonaqueous mediums, even when the forces are calculated directly rather than approximated. You must also assess the repulsive force that develops due to double layer interaction and then combine the attractive and repulsive potentials to improve the accuracy of the predictions and the validity of DLVO.

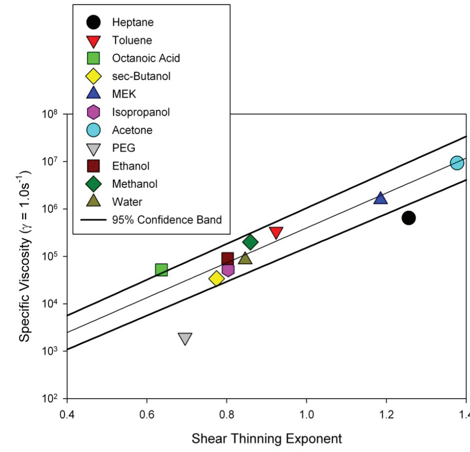


Figure 1. Trend line of specific viscosity as a function of the shear thinning exponent. It was determined that the dispersion mechanism of a given suspension is electrostatic when it falls within the 95% confidence band of the master curve; other mechanisms besides electrostatic are active when values fall outside the band.

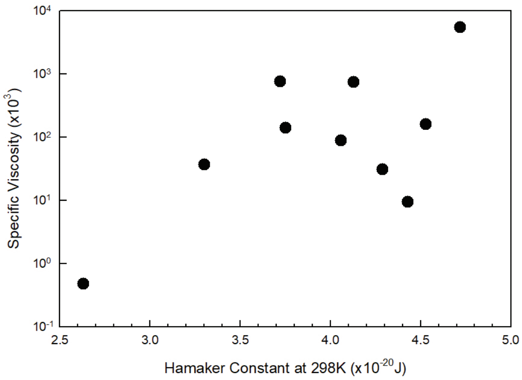


Figure 2. Comparison of the calculated Hamaker constant at 298 K with the measured specific viscosity (×10³) at a shear rate of 1.0 s⁻¹ for each suspension tested.

Furthermore, this study showed that the suspension stabilization mechanism in nonaqueous mediums can be ascertained by viscosity measurements. Comparison of the specific viscosity with the shear thinning exponent at a shear rate of 1.0 s^{-1} reveals a trend that develops for suspensions in which the only significant dispersion mechanism is an electrostatic mechanism. When other stabilization mechanisms, such as electrosteric or steric mechanisms, are no longer negligible, the parameters of the suspension no longer follow the trend line.

Based on the master curve of specific viscosity versus the shear thinning exponent, it was determined that the primary dispersion mechanism of methanol, ethanol, isopropanol, sec-butanol, acetone, 2-butanone, toluene, and water is an electrostatic mechanism. The primary dispersion mechanism of heptane and ocatanoic acid was determined to be a combination of electrostatic and other dispersion mechanisms, based on the fact that the points on the master curve fell just outside the 95% confidence interval. PEG 200 was determined to have a primary dispersion mechanism other than an electrostatic mechanism based upon the master curve.

The master curve for dispersion developed in this study is consistent with the literature and can be used to judge the applicability of DLVO theory for a given suspension medium, provided the medium is composed of molecules of sufficiently short length.

About the authors

Keith J. DeCarlo is executive vice president of technology and operations at Blasch Precision Ceramics (Menands, N.Y.). Contact DeCarlo at KDecarlo@blaschceramics.com.

William M. Carty is Professor Emeritus of ceramic engineering at the New York State College of Ceramics at Alfred University. He is now a consultant to the ceramic industry and chief technology officer of Materials Research Furnaces (Allenstown, N.H.).

References

[1]R. E. Mistler and E. R. Twiname, *Tape Casting: Theory and Practice*. The American Ceramic Society, 2000. p. 298.

[2]R. E. Mistler, D. J. Shanefield, and R. B. Runk, "*Tape casting of ceramics*," in Ceramic Processing Before Firing. John Wiley & Sons, 1978. pp. 411–448.

[3]M. N. Rahaman, *Ceramic Processing and Sintering* (2nd edition). Marcel Dekker, 2003. p. 875.

[4]S. Bhattacharjee, M. K. Paria, and H. S. Maiti, "Polyvinyl butyral as a dispersant for barium titanate in a non-aqueous suspension," *J. Mater. Sci.* 1993, **28**(23): 6490–6495.

[5]J.-C. Lin, T.-S. Yeh, C.-L. Cherng, and C.-M. Wang, "The effects of solvents and binders on the properties of tape casting slurries and green tapes," in *Ceramic Transactions, Vol. 26: Forming Science and Technology for Ceramics*. The American Ceramic Society, 1992. pp. 197–204.

[6]U. Paik, V. A. Hackley, S.-C. Choi, and Y.-G. Jung, "The effect of electrostatic repulsive forces on the stability of $BaTiO_3$ particles suspended in non-aqueous media," *Colloids Surf. A: Physicochem. Eng. Aspects* 1998, **135**(1–3): 77–88.

[7]Y. Chen et al., "The dispersion behavior of Si–C–N nanopowders in organic liquids," *Ceram. Int.* 2001, **27**(1): 73–79.

[8]Y. Hirata and M. Kawabata, "Dispersion and consolidation of ultrafine $BaTiO_3$ powder in non-aqueous solutions," *Mater. Lett.* 1993, **16**(4): 175–180.

[9]J. S. Reed, *Principles of Ceramics Processing*. John Wiley & Sons, 1995. p. 658.

[10]F. Boschini, A. Rulmont, R. Cloots, and R. Moreno, "Rheological behaviour of $BaZrO_3$ suspensions in non-aqueous media," *Ceram. Int.* 2009, **35**(3): 1007–1013.

[11]K. Mikeska and W. R. Cannon, "Dispersants for tape casting pure barium titanate," in *Advances in Ceramics, Vol. 9: Forming of Ceramics*. The American Ceramic Society, 1984. pp. 164–183.

[12]P. D. Calvert, E. S. Tormey, and R. L. Pober, "Fish oil and triglycerides as dispersants for alumina," *Am. Ceram. Soc. Bull.* 1986, **65**(4): 669–672.

[13]W. R. Cannon, R. Becker, and K. R. Mikeska, "Interactions among organic additives used for tapecasting," in *Advances in Ceramics, Vol. 26: Ceramic Substrates and Packages for Electronic Applications*. The American Ceramic Society, 1989. pp. 525–541.

[14]B. Derjaguin and L. Landau, "Theory of the stability of strongly charged lyophobic sols and of the adhesion of strongly charged particles in solutions of electrolytes," *Acta Physicochimica U.R.S.S.* 1941, **14**: 633–662.

[15]E. J. W. Verwey and J. T. G. Overbeek, *Theory of the stability of lyophobic colloids*. Dover Publications, 1999. p. 205.

[16]"ASTM Standard D4187: Methods of test for zeta potential of colloids in water and waste Water," ASTM International. Published 1982, withdrawn 1990. https://standards.globalspec.com/std/3801843/astm-d4187-82

[17]R. J. Pugh, "Dispersion and stability of ceramic powders in liquids," in *Surface and Colloid Chemistry in Advanced Ceramics Processing*. Marcel Dekker, 1994. pp. 127–192.

[18]L. Bergström, "Hamaker constants of inorganic materials," *Adv. Colloid Interface Sci.* 1997, **70**: 125–169.

[19]B. W. Ninham and V. A. Parsegian, "van der Waals forces across triple-layer films," *J. Chem. Phys.* 1970, **52**(9): 4578–4587.

[20]B. W. Ninham and V. A. Parsegian, "van der Waals forces: Special characteristics in lipid–water systems and a general method of calculation based on the Lifshitz theory," *Biophysical Journal* 1970, **10**(7): 646–663.

[21]B. R. Sundlof, "Aqueous processing of alumina and phase behavior of polymeric additives," Ph.D. thesis, Alfred University, 1999.

[22]B. I. Lee and J. P. Rives, "Dispersion of alumina powders in non-aqueous media," *Colloids and Surfaces* 1991, **56**: 25–43.

[23]P. D. Calvert et al., "Dispersion of ceramic particles in organic liquids," in *Better Ceramics Through Chemistry II. Materials Research Society*, 1986. pp. 579–84. ■

Bulletin | Application note

Pushing the boundaries: Internally threaded post-fired ceramics

By Scott Mittl

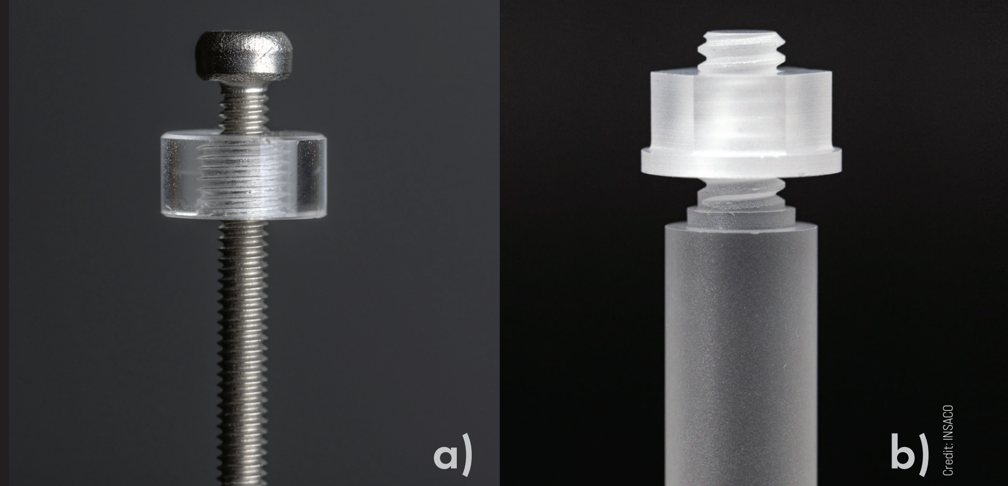


Figure 1. Example of a) ¼–20 thread and b) M2 × 0.4 mm thread in sapphire.

For decades, engineers and designers have faced a persistent challenge: how to reliably join components made from post-fired ceramic materials.

Traditional fastening methods for these materials often require external clamps, brazed fittings, or adhesive bonding. Not only do these approaches increase assembly complexity and take up more physical space, they also introduce points of failure that can reduce reliability under stress. For example, in high-temperature or chemically aggressive environments, joints can degrade, seals can leak, and performance can suffer—often with critical consequences in aerospace, medical, and industrial applications.

In December 2024, we at precision machining company INSACO (Quakertown, Pa.) shared a breakthrough announcement: Our team had developed a proprietary technique that allows us to machine internal threads directly into post-fired ceramic components. This innovation opens entirely new design possibilities for engineers who work with advanced ceramics.

Why threading matters in ceramics

Internal threads may seem like a simple feature, but in ceramics, they represent a major leap forward. By machining internal threads, designers can now create more compact, precise, and integrated ceramic assemblies, improving both function and form. This capability allows for high-precision location and mechanical fastening without accruing the disadvantages mentioned above.

The innovation behind the process

Our internal threading capability is the result of a proprietary blend of materials science, tooling design, and decades of experience machining some of the hardest materials on Earth. Because the highly controlled, precision process works post-firing, after the ceramic component has been sintered and hardened, it preserves the material's full mechanical, electrical, and thermal properties without compromise.

So far, we have used this technique to successfully introduce internal threads into a range of ceramics including sapphire (Figure 1), alumina, zirconia, and silicon carbide, as well as the glass-ceramic Zerodur®. While specific measurements on possible thread classes are in the works, standard off-the-shelf bolts and nuts will fit these threads.

Real-world applications

Numerous sectors can benefit from this internal threading capability:

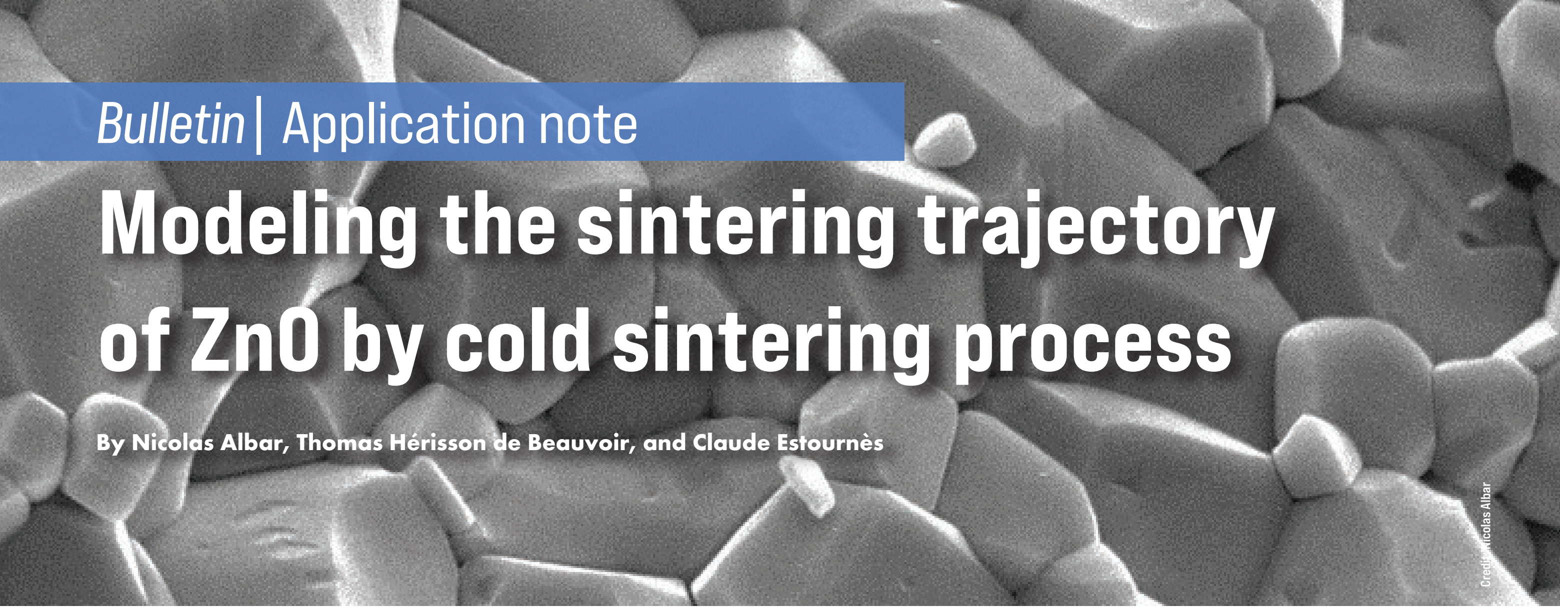
- **Aerospace and defense**: Internally threaded ceramic parts allow for secure mechanical joins without introducing materials that degrade in space.
- **Medical devices**: Being able to mechanically join parts without adhesives or metal inserts allows for cleaner, safer, and more reliable medical-grade ceramic assemblies.
- **Semiconductors and energy**: These stronger, more compact ceramic connections can hold up to harsh chemical or high-heat environments, which are common in semiconductor fabrication or nuclear reactors.

The business case for niche innovation

This new threading capability will not replace every fastening method—projects or applications that require the tensile strength of metal would not be an ideal use of this technique. But in the sectors where it matters, internally threaded ceramics are a game-changer, eliminating the need for metallization, reducing component size, and increasing mechanical integrity.

About the author

Scott Mittl is vice president of sales at INSACO (Quakertown, Pa.), a company founded in 1947 that specializes in precision machining and fabrication of advanced ceramics and optical-grade glass. Contact Mittl at sales@insaco.com. ■



Bulletin | Application note

Modeling the sintering trajectory of ZnO by cold sintering process

By Nicolas Albar, Thomas Hérisson de Beauvoir, and Claude Estournès

Scanning electron microscope image of the microstructure of zinc oxide sintered by the cold sintering process at 250°C.

Sintering ceramics at lower temperatures has been an important objective pursued for decades due to potential economic (e.g., reduced energy consumption) and material (e.g., finer microstructures) benefits.

Among the techniques explored for this purpose, the cold sintering process (CSP) introduced by Guo et al.[1] has proved incredibly efficient over a wide range of materials, including ceramics, polymers, metals, and also new composite systems.[2]

CSP uses a transient liquid phase and external pressure to activate densifying mechanisms, which allow the consolidation of the materials at relatively lower temperatures than traditional sintering processes. The simplicity of the CSP experimental setup belies the numerous mechanisms that occur during low-temperature sintering (Figure 1): rearrangement of grains, dissolution of atoms at the beginning of sintering, diffusion of matter toward the pores/reprecipitation, and finally grain growth.

Traditionally, heating during CSP is accomplished via a heating jacket wrapped around the sintering die. This setup allows heat to flow radially from the heating elements through the die and into the sample.

As an alternative to the jacket heating method, a spark plasma sintering (SPS) setup can be used for CSP. In this case, the sample is heated by passing electric current through the mold, which is made from a material more conducting than the sample by several orders of magnitude.

Using the SPS setup comes with several benefits. For one, it allows for faster temperature ramps (up to 100°C/min) than heating with the heating jacket (around 20°C/min). In addition, an integrated dilatometer can be used to measure the displacement of the die punches, which relates to the shrinkage of the sample over time. By combining this information with the measured gas pressure in the SPS chamber during sintering, it is possible to observe the degassing of the liquid phase that could not be observed in air by conventional CSP.

In a previous study using the CPS–SPS method, it was found that the activation energy required to initiate the densification process was reduced by a factor of four compared to traditional SPS processing (297 kJ/mol to 70 kJ/mol).[3] However, a rigorous mathematical model describing the underlying mechanisms of this alternative heating process does not yet exist.

In two recent open-access studies,[4,5] we aimed to develop an analytic densification and grain growth model to predict the sintering trajectory of a ZnO powder using the CSP–SPS process.

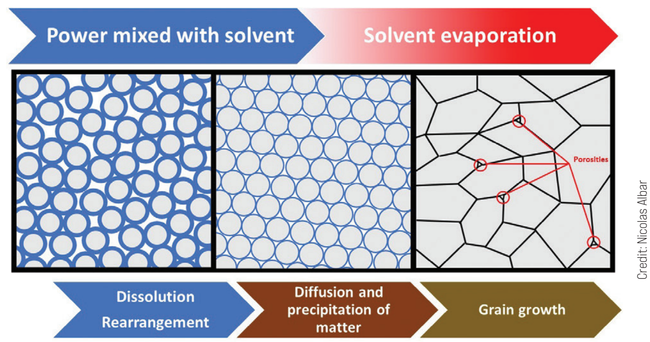


Figure 1. A visual representation of the different stages of the cold sintering process.

Master Sintering Curve: A practical approach to modeling sintering

The diffusion-based processes that contribute to the densification of matter are thermally activated and therefore follow an Arrhenius-type law, characterized by an activation energy (Q). Knowing the activation energy of the diffusion processes during CSP allows the densification kinetics to be predicted as temperature increases, and then these kinetics can be associated with various diffusion mechanisms (e.g., lattice, surface, or grain boundary diffusion).

These activation energies can be determined using kinetic models, such as the Master Sintering Curve (MSC) method. This straightforward method, introduced by Su and Johnson,[6] requires three experiments to be carried out with different heating rates. By analyzing the densification curves obtained at these different rates, it is possible to determine the value of Q for the dominant densification mechanism in the desired density range.

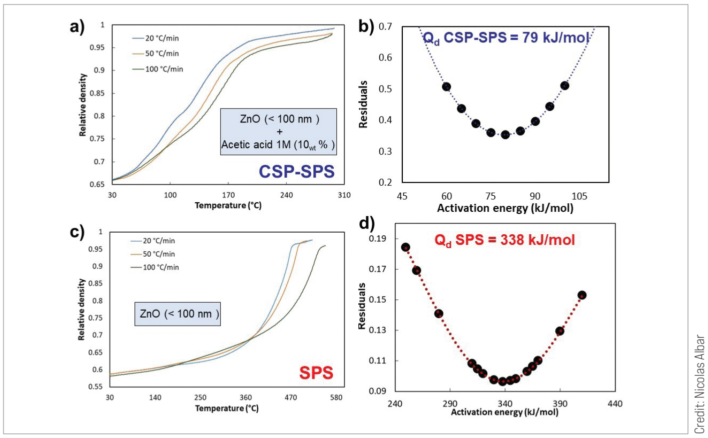


Figure 2. Densification curves plotted at different heating rates in the case of a) CSP–SPS and c) SPS. Mean residual calculations are performed between 70% and 90% of relative density to minimize the difference between the curves for b) CSP-SPS and d) SPS. Adapted from References 4 and 5.

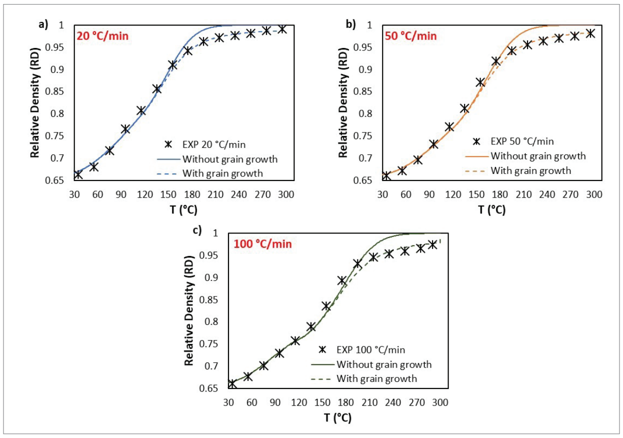


Figure 3. Simulated relative density curves as a function of temperature, with and without grain growth, plotted alongside experimental curves at temperature ramps of a) 20°C/min, b) 50°C/min, and c) 100°C/min. Adapted from Reference 5.

MSC-derived activation energies in CSP–SPS

Figure 2 shows the application of the MSC model to a commercial ZnO powder sintered via two methods: a) CSP–SPS with an addition of 10 wt.% acetic acid and b) conventional SPS (dry powder, no liquid phase). Sintering via CSP–SPS was accomplished in a temperature range that is 250°C lower than the range required for traditional SPS.

With this data, we used the MSC method to determine an activation energy of 79 kJ/mol for CSP–SPS and 338 kJ/mol for SPS for samples between 70% and 90% of relative density.[4] However, elimination of the liquid phase at around 115°C results in a transition of the densification mechanisms. So, we also determined the activation energies in two distinct regimes below and above the 115°C threshold with relative densities of 70–75% and 80–85%, respectively.

The activation energies for these two temperature regimes were 90 kJ/mol (below threshold) and 80 kJ/mol (above threshold). These results suggest that the activation energy measured over the 70% to 90% relative density range was underestimated because it did not account for the different densification mechanisms.

Modeling CSP–SPS densification mechanisms

Using the MSC-derived activation energies, we plugged these values into the Skorohod-Olevsky model,[7] a continuum mechanics-based model used to simulate the sintering process of materials, to describe the sintering kinetics of the CSP–SPS process under load.[5] Our final model successfully took into account the different densifying mechanisms above and below the threshold temperature as well as two phenomena that slow densification: pressure caused by swelling of the liquid phase and grain growth during the last stages.

Figure 3 shows that the simulated curves match well with the experimental curves for the temperature ramps between 20°C/min and 100°C/min. The simulated curves account for the change in activation energy as well as the grain growth at high densities.

Conclusions

Through this work we have shown that the kinetic models used for sintering under load can be adapted to sintering by CSP–SPS. By accounting for the presence of a liquid phase during the first stage of sintering, we successfully modeled the effects of swelling pressure on the densification process and described two distinct regimes with two activation energies. The possibility of simulating the sintering curves and predicting the microstructures makes it possible to optimize the sintering conditions of CSP–SPS, which will allow for the production of samples with desired microstructures.

Acknowledgments

The authors wish to thank Charles Manière, Emeric Sanchez, Geoffroy Chevallier, and Alicia Weibel for their involvement in this work.

About the authors

Nicolas Albar is a Ph.D. student at Université de Toulouse in France. Thomas Hérisson de Beauvoir is research fellow and Claude Estournès is research director at the National Center for Scientific Research in France. All three work together in the Interuniversity Center for Materials Research and Engineering at Université de Toulouse. Contact Albar at nicolas.albar@univ-tlse3.fr.

References

[1]J. Guo et al., "Cold sintering: A paradigm shift for processing and integration of ceramics," *Angew Chem. Int. Ed.* 2016, **55**(38): 11457–11461.

[2]J. Guo et al., "Cold sintering: Progress, challenges, and future opportunities," *Annu. Rev. Mater. Res.* 2019, **49**: 275–295.

[3]J. Liang et al., "Microstructural evolution of ZnO via hybrid cold sintering/spark plasma sintering," *J. Eur. Ceram. Soc.* 2022, **42**(13): 5738–5746.

[4]N. Albar et al., "Master sintering curve analysis of ZnO densified by cold sintering process," *Open Ceramics* 2024, **18**: 100593.

[5]N. Albar et al., "Modeling the sintering trajectory of ZnO by cold sintering process," *Acta Mater.* 2025, **290**: 120974.

[6]H. Su and D.L. Johnson, "Master Sintering Curve: A practical approach to sintering," *J. Am. Ceram. Soc.* 1996, **79**(12): 3211–3217.

[7]C. Manière et al., "Spark plasma sintering grain growth assessment by densification kinetics analysis," *Scr. Mater.* 2023, **228**: 115346.

*All references verified as of July 14, 2025. ■

Vacuum and controlled atmosphere furnaces for hypersonics and other next-generation aerospace materials

Rendering of a hypersonic air-breathing weapon concept vehicle in flight

By Scott K. Robinson

Hypersonic missiles and vehicles are an emerging class of aerospace technology that is developing rapidly toward active use in military and potentially commercial applications.

These machines can achieve sustained speeds of Mach 5 or greater within the Earth's atmosphere, i.e., at altitudes below about 90 km. While conventional intercontinental ballistic missiles can also achieve hypersonic speeds during atmospheric reentry, they follow a high-arching ballistic trajectory with limited maneuverability, in contrast to the real-time in-flight maneuverability offered by hypersonic systems. As such, hypersonic missiles are preferrable for precision strikes,[1] while in the commercial realm, airliners are excited by the possibility of drastically shortened journey durations with hypersonic vehicles.[2]

Because hypersonic missiles and vehicles move at extreme speeds within the Earth's atmosphere, they are subject to significant atmospheric compression and friction effects.[3] These effects result in considerable aerodynamic heating of the leading edges, nose tips, and exhaust-washed structures, from 1,800°C to more than 3,000°C (3,200°F to 5,400°F).

Traditional aerospace materials such as aluminum, stainless steel, and titanium cannot be used at these elevated temperatures without thermal protection engineering. In contrast, an emerging portfolio of materials including refractory metals, carbon–carbon composites, ultrahigh-temperature ceramics (UHTCs), and ceramic matrix composites (CMCs) can more easily deal with this extreme heat.

UHTCs and CMC materials typically are composed of metal carbides, borides, and nitrides, which means they are traditionally processed at very high temperatures. Currently, the leading candidate materials are silicon carbide (melting/decomposition point: 2,730°C)[4] and zirconium diboride (melting point: ~3,246°C)[5] due in part to their reasonable raw material costs.

Processing of UHTCs, CMCs, and other advanced materials for aerospace applications includes one or more of the following high-temperature processing steps, often using vacuum and controlled atmosphere furnace technology:

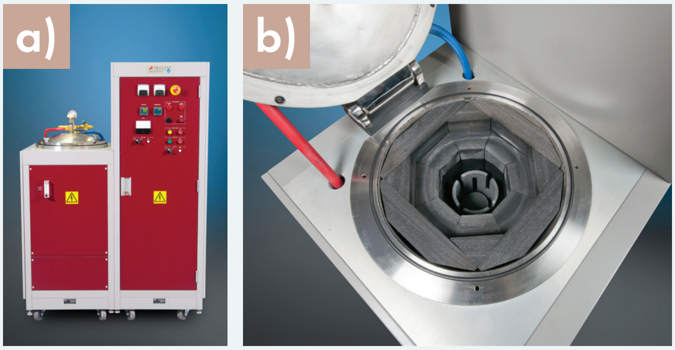
- Chemical vapor infiltration
- Chemical vapor deposition
- High-temperature sintering
- Graphitization
- Silicon melt infiltration of carbon–carbon composites

Each stage of the product development cycle—from laboratory-scale research and development to prototype development to production-scale manufacturing—requires a portfolio of specialized furnaces to achieve the goals of each stage.

This article takes a closer look at the types of furnace solutions available to develop, process, and commercialize these high-performance materials, with examples pulled from the product offerings of furnace manufacturer Centorr Vacuum Industries (Nashua, N.H.).

Laboratory-scale research and development

Laboratory-scale R&D activities focus mostly around the development, fabrication, and testing of small-scale parts, which requires a small, adaptable furnace.



Credit: Centorr Vacuum Industries

Figure 1. a) LF 3,000°C graphite vacuum furnace and b) top view of hot zone.

Credit: Centorr Vacuum Industries

Figure 2. Series 10 3,000°C graphite tube furnace.

A furnace design to answer this need is the LF graphite vacuum furnace (Figure 1). First designed in 2012, the LF is a robust, low-cost development furnace with temperature capability up to 3,000°C in vacuum or inert gas. This temperature range covers most hypersonic, UHTC, and other applications. For example, some current customers fit the small 3" (75 mm) diameter × 4" (100 mm) height hot zone with small graphite crucibles to fire graphite-based powders for applications in battery and electric vehicle technology.

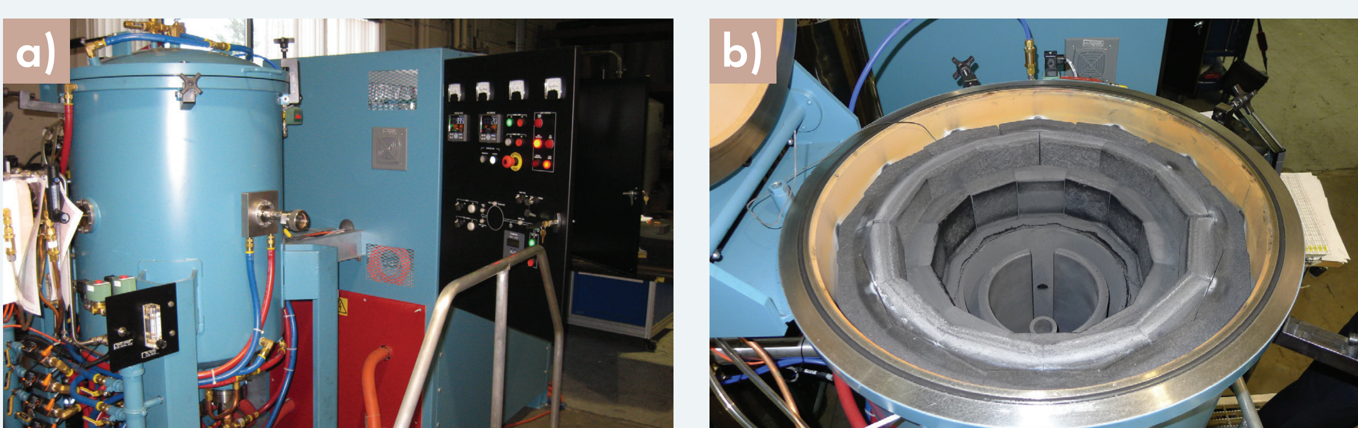
Research-based universities such as Dalhousie University in Nova Scotia, Canada, modified the base LF system by adding a small binder/off-gassing trap and positive pressure exhaust tower for processing of nonoxide ceramics produced by additive manufacturing. These samples include silicon-based ceramics (silicon carbide and silicon nitride), high-entropy ceramics, and cermet systems.

Subsequent laboratory applications require a larger hot zone furnace for processing bigger samples, and the Series 10 graphite tube furnace is an economical choice (Figure 2). This tube furnace, which has a hot zone of 4" (100 mm) diameter × 16" (400 mm) height and 3,000°C maximum temperature, is based on a 50+ year old furnace design, although the traditional alumina or quartz tube has since been replaced with a solid graphite tube. Operating in vacuum or partial/positive pressures of argon, R&D centers use this furnace to process carbon powder formulations to maximize the percent conversion to graphite, as not all carbon-based starting materials will convert to crystalline graphite.

As R&D activities begin to focus on particular material compositions, larger furnaces are needed to synthesize meaningful sizes and quantities of candidate materials prior to scaling up for manufacture. The next larger lab furnace in the Centorr portfolio used for carbon/graphite work is the Series 45 graphite top-loading furnace (Figure 3). With a hot zone measuring approximately 6" (150 mm) diameter × 6" (150 mm) height and rated for 3,200°C maximum temperature, it offers a larger useable firing footprint at higher temperatures than the Series 10 furnace.

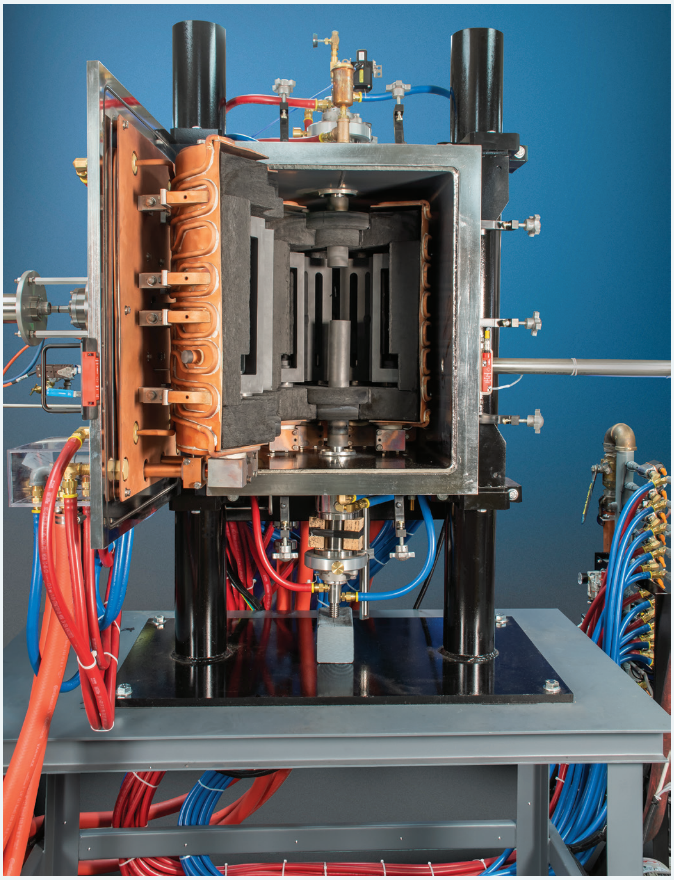
Characterization and prototyping stage

Once the final candidate materials are processed, aerospace design engineers need to test meaningfully sized samples of the materials at high temperature under mechanical loading. Centorr's Testorr® line of furnaces can be combined with mechanical test stands for measurement of mechanical properties at high temperature.



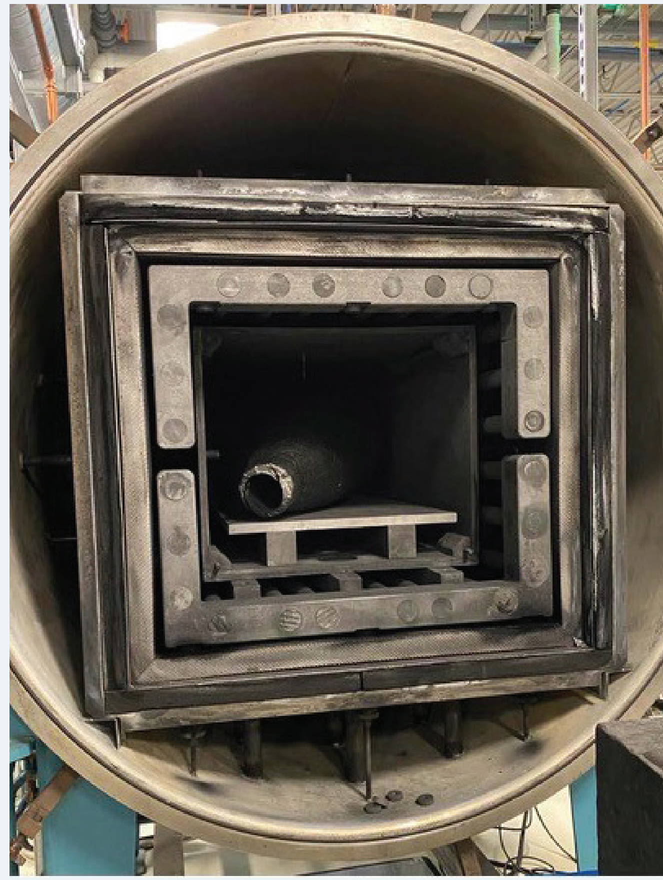
Credit: Centorr Vacuum Industries

Figure 3. a) Series 45 3,200°C graphite top-loading furnace and b) top view of hot zone.



Credit: Centorr Vacuum Industries

Figure 4. Front view of the Series TT Testorr graphite hot zone.



Credit: Exothermics, Nashua, N.H.

Figure 5. Production-size Sintervac vacuum furnace for processing carbon–carbon melt infiltration composite materials.

For example, Wichita State University's National Institute for Aviation Research uses multiple Testorr units to measure tension, compression, and shear properties of ceramic matrix composites, refractory metals, and other materials at high temperature. This particular design is rated for temperatures up to 2,700°C in vacuum or inert gas, which allows it to better simulate some aspects of hypersonic service environments (Figure 4).

An important task of the R&D and prototyping stages is to work out processing parameters that will be translated to production-scale manufacturing processes. For example, simple carbon structures will react with air during reentry and suffer damaging effects at temperatures as low as 500°C. Therefore, any carbon–carbon materials or solid carbon shapes used in hypersonic applications must be protected with advanced ceramic coatings for durability and oxidation resistance.

Chemical vapor deposition is one such coating deposition process, and one of the most popular protective coatings is silicon carbide. The coating is deposited on substrate parts by flowing hydrogen gas through a bubbler of liquid methyltrichlorosilane (MTS; CH_3SiCl_3) gas. Newer systems use a heated evaporator to vaporize the MTS liquid in a hydrogen carrier gas stream. The combination of hydrogen and MTS is introduced at partial pressures into the furnace hot zone inside a graphite retort, where the gases "crack" or decompose, depositing microns-thick coatings of silicon carbide onto the part's surface.

Production stage

Once the advanced materials are properly characterized and prototyped, it is time to look at equipment for full-scale production manufacturing. The furnace configurations for these processes can be either conventional front-loading designs, or for reasons of floor space savings and gas flow dynamics, may be oriented in vertical top- or bottom-loading designs.

The most popular of Centorr's front-loading systems is the Sintervac® front-loading graphite furnace (Figure 5). This unit has integral graphite retort and dual gas flow to the main chamber and retort. Sintervac furnaces are rated for temperatures between 1,600°C–2,600°C in sizes from 2 ft^3 to 135 ft^3 (56 to 3,500 liters). These furnace systems include durable rotary piston pumping systems with inline binder traps and particulate filters to protect the pumping systems from damage from abrasive ceramic particulates. The internal graphite retort compartmentalizes the off-gassing that takes place and prevents it from escaping into the hot zone, where the oxide byproducts can attack and degrade the graphite heating elements and rigid graphite board insulation.

One common application for this type of furnace is melt infiltration of carbon–carbon composites to improve the physical properties and oxidation resistance of the composite. When processed in partial pressures (or even at positive pressures) of argon, silicon will melt at approximately 1,450°C. The silicon liquid and vapor infiltrate into the void spaces of the porous carbon–carbon composite via capillary action. The infiltrated silicon reacts with the free carbon in the carbon–carbon fiber structure, forming a silicon carbide matrix around the carbon–carbon fiber structure.

Firms such as Exothermics (Amherst, N.H.) use this process for missile and aerospace applications. The silicon carbide matrix structure provides an environmental barrier to oxidation during reentry into Earth's atmosphere and improves the matrix's temperature performance to approximately 1,600°C in air.

Smaller production units were also developed for carbon–carbon work at temperatures from 2,450°C and 2,600°C. The addition of dedicated water-cooled filtration traps and 10-μ particulate filters helps deal with the heavy off-gassing expected from processing of carbon–carbon materials.

In contrast to melt infiltration, chemical vapor infiltration drives gaseous reactants into the porous matrix where the gas reacts with the porous structure to form a dense matrix. The chemical vapor infiltration process is used to fabricate larger parts for hypersonics, such as rocket motors and missile components, and carbon–carbon aircraft brakes. For these applications, Centorr designed a line of vertical top- and bottom-loading chemical vapor infiltration units (Figure 6), with sizes ranging from 52" to 80" (1,320 mm to 2,000 mm) in diameter with heights from 80" up to 120" (2.0 to 3.0 meters).

In the chemical vapor infiltration process, gases including hydrogen, methane, and propane are fed into the furnace chamber at high flow rates and at temperatures approaching 1,000°C–1,100°C. The methane and propane gases break down and deposit carbon deep into the matrix of the carbon–carbon fibrous parts. The cycles can be very long, approaching seven to 10 days, for the material to fully densify, and multiple cycles are usually necessary.

Low operating pressures require extremely large mechanical pumping systems with large vacuum blowers or boosters. These furnaces include water-cooled "tar" traps (with a heated stripping system) and large Dollinger particulate filters for handling the resin off-gas byproducts.

These furnaces are almost always induction heated, using multizone induction coils and large, thick-wall graphite susceptors for optimal temperature uniformity. The insulation design uses carbon black powder, which is economical as well as highly efficient for temperature reduction.

While more conventional rigid or flexible graphite board or felt materials can be used, experience shows that the degree of infiltration of carbon resins over time will affect the density and porosity of the insulation pack (as it does the load material), causing degradation and densification of the insulation. The denser insulation results in high coil water temperatures, which compromises hot zone life. Specialized carbon black installation and removal equipment is required by end users to maintain the insulation efficiency of the furnace hot zone. Because gas flow in the furnace is critically important, special diffusor plates or plenums are used to uniformly direct gas flow across the entire geometry of the parts.


Credit: Centorr Vacuum Industries

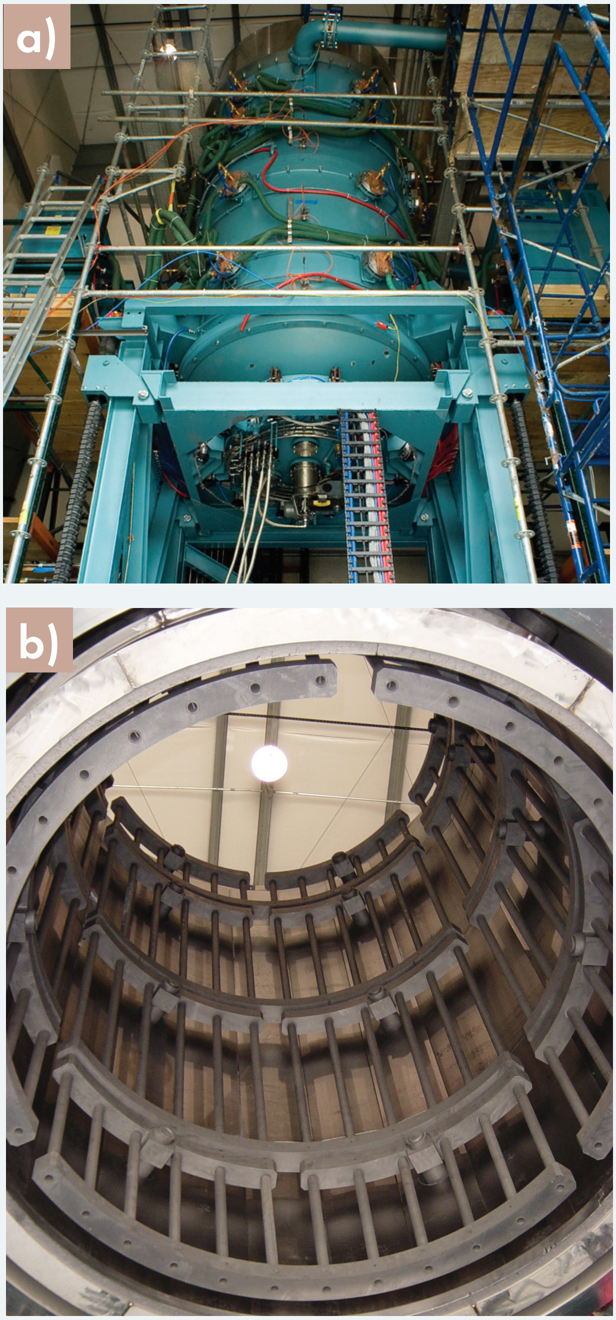
Figure 6. Series 4300 vacuum furnace for chemical vapor infiltration and graphitization. The furnace may be built in a top-loading or bottom-loading configuration.

Once the advanced materials undergo chemical vapor infiltration, they are still composed of a carbon base material, which needs to be converted to a more orderly crystalline graphite structure to impart the durability and strength required in aerospace applications. To accomplish this conversion, the material needs to be heated at temperatures greater than 2,300°C to convert the carbon to a highly ordered graphite structure, a process called graphitization.

The graphitization process employs similar furnace designs to the chemical vapor infiltration process, but the induction heating power supply is changed to the more conventional single zone coil and the vacuum pumping systems are smaller with no tar traps needed. Load sizes of 3,000–5,000 lbs (1,360–2,268 kgs) are possible. Both the smaller and larger chemical vapor infiltration and graphitization units have large, water-cooled heat exchangers inline with large cooling fans, which reduce cooling times from 10+ days to less than 175 hours.

A smaller graphitization unit was also developed in a 30" (762 mm) diameter × 40" (1,000 mm) height size rated to 2,900°C maximum temperature in a vertical bottom-loading configuration for processing smaller parts in lower volumes for aerospace brakes.

The silicon carbide chemical vapor deposition units for laboratory applications discussed previously are also needed for production-size volumes. One of the larger systems available is a



Credit: Centorr Vacuum Industries

Figure 7. a) Series 3800 bottom-loading silicon carbide chemical vapor deposition furnace. b) Series 3800 chemical vapor deposition furnace hot zone with multizone control.

53" (1,350 mm) diameter × 83" (2,108 mm) height graphite hot zone furnace rated for 1,600°C operation for chemical vapor deposition or infiltration of silicon carbide (Figure 7). Due to tight temperature uniformity requirements, these units are multizone control with graphite hot zones constructed of rigid graphite board for process durability. The pumping systems can be either "dry" or "liquid ring" designs for processing the acidic off-gas materials. A post-exhaust chemical scrubber system is required to safely neutralize the hydrogen chloride off-gases.

CENTORR Vacuum Industries

Founding and future goals

Centorr Vacuum Industries, based in Nashua, N.H., is the combination of two companies launched in the mid-20th century: Vacuum Industries, founded in 1954 in Somerville, Mass., and Centorr Furnace, founded in 1962 in Suncook, N.H.

Centorr Vacuum Industries has a long history designing and building production-scale furnaces, primarily for the metals and ceramics industries. The company also manufactures laboratory and R&D furnaces, and it developed some of the first high-temperature furnaces (3,000°C) for processing ultrahigh-temperature ceramics.

Today, Centorr Vacuum Industries is best known for its line of metals and ceramics sintering furnaces sold to the carbon, graphite, and composites industry for aerospace and hypersonics and has an installed base of more than 7,000 units worldwide. It operates a fully staffed aftermarket field service group, and its Applied Technology Center offers R&D support and toll production services.

For more information, visit www.centorr.com.

Enabling the next generation of aerospace materials

The difficult design requirements of next-generation aerospace technologies will continue to push the existing limits of material performance. Characterization and development of new materials will be critical to the success of these aerospace programs, and vacuum and controlled atmosphere furnaces will play a role in the production of these materials. Centorr Vacuum Industries will continue to support this industry through its diverse product offerings, ranging from laboratory-scale testing up to production scale.

About the author

Scott K. Robinson is product manager of ceramics and powder metallurgy at Centorr Vacuum Industries (Nashua, N.H.). Contact Robinson at srobinson@centorr.com.

References

[1]J. Mesa, "What's the difference between a hypersonic missile and ICBM?" *Newsweek*. Published 21 Nov. 2024. https://www.newsweek.com/difference-between-icbm-irbm-missiles-1989780

[2]"Hyperian Aerospace and the dawn of hypersonic flight," *TomorrowDesk*. Published 29 March 2025. https://tomorrowdesk.com/evolution/hyperian-aerospace-hypersonic-flight

[3]C. R. Smith, "Aerodynamic heating in hypersonic flows," *Physics Today* 2021, **74**(11): 66–67.

[4]"Silicon carbide data sheet," American Elements. https://www.americanelements.com/silicon-carbide-409-21-2

[5]"Zirconium diboride data sheet," American Elements. https://www.americanelements.com/zirconium-diboride-12045-64-6

*All references verified as of July 10, 2025. ■

Jonathon Foreman
ACerS journals managing editor

Modeling for glass production

Modeling serves a variety of industrial purposes, from predicting properties of new materials to providing cost estimations for different production scenarios. It can also provide information about the physical and chemical changes that occur during materials processing, which is particularly useful for opaque processes that cannot be easily measured in situ—such as glass manufacturing.

Glass products have been manufactured for millennia, but there are still many unknowns surrounding their fabrication given the material's complexity. As a result, many in the glass community have embraced modeling to help answer some of these questions.

The article "Modeling and optimization of the sagging process for large-size and high-purity silica glass synthesis" authored by Li et al. describes how the authors identified the most critical parameters in the process of converting a cylindrical ingot to a wider disk via gravity-driven flow of the liquid silica.[1] The study sought to optimize the shape of the hydroxyl (OH)-rich zone of the silica for two different applications.

The article explains the assumptions, boundary conditions, and reasoning behind each parameter being modeled, including fluid dynamics, heat transfer, atmospheric interactions, and transport of the OH groups. The input variables for this study include the size of the silica ingot, crucible diameter, distance from the crucible to the floor of the furnace, and power distribution among the furnace's three heating zones.

The results of their modeling indicate that ingot height most influences the total volume of the product's hydroxyl zone, which is important for lens applications. Meanwhile, crucible diameter most influences the radius of the hydroxyl zone, which is important for thin film applications.

The study described in the article "Automated tool for cylindrical glass container blow and blow mold design" takes a different approach to modeling.[2] While the prior study approached the problem using literature and measured property values and relationships, this study by Fibla-Figuerola et al. used historical production data from one company as the basis for their empirical model.

The goal of this study was to design the first stage "preparation" molds that provide optimal glass distributions for new perfume bottle shapes. The authors converted the shapes of the existing molds into eight parameters over four zones of the mold and then correlated these parameters to the glass distributions of the bottles produced. All other parameters were held constant. They found that the precision of the model improved by limiting the ranges of sizes and shape factors, and that additional factors were needed to account for small height-to-diameter aspect ratios.

Using their model, the authors designed a new preparation mold for an existing product (Figure 1). The resulting bottle withstood loads in ISO8113 vertical load resistance testing that were more than 50% higher than those of the production bottle. Furthermore, the mold development time was more than 44% faster due largely to the modeled mold not requiring a second iteration.

While these two articles focus on specific sets of conditions, models are being developed for more general usage. The article "Finite element software for forming processes of glass containers" by Martins discusses models for bottle production, much like Fibla-Figuerola et al., and uses the theoretical–analytical approach of Li et al.[3]

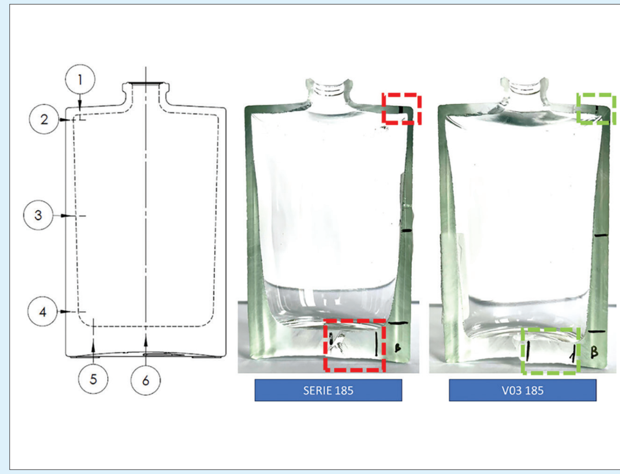


Figure 1. Bottles fabricated using production and experimental preparation molds. The experimental bottle is thicker at the top three positions and thinner at the base, leading to improved load resistance.

The author includes parameters that account for different bottle-forming processes with a greater range of factors being considered, such as glass sticking to the walls at various temperatures. They then go into detail about the modeling process, such as how the data is translated over the various mesh configurations. They conclude by noting that even with the model's complexity, they ran it with acceptable timing on a single processor computer.

These three studies of modeling for glass manufacturing are a small subset of the wide range of glass research and development topics being modeled. Searching the ACerS catalog at https://ceramics.onlinelibrary.wiley.com results in articles on structure, ion exchange, thermodynamics, relaxation, and more.

References

[1]C. Li et al., "Modeling and optimization of the sagging process for large-size and high-purity silica glass synthesis," *Int. J. Appl. Glass Sci.* 2024, **15**: 167–181.

[2]O. Fibla-Figuerola et al., "Automated tool for cylindrical glass container blow and blow mold design," *Int. J. Appl. Glass Sci.* 2025, **16**: e16702.

[3]B. Martins, "Finite element software for forming processes of glass containers," *Int. J. Appl. Glass Sci.* 2025, **16**: e16683. ■

15TH ADVANCES IN CEMENT-BASED MATERIALS BRIDGES SCIENTIFIC INNOVATION WITH ENTREPRENEURIAL THINKING

The American Ceramic Society's Cements Division hosted the 15th Advances in Cement-Based Materials meeting from June 11–13, 2025, at the University of Colorado Boulder. The meeting welcomed almost 170 attendees.

Wednesday's program opened with a presentation by keynote speaker Lori Tunstall, assistant professor of civil and environmental engineering at Colorado School of Mines, titled "Toward carbon-negative concrete: Bridging scientific innovation, field deployment, and entrepreneurial thinking."

Following the lecture, Division Chair Prannoy Suraneni presided over the Division's business meeting. Suraneni also announced the 2025 Brunauer Best Paper Award: "From selective dissolution to crystal chemistry of brownmillerite in sulfate resisting cement" by Alexis Mériot et al., published in *JACerS*. Additionally, the Division's Early Career Award was presented to Alexander S. Brand of Virginia Tech and Nishant Garg of University of Illinois Urbana-Champaign.

Wednesday afternoon, Kimberly E. Kurtis of Georgia Institute of Technology presented the Della Roy Lecture on "Greening our gray world: Sustaining innovation and translating discovery in cement and concrete science." Kurtis' lecture was followed by the Della Roy Reception and poster session, sponsored by Elsevier. More than 50 presenters detailed their research.

Cements 2025 attendees at the University of Colorado Boulder. *Credit: ACerS*

Thursday began with a presentation by keynote speaker Jesse Benck, vice president of research and development at Sublime Systems, titled "Sublime Systems: Electrochemical production of next-generation, clean cement."

Friday's sessions began with a national lab panel discussion, which included Ana Aday of the National Renewable Energy Laboratory, Denise Silva of Oak Ridge National Laboratory, and William Jolin of Savannah River National Laboratory. The final break-out sessions of the conference followed.

The ACerS Conference Mentor Program was also held at Cements 2025 and involved 44 participants.

The meeting concluded with the announcement of the 2026 meeting location, which will be the University of Miami in Coral Gables, Fla.

View more photos from the event on ACerS Flickr page at https://bit.ly/Cements2025. ■

STRUCTURAL CLAY EXPERTS CONVENE IN BIRMINGHAM FOR NETWORKING AND PLANT TOURS

More than 100 attendees converged in Birmingham, Ala., on June 9–11, 2025, to take part in the combined meeting of the ACerS Structural Clay Products Division (SCPD), ACerS Southwest (SW) Section, and Clemson University's National Brick Research Center (NBRC).

The three-day meeting began with a partial day of independent networking, followed by a full day of informative talks along with the NBRC meeting. On the third day of the conference, two local brick manufacturing sites hosted the SCPD conference attendees for full tours of their plants. The meeting wrapped up with an awards banquet on Wednesday night.

NBRC MEETING

During the NBRC's Spring Executive Committee Meeting on Tuesday morning, NBRC Director John Sanders along with research associates Nate Huygen and Kathy Hill provided the members with updates about the center. Sanders then presented

NBRC Director John Sanders, left, presents David McKeown the engraved brick. *Credit: ACerS*

David McKeown with an engraved brick to thank him for his years of service on the NCBR Executive Committee. He concluded by reminding attendees of the upcoming Clemson Brick Forum, which will take place Sept. 29–30, 2025, in Anderson, S.C.

TECHNICAL SESSION

On Tuesday afternoon, 10 industry experts educated attendees on a wide range of topics, spanning from operational safety and plant upgrades to decoration lines and extrudability.

PLANT TOURS

On Wednesday, attendees toured two plants: Acme Brick Company's Birmingham plant and U.S. Brick Company's Bessemer plant. Attendees enjoyed a BBQ lunch at Bessemer Civic Center.

AWARDS BANQUET

Robert T. Belden of Beldon Brick Company was awarded the 2024 SCPD Best Paper award for his presentation titled "Plant 4 Upgrade." Certificates of recognition were awarded to SCPD Chair Bryce Switzer along with ACerS SW Section Chair Jeff Cross in appreciation of the countless hours that they donated to making this meeting such a success.

View more pictures from the meeting on ACerS Flickr page at https://bit.ly/SCPD-2025. Next year's meeting will take place June 8–10, 2026, in Canton, Ohio. ■

UPCOMING DATES

JAN. 25–30, 2026
Register to attend!

HILTON DAYTONA BEACH OCEANFRONT RESORT,
DAYTONA BEACH, FLA.

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

APRIL 12–16, 2026
Submit your abstract!

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

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

MAY 31–JUNE 5, 2026
Submit your abstract!

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

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

JULY 12–16, 2026
Submit your abstract!

THE RENAISSANCE CENTER,
DETROIT, MICH.

Join us in Detroit for the American Conference on Neutron Scattering. More information coming soon.

Calendar of events

September 2025

2–11 ★ Sintering of Ceramics – Virtual; https://ceramics.org/course/castro-sintering-course

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

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

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

October 2025

5–9 ➡ International Symposium on Green Processing of Advanced Ceramics – Ise-Shima, Mie, Japan; https://igpac2025.com

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

29 ★ Hypersonic Workshop – Washington, D.C.; https://ceramics.org/course/hypersonic-workshop-dc

November 2025

30–Dec. 3 ➡ The 14th International Conference on High-Performance Ceramics — Haikou, China; https://cicc14.ceramsoc.com

January 2026

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

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

March 2026

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

April 2026

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

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

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

May 2026

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

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

June 2026

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

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

July 2026

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

August 2026

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

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

Entries in **BLUE** denote ACerS events.

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

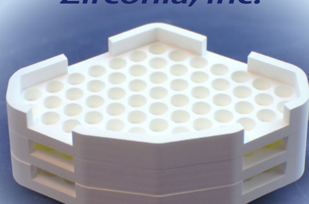
★ denotes a short course

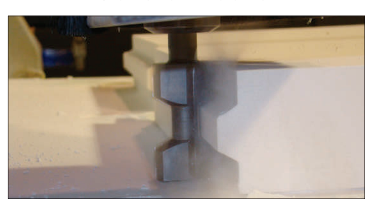
classified advertising

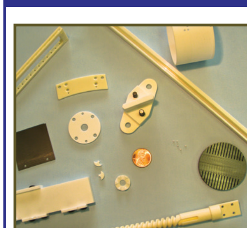
Career Opportunities

Business Services

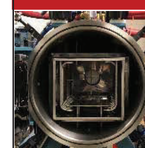
custom finishing/machining







custom/toll processing services



firing/melting/drying

laboratory/testing services

maintenance/repair services

AD INDEX

SEPTEMBER 2025

AMERICAN CERAMIC SOCIETY bulletin

DISPLAY ADVERTISERS

CLASSIFIED ADVERTISERS

* Business Service advertisers

Advertising Sales
Mona Thiel, National Sales Director
mthiel@ceramics.org
ph: 614-794-5834

Advertising Assistant
Pam Wilson
pwilson@ceramics.org
ph: 614-794-5826

By Kay N. Wojtowicz

Guest columnist

Multimaterial processing of novel ceramic formulations

Additive manufacturing (AM) techniques are widely used for the purpose of creating unique and geometrically complex components. Among these techniques, the material-extrusion based method known as direct ink writing (DIW) is applicable to a wide variety of materials.

DIW involves the extrusion of viscoelastic materials referred to as ink. These inks can range in material composition and viscosity, allowing for large material variation.

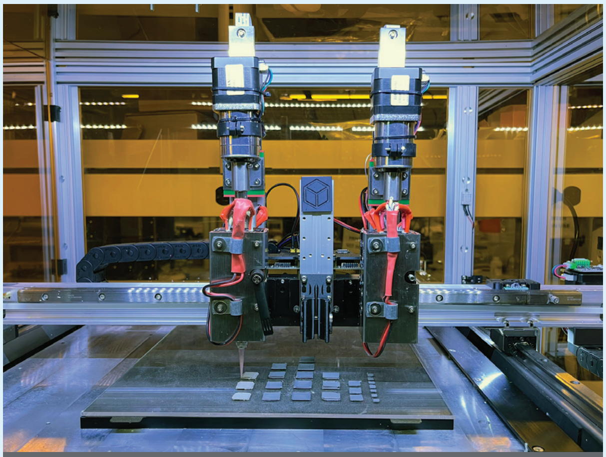
The inherent flexibility of DIW makes it well-suited for the creation of novel ceramic materials for its ability to accommodate small batch sizes and facilitate the high-throughput fabrication of numerous specimens.

During printing, the inks are contained within reservoirs. By applying a compression force, the ink is pushed down within the reservoir, and when the shear stress within the ink exceeds a critical value, it begins to flow out of the nozzle. The single extrusion line that flows from the nozzle features a width roughly equal to that of the nozzle's inner diameter.

A single extrusion line can be created using inks from multiple reservoirs, allowing for varying material compositions within a single component. Each material is controlled independently; therefore, the flow rates of each ink can be adjusted to alter the ratio between them within the extrusion and can accommodate inks of varying viscosity.

My research at the University of Massachusetts, Lowell, under Professor Chris Hansen focuses on the characterization of ceramic materials of varying compositions created with DIW (Figure 1). Test specimens of varying geometries are created from each ink to enable a range of characterization testing to be conducted on the composition.

Silicon carbide is used due to its high strength and temperature resistance. It is combined with other ceramics, such as boron carbide, during the DIW process to create unique specimens. The inks are non-Newtonian, custom colloidal gel formulations comprised of 40–55 vol.% solid particles.[1] A polymer binder called polyethylenimine (PEI), with varying molecular weights, is used within the inks to create the desired suspension of the ceramic particles within the gel base. This suspension results from intermolecular forces between the poles of the ceramic particles and the polymer binder, as well as the entanglement of the polymer chains.



Credit: Kay Wojtowicz

Figure 1. DIW setup for creating specimens of varying material compositions.

To ensure a stable suspension, the PEI chains must coat the ceramic particles. Therefore, the amount of polymer is dependent on the total surface area of the ceramic particles within the ink. Using the Brunauer-Emmett-Teller method, the specific surface area—i.e., the surface area per gram of material—of all the ceramic particles were experimentally determined. A consistent ratio is maintained between the mass of PEI used and the total surface area of the particles within the ink, thus ensuring there is the proper amount of coverage of the ceramic particles.

Multiple molecular weights of PEI are used because of the variation in chain length of the polymer, allowing for better coverage of the ceramic particles. The addition of the lower molecular weight, i.e., shorter polymer chains, causes the inks to exhibit shear thinning behavior when extruded.[2] This behavior is essential for DIW inks; it allows them to flow through a nozzle under shear and then regain their solid-like behavior under quiescent conditions, thus retaining the desired shape after extrusion.

As a first-year Ph.D. student, this work is just the beginning of my research. In the future, I plan to create specimens using both off-the-shelf and custom ceramic particles, and these samples will be sintered through a pressureless heating process under an argon atmosphere in a high-temperature furnace prior to microstructural observation. Further characterization will be completed using a Split Hopkinson Pressure Bar to investigate the dynamic mechanics of the varying compositions.

References

[1]J. A. Lewis, "Direct-write assembly of ceramics from colloidal inks," *Current Opinion in Solid State and Materials Science* 2002, **6**(3): 245–250.

[2]K. Cai et al., "Geometrically complex silicon carbide structures fabricated by robocasting," *J. Am. Ceram. Soc.* 2012, **95**(8): 2660–2666.

Kay Wojtowicz is a Ph.D. student in mechanical engineering at the University of Massachusetts, Lowell. Their research focuses on the creation, processing, and characterization of custom ceramic materials optimized for future applications in ballistic protection. They enjoy playing tennis and painting in their free time. ■

WELCOMING NEW FACULTY

Caio Bragatto, Ph.D.

Alfred University welcomes Assistant Professor of Ceramic Engineering Dr. Caio Bragatto. Bragatto earned his B.S. degree in Industrial Chemistry from the Universidade de São Paulo (São Paulo, Brazil), and his master's and Ph.D. degrees in Materials Science and Engineering from the Universidade Federal de São Carlos (São Paulo, Brazil).

Bragatto worked as a research assistant at the Otto-Schott Institut für Materialwissenschaft at the University of Jena (Thüringen, Germany) and as a physics professor at Coe College (Cedar Rapids, Iowa). He specializes in the ionic conductivity of glasses, like those used for batteries and sensors focusing especially on unveiling the mechanisms behind the phenomena and working on a universal model to predict this property. During his time at Coe College, he was the principal investigator (PI) for an NSF-MRI (National Science Foundation Major Research Instrument) grant for an electrochemical impedance spectrometer, co-PI for another NSF-MRI for a differential scanning calorimeter as well for the institution's NSF-RUI (Research at predominantly Undergraduate Institutions). This research was done in direct collaboration with the undergraduates at Coe College, which led to two of his students being awarded runner-up prizes for the Glass and Optical Materials Cooper Awards ('19 & '22).

Dr. Bragatto has also been deeply involved with student life, advising multiple clubs, including the chapter for the Society of Physics Students. His involvement led to his election as a congressman in the national society, a role he will keep for another two years. He is also involved with ACerS, and is a member of multiple committees, chairing sessions during conferences. He is excited to bring this experience to Alfred University.