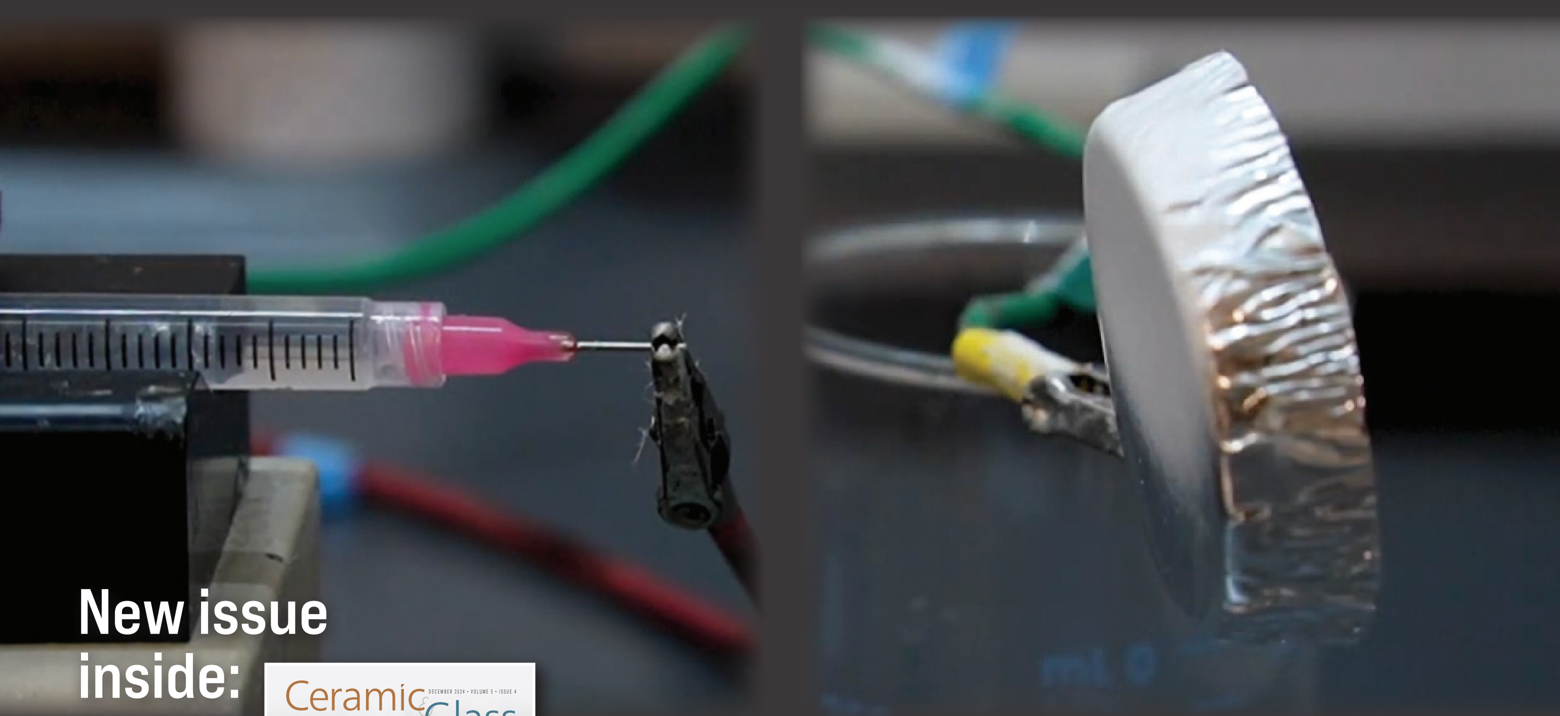
AMERICAN CERAMIC SOCIETY

bulletin

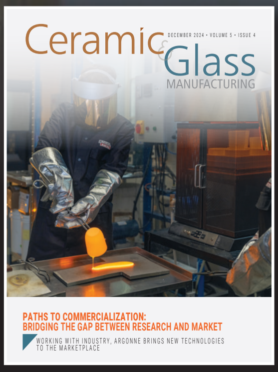
emerging ceramics & glass technology

DECEMBER 2024

Electrospinning for biomaterial applications



New issue inside:



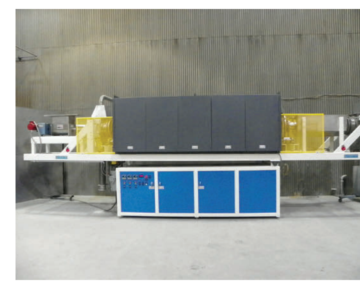
Affirmation of The Age of Glass | Bioactive materials processing | Glass-enabled Nobel discoveries

Your kiln, Like no other.









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

Hundreds of our clients will tell you that our multi-phase application engineering process is what separates Harrop from "cookie cutter" kiln suppliers. A thorough technical and economic analysis to create the "right" kiln for your specific need results in a robust industrial design, fabrication and construction, followed by after-sale service for commissioning and operator training.

Harrop's experienced staff are exceptionally qualified to become your partners in providing the kiln most appropriate to your application.

HARROP

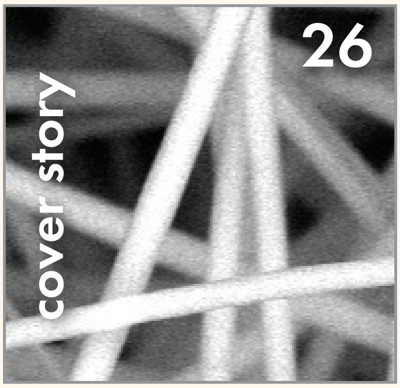
COLUMBUS, OHIO

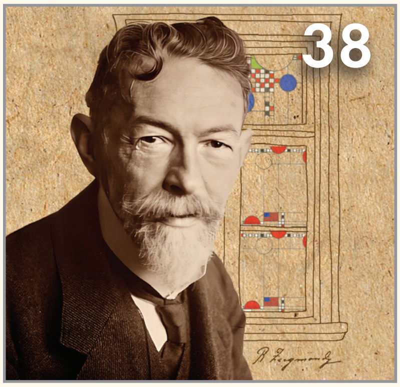
www.harropusa.com
1.614.231.3621

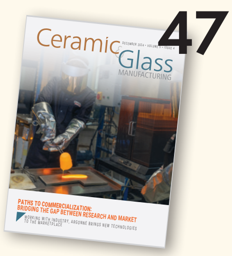
contents

December 2024 • Vol. 103 No.9

feature articles







departments

columns

meetings

resources

AMERICAN CERAMIC SOCIETY
bulletin

online
www.ceramics.org

December 2024 • Vol. 103 No. 9

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

As seen on *Ceramic Tech Today*...


Credit: Jan Storey, U.S. National Science Foundation

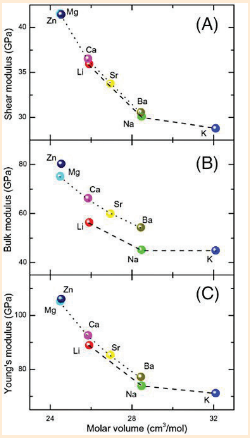
The freeze-tolerant wood frog and its contribution to long-term organ storage

Wood frogs can freeze and thaw themselves completely unharmed, and this unique ability could help revolutionize the organ transplant industry by inspiring methods for long-term storage of organs.

Read more at www.ceramics.org/wood-frog

Also see our ACerS journals...

High-modulus glass fiber for wind renewable energy generation: Selective review on the recent research and development
By H. Li, G. Demirok, S. Atilgan, et al.
International Journal of Applied Glass Science



Credit: Li et al., *IJAGS*

Technoeconomic feasibility of photovoltaic recycling
By B. Crespo, C. Cavanaugh, A. Potter, et al.
International Journal of Applied Glass Science

Effective thermal conductivity of fiberglass insulation
By M. K. Choudhary and W. Eastes
International Journal of Applied Glass Science

Impact of impurities on the thermal properties of a $Li_2S–SiS_2–LiPO_3$ glass
By J. Wheaton and S. W. Martin
International Journal of Applied Glass Science

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 www.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 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. Nonmember 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, 550 Polaris Parkway, Suite 510, Westerville, OH 43082-7045. Periodical postage paid at Westerville, Ohio, and additional mailing offices. Allow six weeks for address changes.

American Ceramic Society Bulletin (ISSN No. 0002-7812). ©2024. Printed in the United States of America.

ACSBA7, Vol. 103, No. 9, pp. 1–64. All feature articles are covered in Current Contents.

Affirmation of The Age of Glass

To the editor:

As a means of proclaiming epochal periods in the history of humankind, historians have classified eras from several perspectives, such as materials, human activity, and astrological theory. Respective examples are "The Iron Age," "The Age of Enlightenment," and the "Age of Aquarius." During the last decade, there has been an emerging sense that we live in "The Age of Glass." Based on the discussion below and our professional experiences—both individually and collectively—we wish to affirm this epic moment in the history of glass.

That we have arrived at this milestone is supported by the United Nations declaring 2022 "The International Year of Glass," the first time this honor was bestowed on a material.[1] This celebratory year gave us a platform through which to confirm the centrality of glass in modern society, look into the crystal ball to muse on the material's future, and thank some of the glass pioneers who helped bring us to this point.

Though the International Year has come and gone, glass continues to flow into our lives, enabling a menagerie of daily uses and appreciation in architecture, transportation, communications, science, art, and especially medicine, e.g., glasses for wound healing, cancer treatment, and eye care. Some of these threads are obvious while others less so: glass windows in homes and cars; fiberglass insulation; glass jars to store food; glass cover plates on phones, tablets, and TVs; glass optical fibers that enable e-commerce and the internet; and glass art all around us, to name just a few. Glass lets us peer into the extremes of nature: from the celestial scale through the lens of the James Webb Space Telescope to the infinitesimal through the lens of microscopes; from the intensely bright glass fiber lasers that outshine the sun to the dimmest glass lightbulbs that help illuminate the darkness. A day without glass is a day without most modern conveniences and enjoyments.

Mother Nature has a soft spot for glass. Despite millennia of study and development, she has hidden a plethora of questions about glass science and engineering that provide numerous opportunities for future discovery. Some especially noteworthy questions offered by the authors of this letter include

- Can we learn to predict using theoretical models or computer simulations the crystallization speed (or critical cooling rate) required to avoid devitrification?
- Will all glasses eventually crystallize in the limit of infinite time?
- What are the structural origins of glass relaxation?
- What are the silica glass network's four yield strengths (in dilation, pure compression, shear tearing mode, and shear twisting mode)?
- What is the nature of the glassy state?
- Can industry develop rapid homogenization and fining technology that permits single melter–multiforehearth factories to produce multiple compositions that optimize glass properties for specific applications and minimize production costs?
- How to decarbonize glass manufacturing?

For as long as humans have existed, glass has played an important role in enabling community and progressing society. Its future remains as bright as ever, arguably more so than in the past. We stand here, now, on the shoulders of giants, with a list of unanswered questions that will help define the role of glass in our future. Let's get started!

Lastly, in recognition and appreciation of those who contributed so much to laying the groundwork of glass science, the Glass & Optical Materials Division of The American Ceramic Society established the L. David Pye Lifetime Achievement Award in 2019. The history of this Award and its greater meaning to those recognized are given on the next page.

Sincerely,

John Ballato,[a] Kathleen Richardson,[b] Mario Affatigato,[c] Richard Brow,[d] John Mauro,[e] Edgar Zanotto,[f] Lisa Klein,[g] Minoru Tomozawa,[h] William LaCourse,[i] Doris Möncke,[i] Collin Wilkinson,[i] L. David Pye,[i] S.K. Sundaram,[i] Alastair Cormack,[i] Manoj Choudhary,[j] Arun Varshneya,[k] and Carol Jantzen[l]

[a]Clemson University, Clemson, S.C.

[b]University of Central Florida, Orlando, Fla.

[c]Coe College, Cedar Rapids, Iowa

[d]Missouri University of Science and Technology, Rolla, Mo.

[e]The Pennsylvania State University, University Park, Pa.

[f]Federal University of São Carlos, Brazil

[g]Rutgers University, Piscataway, N.J.

[h]Rensselaer Polytechnic Institute, Troy, N.Y.

[i]Alfred University, Alfred, N.Y.

[j]The Ohio State University, Columbus, Ohio

[k]Alfred University, Saxon Glass Technologies, Inc., Alfred, N.Y.

[l]University of South Carolina, Aiken, S.C.

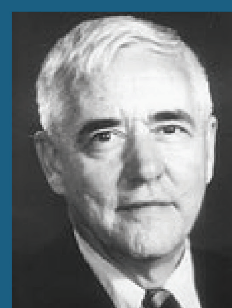
References

[1]A. Durán and J. M. Parker, "Celebrating glass, achieving sustainability, inspiring transformation: A report on the activities undertaken for the United Nations International Year of Glass 2022," Consejo Superior de Investigaciones Científicas, Madrid 2024. https://saco.csic.es/index.php/s/BS7sAXsBr4zQ79P

L. David Pye Glass Hall of Fame Recipients


John Mackenzie (2019)


Charles Kurkjian (2019)


Donald Uhlmann (2020)


Dale Chihuly (2020)

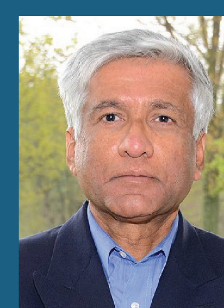

Reinhard Conradt (2020)


William LaCourse (2022)


Steve Feller (2023)


Carlo Pantano (2023)


Carol Jantzen (2024)


Manoj Choudhary (2024)

L. DAVID PYE GLASS HALL OF FAME AWARD

The year 2019 was a seminal moment for both The American Ceramic Society and the Glass & Optical Materials Division. For GOMD, it was the 100th anniversary of its founding by ACerS (originally called the Glass Division, renamed in the 1990s). For ACerS, it was the convening of the 25th International Congress on Glass in Boston, Mass. It was the fourth time ACerS had been given the honor of hosting this conference by the International Commission on Glass, and the decision was based to a large degree on it being the GOMD centenary.

This year was also when GOMD established and first bestowed the L. David Pye Lifetime Achievement Award. This annual award recognizes a deserving individual(s) for their dedication, vision, and accomplishments in advancing the fields of glass science, engineering, and art. It is named in honor of L. David Pye, dean emeritus and professor emeritus of glass science at The New York State College of Ceramics at Alfred University and ACerS past president, Fellow, and Distinguished Life Member.

That first year, two luminary individuals, John Mackenzie and Charles Kurkjian, were chosen for this honor, which was presented to them at the Glass Congress in Boston. Subsequently, this award has been presented to several other deserving individuals (see photo collage above).

As the list of award recipients has grown, the GOMD Executive Committee reflected on the fact that this group serves essentially as a "Hall of Fame" for those in the glass community. Accordingly, this award will now be called "The L. David Pye Glass Hall of Fame Award."

Nominations for the 2025 award are due by Jan. 21, 2025. Nominations should be sent electronically to GOMD chair Michelle Korwin-Edson (Michelle.Korwin-Edson@owenscorning.com) and ACerS staff member Vicki Evans (vevans@ceramics.org). Details on the nomination process can be found at https://ceramics.org/Glass-Hall-of-Fame-Award. ■

Minerals Security Partnership welcomes new members and initiatives

In June 2021, the Biden-Harris Administration released a first-of-its-kind supply chain assessment that found the U.S. relies heavily on foreign sources and adversarial nations for critical minerals and materials. This reliance "erodes the resilience of U.S. critical supply chains and industries more broadly," the report stated, and then it recommended several ways to establish diversified, sustainable material sources.

One recommendation was to work with allies and partners to decrease vulnerabilities in global supply chains. Within a year, the U.S. announced the establishment of the Minerals Security Partnership (MSP) in June 2022.

MSP is a multinational partnership initiative that aims to ensure critical minerals are "produced, processed, and recycled in a manner that supports the ability of countries to realize the full economic development benefit of their geological endowments," according to a media note announcing the initiative.

Originally, 10 countries and the European Union (represented by the European Commission) were involved in the partnership: Australia, Canada, Finland, France, Germany, Japan, the Republic of Korea, Sweden, the United Kingdom, and the United States. Since then, India, Italy, Norway, and Estonia have joined the partnership as well.

Credit: Under Secretary Jose W. Fernandez, X

Members of the Minerals Security Partnership pose for a picture in March 2024 at the Prospectors and Developers Association of Canada annual convention.

In March 2024, the MSP partners met at the Prospectors and Developers Association of Canada annual convention. At the meeting, they announced the creation of the Minerals Security

Partnership Forum, which provides a platform for the MSP partners to discuss and advance supply chain projects and policies with other countries around the world.

During that first MSP Forum gathering in March, the MSP partners discussed critical mineral supply chains with several countries from the Western Hemisphere, including Argentina, Brazil, Chile, Jamaica, Mexico, and Peru. They also confirmed support for several ongoing supply chain projects, which include projects on upstream mining and mineral extraction, midstream processing, and recycling and recovery.

In September 2024, the MSP partners met again in New York City on the margins of the United Nations General Assembly High-Level Week and Climate Week NYC. In addition to welcoming new members to the MSP Forum and discussing project updates, the MSP partners announced the establishment of the Minerals Security Partnership Finance Network, which provides a platform through which the finance institutions and export credit agencies of the MSP partners can connect.

The next MSP Forum event will take place on the margins of Raw Materials Week in Brussels, Belgium, in December 2024. Find updates from this meeting and other events on the MSP website at https://www.state.gov/minerals-security-partnership. ■

Corporate Partner news

Cerion hired by NASA to develop nanoparticles for deep space initiative

Cerion, a leader in developing metal, metal oxide, and ceramic nanomaterials, was brought on by NASA to develop a custom silver nanoparticle to be used in deep space applications. Potential manufacturing of the product may begin in early 2025. Learn more: https://cerionnano.com/category/cerionnews

Free Form Fibers earns ISO standard accreditation

Free Form Fibers earned accreditation for its quality management system to ISO 9001:2015 standard. This achievement comes out of the company's efforts to supply high-quality materials for the various industries it serves, including aviation, defense, energy, and semiconductors. Learn more: https://www.fffibers.com/in-the-news

Refratechnik México acquires Refrasol

Chile-based refractory materials company Refrasol became a global member of the Refratechnik Group under the name Refratechnik Chile. The acquisition comes after a long-term strategic partnership and the desire to bring Refratechnik to South America. Learn more: https://www.refra.com/en/News ■

By Ender Suvacı and Servet Kızılırmak
Guest columnists

Medical ultrasound applications of piezoceramics and recent trends

The medical ultrasound industry has seen significant advancements driven largely by the development and application of ceramic materials. These materials, particularly piezoceramics, play a crucial role in device functionality.[1,2]

Piezoelectric materials convert electrical signals into mechanical vibrations, generating ultrasound waves that penetrate the body and reflect off internal structures. The returning echoes are then converted back into electrical signals to create detailed images. This dual capability makes piezoceramics ideal for ultrasound transducers, which are the components responsible for generating and/or sensing ultrasound energy in ultrasound machines (Figure 1).

Several recent trends in the ultrasound industry include

- **Portable and handheld ultrasound devices**, which are enabled by the development of smaller, more efficient ceramic transducers.
- **Expanded use of high-frequency ultrasound devices**, which rely on advanced piezoceramics that can operate at higher frequencies.
- **Adoption of 3D and 4D imaging techniques**, which produce real-time, high-resolution images through the use of piezoceramic materials.
- **Development of high-intensity focused ultrasound**, an emerging noninvasive therapeutic technique that uses piezoceramic materials to generate focused ultrasound waves to target and destroy diseased tissue without damaging healthy tissue.

However, likely the biggest trend is the shift toward lead-free piezoceramics.

Shift from lead-based to lead-free piezoceramics

Lead-based piezoceramics, such as lead zirconate titanate (PZT), traditionally have been the material of choice for piezoelectric applications due to their excellent piezoelectric properties. However, with the global push toward sustainable and eco-friendly technologies, a spotlight has been shown on the environmental and health risks associated with lead. Moreover, many countries are implementing stricter regulations on the use of hazardous substances.

As a result of these societal and market forces, manufacturers are exploring the adoption of lead-free alternatives to traditional PZT materials, such as bismuth sodium titanate, potassium sodium niobate, and bismuth ferrite.[3,4] Texturing techniques such as templated grain growth have been developed to enhance the piezoelectric properties of lead-free ceramics, making them more competitive with traditional PZT materials.[5]

Consequently, the global market for lead-free piezoelectric ceramics is expected to rise from $184.1 million in 2021 to $402.1 million by 2026.[6]

Industry adoption and outlook

The shift to lead-free piezoceramics presents challenges, such as the need for new manufacturing processes and potential cost implications. Overcoming these challenges will require a collaborative effort by powder manufacturers, ceramic manufacturers, and ultrasound designers and manufacturers.

An example of such activities is the Life Med-U Project.[7] This project, which is funded by the European Union through the Horizon Europe @Eureka Eurostars Program, involves innovative powder designer and manufacturer Entekno Materials (Eskişehir, Turkey) working to develop lead-free medical ultrasound devices with partners CTS Denmark/Ferroperm (ceramic manufacturing), Vermon (medical ultrasound imaging), and Precision Acoustics (high-intensity focused ultrasound).


Credit: iStock

Figure 1. There are many uses of ultrasound imaging in healthcare, including diagnosing injuries to tendons, ligaments, and muscles.

The medical ultrasound industry is at a pivotal point, with significant advancements in ceramic materials driving innovation and improving diagnostic capabilities. As the industry continues to evolve, we can expect further improvements in the performance and availability of lead-free piezoceramic materials, ultimately enhancing the quality and safety of medical ultrasound technology.

About the authors

Ender Suvacı is professor of materials science at Eskişehir Technical University in Turkey and founder and chief technology and innovation officer at Entekno Materials Corp. (Eskişehir, Turkey). Servet Kızılırmak is sales manager at Entekno. Contact Suvacı at esuvaci@enteknomaterials.com and Kızılırmak at servetk@enteknomaterials.com.

References

[1]K. K. Shung, J. M. Cannata, and Q. F. Zhou, *J. Electroceram.* 2007, **19**: 139–145.
[2]Y. He, H. Wan, X. Jiang, and C. Peng, *Biosensors* 2023, **13**(1): 55.
[3]H. Liu et al., *National Science Review* 2022, **9**(8): nwac101.
[4]X. Lv, X.-X. Zhang, and J. Wu, *J. Mater. Chem. A* 2020, **8**: 10026–10073.
[5]A. M. Avcı, S. Kızılırmak, and E. Suvacı, *American Ceramic Society Bulletin* 2023, **102**(8): 38–41.
[6]"Lead-free piezoelectric ceramics: Technologies and global opportunities," BCC Research, April 2022, Report Number NAN063B.
[7]Entekno Global, "Exciting announcement: Unveiling the Life Med-U Project," LinkedIn. Published 30 Nov. 2023. https://bit.ly/Life-Med-U-announcement ■

bccResearch

Markets for advanced wound management technologies

By BCC Publishing Staff

The global market for advanced wound management products was valued at $10.7 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 6.2% to reach $15.3 billion by 2028.

It is estimated that nearly 50 million people suffer from hard-to-heal wounds globally. The incidence is expected to rise with ageing populations worldwide as well as the increasingly common occurrence of chronic conditions such as diabetes and obesity.

For hard-to-heal wounds, traditional wound care therapies such as bandages, gauze, and plasters are often not sufficient to produce adequate healing and comfort. Instead, advanced wound management products can help manage biofilm and bioburden to reduce rates of infection, inflammation, and wound chronicity, thus accelerating the wound healing process.

The global market for advanced wound management products is segmented into five categories (Table 1):

- **Advanced nonbiological wound dressings** cover the site of injury to provide protection from exogenous infection and maintain an optimal moist environment for healing. These dressings are made from both natural materials, such as alginate, and synthetic materials, such as hydrogels.
- **Wound biologics/bioactives**, also known as biological dressings, are wound care products produced from biomaterials. These products are known for their biocompatibility, biodegradability and nontoxic nature. They generally fall into two categories: skin grafts or substitutes and growth factor technologies.
- **External wound healing devices** use different mechanisms to activate the body's normal regenerative processes to accelerate wound healing. Examples include negative pressure wound therapy, which applies continuous or intermittent subatmospheric pressure to the surface of a wound, and transcutaneous oxygen therapy, which encourages oxygen flow while not drying out the wound bed.
- **Anti-adhesion products** prevent tissue from forming between two surfaces inside the body following operation. Meanwhile, **advanced debriding and cleansing agents** are used to remove damaged tissue from wound beds by softening or loosening necrotic debris.

Table 1. Global market for advanced wound management products, by type, through 2028 ($ millions)

Type	2021	2022	2028	CAGR % (2023–2028)
Advanced nonbiological wound dressings	4,079.9	4,169.1	5,264.2	3.9
Wound biologics/bioactives	2,028.7	2,149.7	4,137.3	12.2
External wound healing devices	2,332.2	2,434.9	3,175.1	4.1
Anti-adhesion products and advanced debriding and cleansing agents	1,161.8	1,219.0	1,812.4	6.8
Wound closure sealants and glues	697.4	727.4	946.6	4.1
Total	10,300.0	10,700.0	15,335.6	6.2

- **Wound closure sealants and glues** are used to close wounds. While sealants are typically made from absorbable materials designed to control internal bleeding, glues are usually nonabsorbable and used to seal topical wounds.

The largest suppliers for advanced wound management products are all headquartered in Europe or the U.S. However, increasing awareness of the benefits of advanced wound management technologies and proper wound care protocols is driving increased demand in other areas of the world, such as Asia-Pacific. But the high cost of advanced wound management products and insufficient reimbursement policies remain restraining factors in the market.

About the author

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

Resource

BCC Publishing Staff, "Markets for advanced wound management technologies," BCC Research Report PHM011K, July 2023. https://bit.ly/BCC-July-2023-wound-management

acers spotlight

SOCIETY
DIVISION
SECTION
CHAPTER
NEWS

Welcome new ACerS Corporate Partners

ACerS is pleased to welcome its newest Corporate Partners:

GCA Glass Packaging

Japan Fine Ceramics Co., Ltd.

Pacific Clay Products Inc.

Triangle Brick Company

UL Research Institutes

Xinxing Electronic Ceramics Co., Ltd

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

ACerS Pittsburgh Section seeks nominations for the J. Earl Frazier Memorial Scholarship

The ACerS Pittsburgh Section is seeking nominations for this year's Earl Frazier Memorial Scholarship. The scholarship is named in honor of J. Earl Frazier, past president and honorary member of The American Ceramic Society. The student who best exemplifies Frazier's commitment to the ceramic sciences will be awarded $5,000 to support their studies in ceramics, materials science, and/or engineering.

For more information and details on how to apply, visit https://ceramics.org/Frazier-scholarship-2024. ■

ACerS Pittsburgh Section presents the William S. Bates Award

The ACerS Pittsburgh Section presented the William S. Bates Award to Section member Glenn McIntyre on Monday, Aug. 26, 2024, during the Annual Pittsburgh Golf Outing at the Birdsfoot Golf Course in Freepost, Pa. The award recognizes individuals who further the efforts of the Pittsburgh Section as well as the local community.

McIntyre has been active with the Pittsburgh Section for more than 20 years and is currently serving as treasurer. He says his favorite Section activity is helping judge the Future City competition for junior high school students. ■

Eric Young, right, presents Glenn McIntyre with the ACerS Pittsburgh Section William S. Bates Award.

FOR MORE INFORMATION:

ceramics.org/spotlight

ACerS Pittsburgh Section Annual Golf Outing: Photos and results

The ACerS Pittsburgh Section held the Annual Pittsburgh Golf Outing on Monday, Aug. 26, 2024, at the Birdsfoot Golf Course in Freepost, Pa. The day boasted wonderful weather and fun for all. The Section thanks the following hole sponsors for their support:

- Aluchem
- Fusion Ceramics Inc.
- Imerys / KT Clay
- Standard Ceramic
- BNZ
- HarbisonWalker International
- Mount Savage
- Swindell Dressler
- Chiz Brothers
- Henry F. Teichmann
- Refractory Anchors

All proceeds from the outing go toward the Pittsburgh Sections' J. Earl Frazier Memorial Scholarship Fund, which will be awarded to a college senior majoring in ceramics, materials science, and/or engineering. Special thanks to Brad Lynne of Imerys for his donation of the 50/50 winnings to this fund.

Thanks to all the winners, participants, and staff at Birdsfoot Golf Course for helping make this year's annual outing a huge success. ■

First place (top photo): Scott Carter, John Sklarsky and Nick Kreitzer. Bryan Kraus is absent from the photo.

Second place (not pictured): Jordan Baker, Lee Dawber, Mick Geller, and Ray Crothers.

Third place (bottom photo): (Seated) Jay Hope and Dave Meuschke. (Standing) Eric Meuschke and Chad Rittle.

more SOCIETY DIVISION SECTION CHAPTER NEWS

ACerS International Brazil Chapter invites members to attend the Third São Carlos School on Glasses and Glass-ceramics

The ACerS International Brazil Chapter invites ACerS members to attend the Third São Carlos School on Glasses and Glass-ceramics in March 2025. This event, which is organized by the Center for Research, Technology, and Education in Vitreous Materials (CeRTEV), offers Brazilian and international Ph.D. students the opportunity to advance their knowledge in glass science.

- **Date and venue:** March 10–15, 2025, São Carlos, Brazil
- **Key topics:** Glass structure; crystallization; optical, electrical, mechanical, and biochemical properties
- **Instructors:** Esteemed faculty from CeRTEV and The New York State College of Ceramics at Alfred University
- **Student grants:** 40 available, with the possibility for more based on industry support
- **Application requirements:** Submit an abstract of your research and proof of travel funds by **Dec. 20, 2024**.

For more details, visit the website at https://bit.ly/Sao-Carlos-Glass-School-2025 or contact Edgar Zanotto (dedz@ufscar.br), Laurie Leal (certevlamav@gmail.com), and Ricardo Felipe Lancelotti (lancelotti.r@dema.ufscar.br). ■

ACerS International Brazil Chapter co-hosts workshop on 'How to Prepare and Publish a Scientific Paper'

The ACerS International Brazil Chapter, in collaboration with the Jovens Ceramistas do Brasil network, hosted the workshop "How to Prepare and Publish a Scientific Paper" on Sept. 10, 2024. The event attracted more than 60 participants both in person and remotely.

Leticya L. Coelho, seasoned scientific editor at Elsevier and Ph.D. graduate in chemical engineering from the Federal University of Santa Catarina, led the workshop, offering invaluable insights into the scientific publication process. Key topics included navigating the publication process, submission tips, ethical compliance, and effectively handling rejections.

For those who missed the event or wish to revisit it, the recording is available at https://youtu.be/9WscXlJPA8o. Additionally, Elsevier offers a free e-learning platform that contains extensive resources on research publishing and career development at https://researcheracademy.elsevier.com. ■

ICACC 2025: Student and young professional registration waiver and travel grant

Students or young professionals who are giving a presentation at the 49th International Conference and Expo on Advanced Ceramics and Composites in January 2025 may be eligible to apply for a registration waiver and/or travel grant. For more information, including the application, visit https://ceramics.org/ICACC-2025-travel-grant. ■

ACerS Engineering Ceramics Division announces childcare grant initiative for ICACC 2025

The Engineering Ceramics Division is offering childcare grants for those attending the 49th International Conference and Expo on Advanced Ceramics and Composites, which will be held Jan. 26–31, 2025, in Daytona Beach, Fla.

Grants of up to $400 will be given to selected registered meeting attendees who are bringing one or more young children to the conference or who incur extra expenses in leaving them at home (i.e., added hours of daycare or babysitting services).

For more information, including the application, visit https://ceramics.org/ICACC-2025-childcare. ■

more SOCIETY DIVISION SECTION CHAPTER NEWS

ACerS Mentor Programs: Registration open for 2025

ACerS Mentor Programs facilitate knowledge transfer, skill development, and career guidance by pairing seasoned professionals with emerging talents. These year-long programs are offered for students, faculty, and industry.

In 2024 alone, nearly 200 participants connected and collaborated through the ACerS Mentor Programs. You can join the 2025 Mentor Programs and start building the connections that will shape your future by visiting www.ceramics.org/mentorship. ■

MEMBER HIGHLIGHTS

Ceramic Tech Chat: Collin Wilkinson

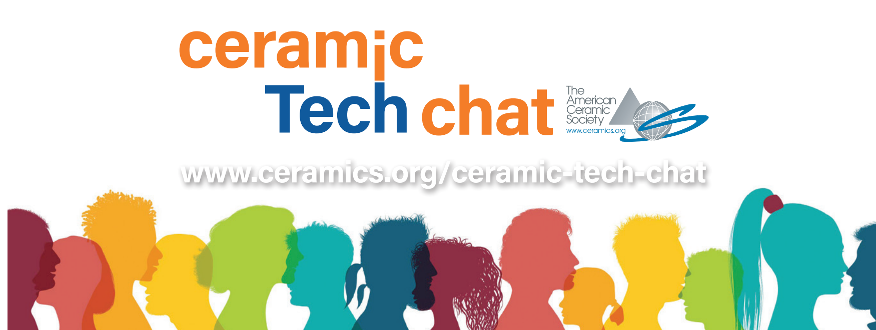
Hosted by ACerS Bulletin editors, Ceramic Tech Chat talks with ACerS members to learn about their unique and personal stories of how they found their way to careers in ceramics. New episodes publish the third Wednesday of each month.

In the August 2024 episode of Ceramic Tech Chat, **Collin Wilkinson**, assistant professor of glass science at Alfred University, shares how he became interested in glass recycling challenges, describes how he uses both modeling and experimentation to develop sustainable solutions, and discusses the importance of involving undergraduate students in the research process.

Check out a preview from his episode, where he talks about how to set up an undergraduate research program.

"So, the first thing you should know if you would like to start an undergraduate research program is that from a papers-published standpoint, you're not necessarily there. And that's okay. But from like an impact standpoint, it's really high because it's very clear that students who engage in the program are very quickly learning whether they want to do science or not. And if they do, they realize really quickly what it's like. And so for many of them, you can watch them grow in the course of a summer more than you've seen them grow in like two years."

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



FOR MORE INFORMATION:

ceramics.org/membership

more MEMBER HIGHLIGHTS

Volunteer Spotlight: Irene Peterson

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

Irene Peterson is a principal research scientist in the Materials Conversion Directorate at Corning Research and Development Corporation in Corning, N.Y. She received a Ph.D. in materials science and engineering from the University of Michigan–Ann Arbor. After graduation, she worked as a post-doctoral researcher at the National Institute of Standards and Technology before joining Corning.

At Corning, Peterson studies the kinetics of phase reactions in ceramic materials, invents and scales up new products and processes, and provides technical support to glass production plants in the United States, Europe, and Asia.

Peterson is an ACerS Fellow, Global Ambassador, and past chair of the Glass & Optical Materials Division. She enjoys organizing sessions for ACerS conferences, especially the "Challenges in Manufacturing" session at the annual GOMD meeting.

We extend our deep appreciation to Peterson for her service to our Society! ■

IN MEMORIAM

James Ballenger

David Swinehart

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

ACerStudent Engagement: Kartik Nemani

Kartik Nemani is a Ph.D. candidate in mechanical engineering at Purdue University and served as chair of the Professional Development Committee of ACerS President's Council of Student Advisors (PCSA) from 2021–2023. Apart from research, Nemani is a passionate artist and bridges science and art using digitally altered electron microscopy images.

"Participating in the development and implementation of ideas and leading a small team in organizing professional development activities at various levels within ACerS was a pivotal aspect of my journey, as it allowed me to serve the Society through the PCSA. As an international delegate, I found this experience incredibly enriching, and I can envision many of my colleagues embracing voluntary roles within the Society."

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

Names in the News

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

WORLD ACADEMY OF CERAMICS

Several ACerS members were elected as Academicians of the World Academy of Ceramics (WAC). Nominations were approved by the Council on Sept. 4, 2023, and inductions took place during the 14th International Conference on Ceramic Materials and Components for Energy and Environmental Systems on Aug. 19, 2024, in Budapest, Hungary. Congratulations to the following members:

- **Bikramjit Basu**, FACerS, Indian Institute of Science, Bangalore
- **Geoff Brennecka**, FACerS, Colorado School of Mines
- **Kyle Brinkman**, FACerS, Clemson University
- **Xiang Ming Chen**, FACerS, Zhejiang University
- **Manoj Choudhary**, FACerS, The Ohio State University
- **Manabu Fukushima**, FACerS, National Institute of Advanced Industrial Science and Technology
- **Gideon Grader**, Technion - Israel Institute of Technology
- **Chun-Hway Hsueh**, FACerS, National Taiwan University
- **John C. Mauro**, FACerS, The Pennsylvania State University
- **Eugene A. Olevsky**, FACerS, San Diego State University
- **Zbigniew Pedzich**, AGH University of Science and Technology
- **Sanjay Sampath**, FACerS, Stony Brook University
- **Shujun Zhang**, FACerS, University of Wollongong

Jincheng Du, FACerS, University Distinguished Research Professor of materials science and engineering at the University of North Texas (UNT), was appointed as the new chair of the Department of Materials Science and Engineering at UNT.

Hiroyuki Inoue, emeritus professor at the University of Tokyo, was appointed as the new president of the International Commission on Glass. He takes over for Reinhard Conradt, who served as president from 2021–2024. ■

AWARDS AND DEADLINES

Nomination deadlines for Division awards: Jan. 15, Jan. 21, and Jan. 31, 2025.

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

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

FOR MORE INFORMATION:

ceramics.org/members/awards

Call for Society award nominations

The 2025 ACerS Society award nomination portal is open and accepting submissions through **March 1, 2025.** ACerS is fully committed to running a thriving awards program that recognizes the contributions of deserving individuals and companies within the ceramics and glass community. Nominations are encouraged for candidates from groups that have been underrepresented in ACerS awards relative to their participation in the Society, including women, underrepresented minorities, industry scientists and engineers, and international members. For specific award information and to access the online submission portal, visit ceramics.org/awards. ■

2024 Ceramographic Exhibit winners

Roland B. Snow Award for Best in Show

A conversation across 2,000 years–**Alexander Frisch**, Karlsruhe Institute of Technology, Karlsruhe, Germany

<u>Optical microscopy category</u>

First: *A conversation across 2,000 years*–**Alexander Frisch**, Karlsruhe Institute of Technology, Karlsruhe, Germany

Second: *The cracked rainbow fish*–**Xufei Fang**, Karlsruhe Institute of Technology, Karlsruhe, Germany

Third: *MXene cichlid*–**Perona Kaushik**, Purdue University, West Lafayette, Ind.

<u>Scanning electron microscopy category</u>

First: *Spinel tennis ball on a MgO court*–**Otávio H. Borges**, Federal University of São Carlos, Brazil

Second: *Multiple personalities: The destructive and the curative faces of temperature*–**Anita Razavi**, University Koblenz, Germany

Third: *Fractal-fractography*–**Jia-Huei Tien**, Purdue University, West Lafayette, Ind.

<u>Transmission electron microscopy category</u>

First: *Sherlock: The MXene chronicles*–**Krutarth Kamath**, Purdue University, West Lafayette, Ind.

Second: *Nanoparticle collision in infinity*–**Anupma Thakur**, Purdue University, West Lafayette, Ind.

Third: *MXenes by the sea*–**Krutarth Kamath**, Purdue University, West Lafayette, Ind. ■

CERAMIC AND GLASS INDUSTRY FOUNDATION

Celebrating 10 years with a new look and renewed commitment

As the Ceramic and Glass Industry Foundation (CGIF) commemorates its 10th anniversary, this milestone is marked by a refreshed logo, a generous matching gift fund, and a celebration of the young minds the Foundation has inspired.

New logo for a new era

Central to the new CGIF logo design is a distinctive flame, representing the transformative power of high temperatures essential to the field, coupled with a gear symbolizing the industry it serves. The logo captures the essence of the CGIF's science and technology focus through these industry motifs.

Investing in the future: ACerS Matching Gift Fund

The American Ceramic Society is providing a $250,000 matching gift fund to commemorate the CGIF's 10th anniversary. This generous gift allows donors to maximize their contribution with every dollar donated.

Celebrating a decade of inspiring young minds

Reaching more than 50,000 students annually, the CGIF has made significant strides in introducing young people to the wonders of ceramic and glass materials science.

From Material Science Classroom Kits that equip teachers with engaging resources to scholarships specifically designed for underrepresented students, the CGIF has created a multifaceted approach to fostering and engaging young talent. The Foundation also nurtures future leaders through the ACerS President's Council of Student Advisors (PCSA) by offering travel grants and professional development opportunities.

Looking ahead

The CGIF is grateful to all who have collaborated with or supported the Foundation and its endeavors in engaging the next generation of ceramic and glass science professionals.

"Your support is crucial as we continue to foster the talents that will lead the ceramic and glass materials community into the future," says Marcus Fish, director of development and industry relations at the CGIF.

Join the celebration

Join in celebrating this milestone by contributing to the continued growth and success of the CGIF. Visit ceramics.org/donate to make a donation and have your impact doubled by the ACerS Matching Gift Fund! ■

Semi-automatic annotation accelerates data extraction from science literature

The emergence of large language models, such as those that power ChatGPT, have the potential to revolutionize the extraction and curation of materials science data. Extracting relevant data from the literature, however, can only happen after the text is properly labeled and organized. Unfortunately, scientific texts typically do not present data in a structured, uniform manner. So, researchers are often left with the cumbersome task of annotating the data before extraction.

Several groups have explored the development of semi-automatic annotation methods to reduce the need for manual labeling. Inspired by these past works, researchers led by University of Utah associate professor Taylor Sparks developed a method that harnesses the power of Google's Gemini Pro language model to further reduce the need for manual annotation.

To develop this method, Sparks and his graduate students Hasan M. Sayeed and Trupti Mohanty fed text from materials science literature into their model one section at a time. They then selected a diverse set of 10 articles spanning various domains within materials science, such as supercapacitors, high-entropy alloys, batteries, and ceramics, to test their method.

Compared to manual annotation of the papers, which typically requires about 55 minutes per paper, the use of Gemini Pro reduced the need for manual editing and corrections to about 15 minutes per paper. However, Sparks and his students note that their method used only a single language model, so future studies should consider using multiple models for benchmarking purposes.

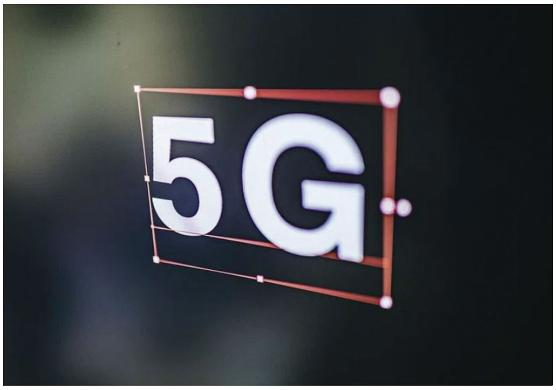
The paper, published in *Integrating Materials and Manufacturing Innovation*, is "Annotating materials science text: A semi-automated approach for crafting outputs with Gemini Pro" (DOI: 10.1007/s40192-024-00356-4). ■

Designing next-gen communication networks: Review of niobium-containing ceramics for 5G

As the telecommunications industry continues its push to implement 5G networks in cities around the world, researchers persist in their quest to identify low-cost materials with enhanced properties to support this technology.

Ceramic materials play a vital role in this development, as their excellent dielectric behavior enables their use in devices that require high-frequency response in the GHz range. In particular, ceramic compositions containing niobium have demonstrated great potential for this application.

In a recent open-access paper, ACerS members Reginaldo Muccillo and Eliana N. S. Muccillo reviewed the key properties of niobium-containing ceramics to demonstrate their potential for application in 5G communication devices.



Credit: Rawpixel

5G global connections may reach 7.7 billion by 2028, according to industry trade organization 5G Americas.

Key properties of 5G ceramics

For ceramics to perform well in GHz-range devices, there are three key material properties that must be considered:

- **Dielectric constant**, which determines the material's ability to store electrical energy.
- **Quality factor**, which reflects the material's efficiency in transmitting and storing energy.
- **Temperature coefficient**, which indicates the material's sensitivity to temperature changes.

The sintering temperature should also be considered to ensure compatible integration of the ceramic within electronic components.

Trends within the key properties of niobium-containing ceramics

Pulling from the literature, the researchers created a table of key property values for more than 80 different compositions of niobium-containing ceramics. They then created two figures to visually illustrate the relationships between different properties.

Based on these figures, they noted several trends among the key properties:

1. An inverse correlation exists between the quality factor and dielectric constant. Higher quality factors correspond to lower dielectric constants.
2. The temperature coefficient remains within the range of about −45 to +38 ppm/°C for dielectric constants ranging from 12 to 25.
3. The quality factor falls within the range of approximately 12,000–170,000 GHz.

The researchers note "it is evident that there is considerable variation in these parameters among different compositions."

"Therefore, the selection of compositions based on oxides for telecommunication devices by industries depends on various factors, such as the sustainability of material production, … and, of course, dielectric properties suitable for telecommunication applications," they write.

Ongoing research and future directions

The researchers urge other groups to make use of this data to develop niobium-based dielectrics. But they also note that studies beyond characterization analyses, such as device integration, are needed to demonstrate the material's reliability for commercialization.

The open-access paper, published in the *International Journal of Ceramic Engineering & Science*, is "Ceramic compositions for 5G devices containing niobium: A survey" (DOI:10.1002/ces2.10201). ■

Research News

Shedding light on superconducting disorder

Researchers at Max Planck Institute for the Structure and Dynamics of Matter in Germany and Brookhaven National Laboratory in the U.S. demonstrated a new way to study disorder in superconductors using terahertz pulses of light. Their method, which is based on multidimensional spectroscopy techniques initially developed for nuclear magnetic resonance, involves sequentially exciting a material of interest with intense collinear laser pulses. The technique's versatility allowed disorder to be measured up to a relatively warm 70% of the superconducting transition temperature. For more information, visit https://www.mpsd.mpg.de/907417/2024-09-2Dspectroscopy-liu?c=2736.

Small electric currents could reduce skin infections

Researchers from the University of Chicago and the University of California, San Diego found that, under the right environment, a few zaps of electricity to the skin can stop bacterial infections without using any drugs. They tested the technique on Staphylococcus epidermidis, a generally harmless bacterium that can cause serious infections when it enters the human body through a cut or medical procedure. The team found that in acidic environments, small electric currents prevented biofilm formation and reduced the number of S. epidermidis cells. This finding could help with treating infections caused by antibiotic-resistant bacteria. For more information, visit https://www.sciencedaily.com.

Preventing concrete failure: Understanding how calcium nitrate mitigates alkali–silica reactions

Researchers from the University of California, Los Angeles aimed to clarify exactly how calcium nitrate helps mitigate alkali-silica reactions (ASR) in concrete.

ASR is a common cause of concrete deterioration. It occurs when aggregates containing certain forms of silica react with hydroxyl ions in the alkaline cement pore solution. The reaction produces a gel, which absorbs water from the surrounding environment and expands. Expansion of the gel exerts pressure on the concrete, causing it to crack and fail.

Manufacturers often rely on additives such as fly ash to mitigate and slow the progress of ASR. Recently, the agricultural fertilizer calcium nitrate has been found to effectively mitigate ASR in cementitious systems, but the exact mechanisms behind this mitigation remain unclear.

To clarify this mechanism, the UCLA researchers combined calcium nitrate with two types of cement (Type I/II and Portland limestone). They then added aggregates of varying reactivity as well as different types and dosages of supplementary cementitious materials, such as amorphous steel slag and Class C and Class F fly ashes.

Using microstructural examinations, dissolution studies, and thermodynamic calculations, the researchers determined that calcium nitrate induces the formation of calcium silicate hydrate, portlandite, and calcite precipitate mixtures, which form on the aggregates' surfaces at the expense of typical ASR gels. Such precipitates create a dissolution barrier and inhibit ASR in formulations both with and without supplementary cementitious materials.

"The outcomes indicate that CN [calcium nitrate] is an efficient and cost-effective ASR mitigation additive (~$250–$600 per tonne), particularly in a time of dwindling fly ash supplies," they conclude.

The paper, published in *Journal of the American Ceramic Society*, is "Calcium nitrate effectively mitigates alkali–silica reaction by surface passivation of reactive aggregates" (DOI: 10.1111/jace.20004). ■

New coatings to help boost turbine engine efficiency

Researchers led by the University of Virginia developed new protective coatings that allow turbine engines to run at higher temperatures before components begin to fail. The coatings consist of multiple rare earth oxides and are used to protect refractory metal alloys. Refractory metal alloys are durable and heat-resistant, but their poor oxidation resistance keeps them from being used in the hot section of turbine engines. The new rare earth oxide coatings could enable this application of refractory metal alloys, however. The researchers plan to use computer simulations to continue improving the coatings and analyze the best ways to apply them. For more information, visit https://engineering.virginia.edu/news-events/news. ■

Stabilizing perovskite solar cells—researchers decouple the synergistic role of water and oxygen in degradation

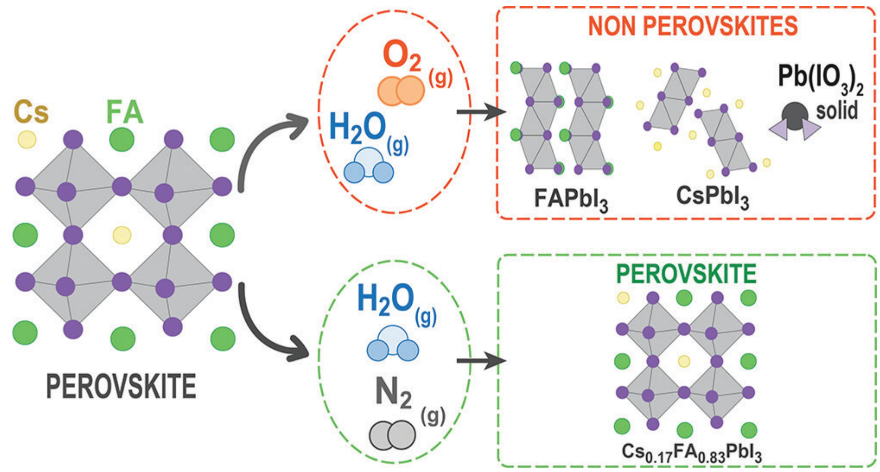


Illustration showing how metal halide perovskites will degrade when exposed to both water and oxygen but not when exposed to just one of the stimuli.

Researchers led by Georgia Institute of Technology made a surprising discovery about the mechanism that causes degradation of perovskites, which could help in developing all-perovskite solar cells with long-term operational stability.

Perovskites are a class of materials with the same crystal structure as calcium titanate. They have high light absorption efficiency and are easily fabricated, which makes them a desirable alternative to silicon, the main material used in today's solar cells. However, it is well documented that perovskites degrade quickly in sunny and humid environments, so a lot of research has focused on improving the durability of perovskites, such as by combining them in tandem with silicon.

In the recent study, the Georgia Tech researchers investigated mixed ion perovskites, which are known to provide improved stability compared to their single-cation counterparts. However, these perovskites still "degrade" when exposed to ambient air, i.e., the perovskite structure transforms into nonperovskite phases.

Even though this degradation is well documented, "we lack a clear understanding of the mechanisms that lead to phase instabilities," the researchers write. So, they used X-ray scattering and spectroscopy, along with density functional theory calculations, to provide a deeper understanding of the chemical interactions that occur between perovskites and the environment.

Their investigation led to an unexpected observation. While exposing perovskites to both water and oxygen led to instability, taking away one of those factors preserved the perovskites' energy-capturing crystal structure.

"Before this paper, people thought if you expose them to just water, these materials degrade. If you expose them to just oxygen, these materials degrade," says senior author Juan-Pablo Correa-Baena, assistant professor and Goizueta Early Career Faculty Chair in the School of Materials Science and Engineering at Georgia Tech, in a press release. "[But] if you prevent one or the other from interacting with the perovskites, you mostly prevent the degradation."

The researchers demonstrated the validity of this statement by coating a cesium-and-formamidinium-based halide perovskite film with a hydrophobic layer of phenethylammonium iodide (PEAI). The PEAI molecules' ability to repel water was enough to stabilize the perovskites' structure and thus their power conversion efficiency.

However, PEAI does not have good thermal stability, so once sunlight hit the perovskite cells, efficiency dropped. The researchers are working to develop new molecules that can prevent water interactions and remain stable at high temperatures.

The open-access paper, published in *Journal of the American Chemical Society*, is "Synergistic role of water and oxygen leads to degradation in formamidinium-based halide perovskites" (DOI: 10.1021/jacs.3c05657). ■

Relaunched 'World of Glass Map' supports efforts to improve glass recycling rates

In August 2024, the National Glass Association (NGA) relaunched its newly updated "World of Glass Map."

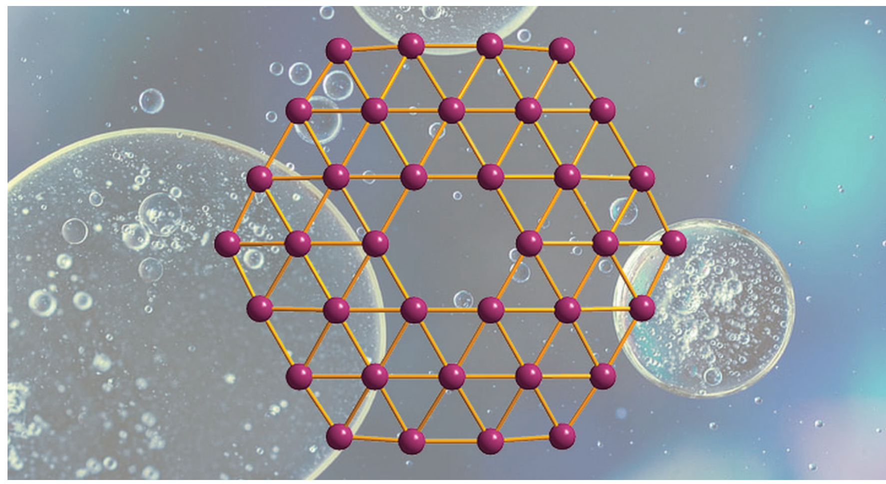
The "World of Glass Map" is an online, interactive map of global float glass manufacturing locations and North American glass fabrication facilities. Thanks to recent updates, website visitors can now easily view locations and capabilities, as well as search and sort companies by name and location.

In an NGA press release, NGA president and CEO Nicole Harris says that the map and its accompanying downloadable database are "vital for understanding the vast capacity and capability of glass manufacturers and fabricators."

The association is now working on adding glass recycling locations to the map to "help move NGA forward on its priority issue to keep glass out of the landfill," Harris says.

View the "World of Glass Map" at https://www.glass.org/world-glass-map. ■

Improving implantable technology: Chiral borophene demonstrates distinct interactions with cells



The hexagonal structure of borophene, illustrated above, has several polymorphs, which makes it easier to customize for specific applications, such as medical treatments.

Researchers at The Pennsylvania State University showed that synthesizing borophene with chiral structures allows it to interact with mammalian cells in distinct ways.

Borophene is one of the newest nanomaterials to begin making its way into biomedical applications. This material is very similar to graphene, consisting of boron rather than carbon atoms arranged in a hexagonal network. However, unlike graphene, borophene regularly forms in several different crystal structures (polymorphs), which allows for easier structural manipulation and thus customization of its material properties.

The ease with which researchers can manipulate the structure of borophene positions the material as a potential candidate for chirality. Chirality refers to the potential of a molecule to occur in two asymmetric forms that are nonsuperimposable mirror images of each. In other words, chiral molecules are like your hands: they can mirror each other precisely, but a left mitten will never fit the right hand as well as it fits the left hand.

Chirality is an important concept in drug design and development because chiral molecules can have different pharmacological activities and biological effects in the human body, despite having the same chemical formula. So, investigating the chirality of borophene molecules is vital to understanding how the material will interact with biological systems.

Borophene, though, is a highly reactive material that rapidly oxidizes in air. As such, developing a method to introduce chirality into the nanomaterial while preserving its stability is challenging.

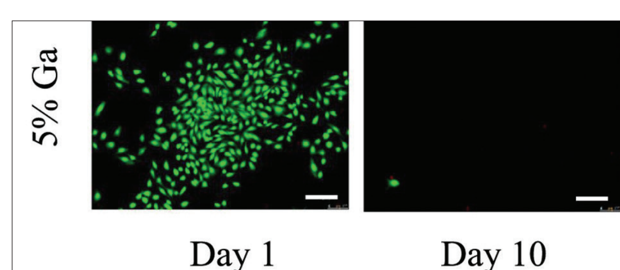
The Penn State researchers described a method based on liquid-phase probe sonication to produce chiral $\chi3$ and $\beta12$ phases of borophene nanoplatelets via interaction with chiral amino acids.

Physicochemical characterization of the chiral borophene, along with exposure to mammalian cells, revealed the nanoplatelets have distinct interactions with the cellular membrane based on their chirality. For example, while $\beta12$ borophene primarily entered the cell through energy-dependent and clathrin-independent endocytosis pathways, $\chi3$ borophene entered the cell through dynamin-mediated and clathrin-dependent endocytosis pathways.

This finding "demonstrated the potential for using such molecules in life science," the researchers write.

The paper, published in *ACS Nano*, is "Chiral induction in 2D borophene nanoplatelets through stereoselective boron–sulfur conjugation" (DOI: 10.1021/acsnano.4c01792). ■

Multimodal cancer treatment: Gallium-doped bioactive glasses kill cancer cells while stimulating new bone growth



Live/Dead fluorescence images for osteosarcoma cells treated with 20 mg mL^{-1} conditioned media (10× magnification). Green (live), red (dead). Scale bar equals 100 μm.

Researchers from Aston University in the U.K. explored the potential of using gallium-doped bioactive glasses as a treatment plan for osteosarcoma.

Osteosarcoma is the most common primary bone cancer and affects primarily children and young adults. Survival rates for osteosarcoma increased significantly in the late 1970s and early 1980s with the development of chemotherapy. Since then, though, the five-year survival rate has plateaued, with current rates relatively static around 53–55%.

The Aston University researchers had a two-fold purpose for choosing gallium-doped bioactive glasses as a possible treatment plan. First, gallium-based compounds are known for tumor suppression and so can help prevent local recurrence. But there can be side effects from injecting this metal into the body, so localized delivery is preferable. Bioactive glasses can be used for localized drug delivery, plus they can foster the growth of bone cells, which makes them ideal for repair and regeneration applications.

Preliminary studies on gallium-doped bioactive glasses helped slow the growth of osteosarcoma cancer cells. But given how rapidly cancer cells can multiply, "a significantly higher rate of kill is needed if these glasses are going to be a viable to treatment option," the researchers write.

To achieve this higher killing rate, the researchers used rapid quenching techniques to extend the glass forming region of the bioactive glasses. This extension allowed them to have higher gallium concentrations in the glass.

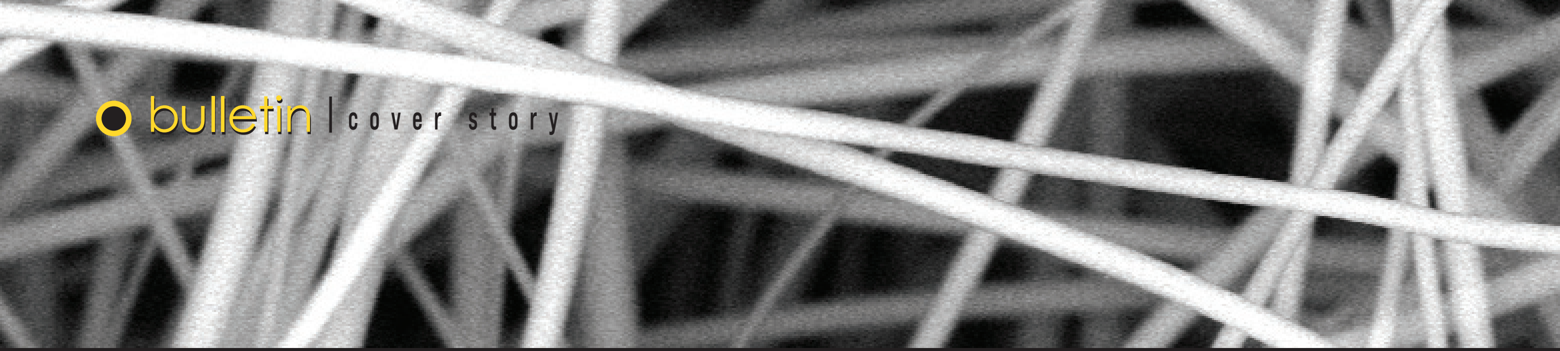
Testing of the gallium-doped bioactive glasses resulted in 99% of the human-derived osteosarcoma cells being killed while the normal human osteoblasts were minimally affected.

The reason gallium significantly affected the cancerous cells and not the healthy ones is because of its effect on a cell's iron uptake. Gallium forms complexes with transferrin receptors, which are the conventional pathway by which cells acquire iron for physiological requirements. Cancer cells are strongly dependent on iron for their growth and proliferation, so they are more sensitive to iron depletion when gallium forms complexes and blocks iron uptake.

In addition to suppressing tumor growth, the researchers observed that a layer of amorphous calcium phosphate/hydroxy apatite formed on the surface of the bioactive glass particulates after incubating in simulated body fluid—indicating the early stages of bone formation.

"The safety and effectiveness of these biomaterials will need to be tested further, but the initial results are really promising," says coauthor Lucas Souza, research laboratory manager for the Dubrowsky Regenerative Medicine Laboratory at the Royal Orthopaedic Hospital, in an Aston University press release.

The open-access paper, published in *Biomedical Materials*, is "Multifunctional gallium doped bioactive glasses: a targeted delivery for antineoplastic agents and tissue repair against osteosarcoma" (DOI: 10.1088/1748-605X/ad76f1). ■



Electrospinning for biomaterial applications

By Tessa Gilmore and Pelagia-Irene Gouma

After a slow rise to fame, the nanomanufacturing technique of electrospinning is gaining steam. The development of a high-throughput electrospinning setup at The Ohio State University opens the door to widespread use of this technique.

Since the turn of the 21st century, the field of nanomaterials has grown and gained prominence in numerous industrial sectors, including agriculture, pharmaceuticals, and chemicals processing. Yet even before these materials could be properly imaged and analyzed, people unwittingly employed nanomanufacturing techniques centuries beforehand.[1]

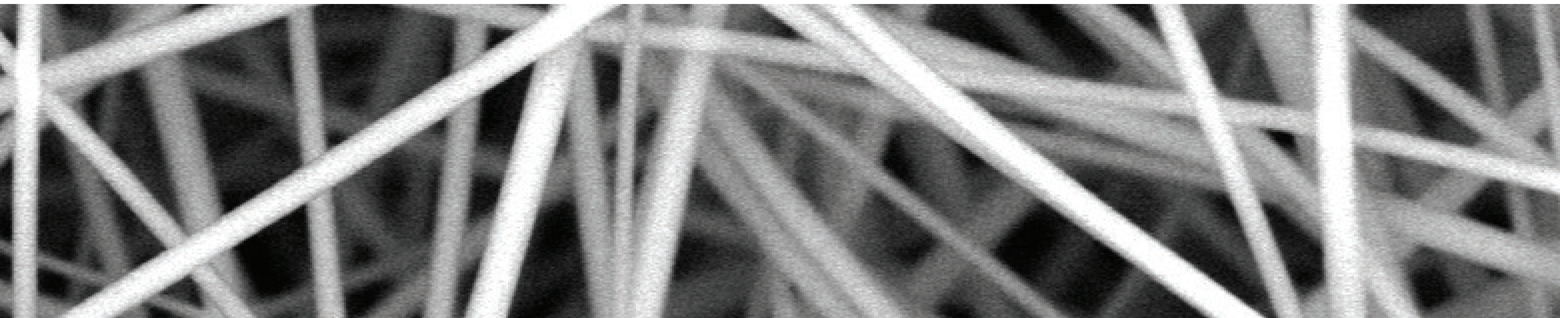
Of these techniques, electrospinning remains one of the most affordable and accessible approaches to nanofabrication. This technique produces submicron-diameter fibers and nonwoven mats via an electrostatic drawing process. It is primarily performed with polymeric materials, but it can also incorporate composites with ceramics or biomolecules.[1]

The electrospinning process was first patented by John Cooley in the early 1900s; however, initially there was little interest due to the low production rate and limited ability to characterize the fiber microstructures. Decades later, as advanced imaging and characterization methods were developed to analyze small-scale structures,[2] interest in nanotechnology grew in the 1990s. Yet despite this increased interest, publications focused on electrospinning remained sparse for almost two more decades.

This article provides a brief overview of the electrospinning process followed by a summary of work on electrospun bioceramics and biomaterials for health-related applications. A discussion of high-throughput electrospinning (HTES) is presented along with the potential for its widespread adoption using a new device developed by ACerS Fellow Perena Gouma's group at The Ohio State University (OSU).

The electrospinning process

The process of electrospinning, much like electrospraying, involves a polymeric solution that is electrically charged via an electrostatic field. This solution is pushed through an extruder and depos-



ited on a collector, facilitating the formation of a material with desired micro- and nanoscale features.

The simplest setup includes a syringe extruder with a needle or other small-diameter conductive capillary tip. A precursor solution of polymer and solvent is loaded into the syringe, which is placed into a syringe pump to produce a slow, continuous flow, typically within the ranges of 0.5–2.5 mL/h. The positive lead of the power supply is connected to the needle tip and the ground is connected to the collector to create a static electric field.

As the solution droplet at the needle tip encounters the electric field, the positive electromagnetic force of the field pushes against the surface tension of the solution. The electromagnetic force causes the solution droplet to narrow and extend into a conical shape known as the Taylor cone. Once the repulsive force of the field overcomes the surface tension, the cone tip narrows into a jet that eventually splits into fine fibers that fly through the air and deposit onto the collector. A schematic and experimental image of the Taylor cone can be seen in Figure 1.[3]

Over this flight distance (also known as the working distance), the precursor solvent evaporates, leaving the dried polymer fibers to land on the collector. The grounded collector then dissipates the fibers' charge, thus allowing for more fibers to deposit on top.

The resulting electrospun material is a nonwoven, flexible, and self-supporting mat of fibers that can be peeled from the collector for further processing or application (Figure 2). Depending on the collector used, different orientations of fibers can be obtained. For example, a standard flat plate collector yields randomly oriented fibers, whereas a spinning barrel drum collector yields aligned fibers. The geometry of the fibers can lend to different applications. For instance, randomly oriented fibers have advantages in filtration applications due to their low porosity and high surface area, while aligned fibers have advantages in mechanical applications due to their higher tensile strength.

Publications focused on electrospinning began appearing in greater numbers in the mid-2000s when the chemical fiber industry received increased focus and support. Since then, electrospinning has shown applications in filtration, photocatalysis for energy generation, and biomedicine, among others.[4]

Electrospinning opportunities in health-related applications

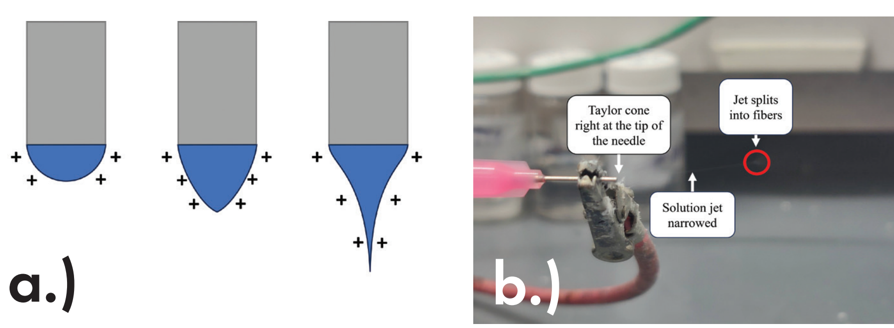
Gouma's group at OSU has been at the forefront of this resurged interest in electrospinning (see sidebar: "Perena Gouma: Leading the way in ceramic electrospinning at The Ohio State University"). They have demonstrated several innovations and applications for electrospun bioceramics and biomaterials, starting with the development of enzyme-containing electrospun fibers for biosensing applications in 2005.[5]

In medicine, a higher amount of urea in the human body can indicate kidney and liver function issues. So, researchers need a way to determine how much urea is in the body. The urease E.C.3.5.1.5. enzyme is a catalyst in the hydrolysis of urea to ammonia and carbon dioxide. By using urease to measure the amount of ammonia in the hydrolysis reaction, a relationship can be postulated to predict the amount of urea that is present.

As described in the 2005 publication,[5] Gouma's group electrospun a fibrous mat comprised of polyvinylpyrrolidone (PVP) and urease. It was the first time that a phosphate buffer solution (PBS) and ethanol were used for electrospinning enzymes. The electrospun receptor mat displayed rapid response times with the ability to detect ammonia at the trace concentrations needed for clinical applications. It also demonstrated a preservation of enzyme functionality for several months post-processing.

By showing this preservation of functionality, Gouma's research opened up the avenue for other research groups to use the PBS+ethanol method for electrospinning proteins, such as collagen.[6] As a result, the Collegiate Inventor's Competition recognized this electrospun receptor as a breakthrough in biosensors based on nanotechnology. Today, this enzyme encapsulation method is important in preserving synthetic proteins for transfer and use.

Electrospinning has other applications in biosensing and health diagnostics, such as the use of blend electrospinning with sol-gels to synthesize metal oxide nanowires for gas sensing. This sol-gel-based electrospinning method involves a variation on the traditional electrospinning process: Instead of a purely



Credit: (a) Tessa Gilmore; (b) Credit: Gilmore and Gouma, *Scientific Reports* (CC BY-NC-ND 4.0)

Figure 1 (above). (a) Schematic of the Taylor cone formation. The positive force of the electrostatic field helps form the droplet into the cone by pushing on the surface tension. (b) A Taylor cone during an electrospinning experiment.[3] Note how the cone extends for a small length before finally splitting into fibers (circled).

Credit: Tessa Gilmore

Figure 2 (left). An electrospun nonwoven mat of polyvinylpyrrolidone (PVP) fibers. The fibers were collected on a flat plate and therefore are randomly oriented.

Perena Gouma: Leading the way in ceramic electrospinning at The Ohio State University

By Charlee Gutridge, Ceramic and Glass Industry Foundation summer 2024 intern

Perena Gouma, the Edward Orton Jr., Chair in Ceramic Engineering at The Ohio State University, is well-known for her work on breath analyzers to detect various diseases. Less well-known are her contributions to the advancement of electrospinning for ceramic fiber manufacturing.

Gouma's journey into "the poor man's way to nanotechnology," as she calls the technique, began at a conference in Monterey, Calif, in the early 2000s. She was inspired by an Army Research Laboratory presentation on potentially using electrospinning to create soldier uniforms with built-in sensors. She began experimenting with the technique in her lab, and between 2005 and 2011, she published numerous papers demonstrating how electrospinning could be used to produce ceramic materials and composites for sensing, catalytic, and energy applications.[a–q]

Despite these successes, Gouma faced funding challenges while developing these ceramic electrospinning techniques. Reflecting on her experience, she notes, "Though I received grants for scalable manufacturing of materials using electrospinning, there wasn't much interest in supporting the development of the electrospinning equipment and process as a standalone tool, especially one that could be applied in industry."

Fortunately, 20 years later, Gouma says electrospinning is in a much better position. Fields such as bioengineering, biomedicine, and nanomedicine have embraced this manufacturing technique for applications including drug delivery, tissue engineering, and most recently artificial meat production. This recharged interest has spurred her latest breakthrough in the field: the development of a turnkey desktop system for high-throughput electrospinning.

Until now, researchers had to put together electrospinning systems by purchasing each component separately and assembling them. Now, with support from the Edward Orton Jr. Ceramic Foundation, along with an Accelerator Award from the State of Ohio and The Ohio State University, Gouma had the funding to develop a compact electrospinning system that researchers and small business owners can soon purchase and easily install in their laboratories.

"This system can be widely adopted, opening up new opportunities in nanofiber-based industries," she says.

This development, in addition to her other advancements, demonstrates how persistence can pay off and solidifies Gouma's impact on the field of electrospinning-based nanomanufacturing.

References

[a] A.M. Azad and P.I. Gouma, "Functional ceramic nanofibers via electrospinning," in *Encyclopedia on Nanoscience and Nanotechnology*, ed. H.S. Nawla, ASP, vol. 14, pp. 301–329, 2011.

[b] J. Lee and P.I. Gouma, *J. Nanomaterials* 2011, **2011**(1): 863631.

[c] Balazsi, A. Bishop, J.H.C. Yang, K. Balazsi, F. Weber, and P.I. Gouma, *Composite Interfaces* 2009, **16**(2–3): 191–200.

[d] K. Ramachandran and P.I. Gouma, *Recent Patents on Nanotechnology* 2008, **2**(1): 1–7.

[e] A. S. Haynes and P.I. Gouma, *IEEE Sensors Journal* 2008, **8**(6): 701–70.

[f] D. Rubenstein et al., *Microcirculation* 2007, **14**(7): 723–737.

[g] Bishop-Haynes and P. Gouma, *Materials and Manufacturing Processes* 2007, **22**(5–6): 764–767.

[h] A. Bishop, Cs. Balazsi, J. Yang, and P. Gouma, *Polymers for Advanced Technologies* 2006, **17**(11–12): 902–906.

[i] P. Gouma, A. Bishop, and K.K. Iyer, *Rare Metal Materials Engineering* 2006, **35**: 295–298.

[j] P. Gouma, K. Kalyanasundaram, and A. Bishop, *Journal of Materials Research, Nanowires and Nanotubes special issue* 2006, **21**(11): 2904–2910.

[k] K. Sawicka and P. I. Gouma, *J. Nanoparticle Research* 2006, **8**(6): 769–781.

[l] G.A. Wang et al., *J. Phys. Chem. B* 2006, **110**(47): 23777–23782.

[m] D. Han and P. I. Gouma, *Nanomedicine* 2006, **2**: 37–41.

[n] K.M. Sawicka, A.K. Prasad, and P.I. Gouma, *Sensor Letters* 2005, **3**: 1–5.

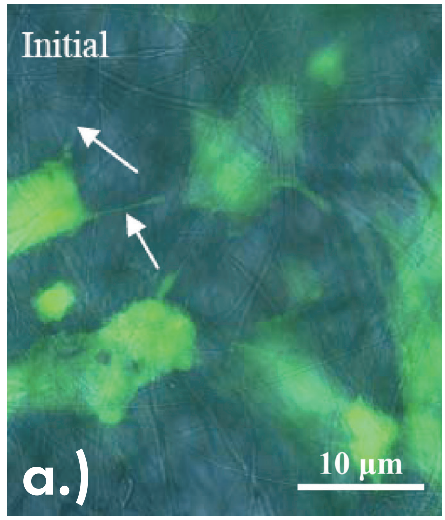
[o] A. Bishop and P. Gouma, *Rev. Adv. Mater. Sci* 2005, **10**: 34–40.

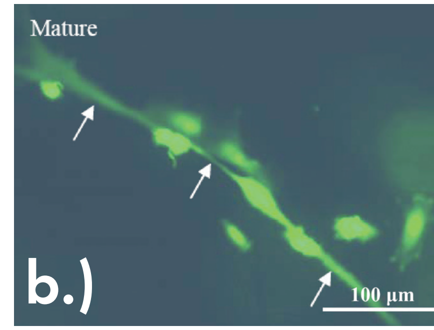
[p] K. M. Sawicka, P. Gouma, and S. Simon, *Sensors Act. B* 2005, **108**(1–2): 585–588.

[q] D. Han, S. Goldgraben, M. D. Frame, and P.I. Gouma, *MRS Online Proceedings Library* 2004, **845**: 222–227.

polymer precursor, with particles possibly dispersed within the matrix, a sol-gel precursor is used along with an amenable polymer carrier. Generally, a metal salt and carrier polymer are dissolved in a common volatile solvent. After electrospinning, each fiber consists of the sol encased within the polymer. Subsequent calcination in a furnace burns off the polymer and leaves nanowires of the desired metal oxide.

In 2006, Gouma's group successfully employed this sol-gel method to synthesize single crystal molybdenum trioxide (MoO_3) nanowires for ammonia (NH_3) gas sensing probes.[7] NH_3 is released through the breath and skin in small quantities and is an important biomarker in health monitoring because it relates to internal organ function. The goal in obtaining single crystals was to reduce

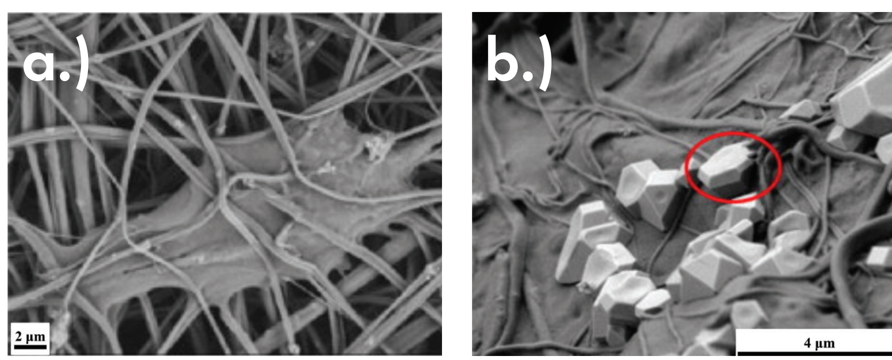




Credit: Han et al., *MRS Online Proceedings Library*

Figure 3 (left and above). Fluorescence microscope image of endothelial cells growing on CA + carbon nanotube membranes. Green indicates live cells (marked by white arrows).[10] (a) Cells after initial seeding. (b) Cells after five days of maturing; note the tubular structures formed along the fiber. Republished with permission.

Figure 4 (below). Scanning electron microscopy images of growth on electrospun mat.[11] (a) Osteoblast cells grown on CA and n-HA composite fibers. (b) New apatite mineral crystallites grown on composite fibers; the circled crystallite most clearly shows the hexagonal structure. Republished with permission.



Credit: Gouma et al., *Materials Science and Engineering: C*

the instability caused by the grain boundaries in multigranular oxides usually employed in gas sensing. The single crystal MoO_3 nanowires displayed a sensitivity to NH_3 much higher than that of the polycrystalline sol-gel-based MoO_3 films stabilized under the same conditions. Specifically, the single crystal MoO_3 displayed a sensitivity that scaled with the aspect ratio of the nanowires.

This experiment demonstrated that electrospinning not only could be used to create single crystal nanowires, but it also showed that these nanowires had an extremely high sensitivity to gases and the potential for use in breath analysis devices. Additionally, the group used this method to synthesize tungsten oxide nanowires for nitrogen dioxide gas sensing. These wires also displayed an improved gas sensitivity and response time when compared to tungsten oxide sol-gel films.[8] Ultimately, this nanotechnology has enabled the miniaturization of artificial olfactory devices for noninvasive medical diagnostics.

Also in 2006, Gouma's group demonstrated the use of electrospinning for tissue scaffolding by processing 3D scaffolds that mimicked the topology of the extracellular matrix (ECM) of a porcine unary bladder.[9] The ECM is a 3D structure system in the body that provides attachment points and mechanical support for cell growth. The ECM from the porcine small intestine or urinary bladder is especially suitable for regenerating tissues such as vena cava, small-diameter arterial grafts, and urinary bladder.

The electrospun mat consisted of cellulose acetate (CA), which is a biopolymer capable of imitating the biofunctions of the ECM. The mat also incorporated a dense layer, a cellular layer, and a fibrous layer on top of one another to imitate a natural ECM. The experiment illustrated that electrospinning as a single technique could be used to control both the architecture and the chemistry of a bioscaffold and that these scaffolds could be made using a single-step process with minimal required patterning.

Similarly, in collaboration with biotechnology colleagues, Gouma's group used electrospinning to create a thin, porous membrane of CA for scaffolds demonstrating microvascular cell growth.[10] Here, precursor solutions of CA with various concentrations of added carbon nanotubes were electrospun into fibrous mats. Endothelial cells then were trypsin digested, deposited onto the mats, and left to mature over several days. The results indicated that all electrospun mats, including the control mat with no carbon nanotubes, could support the cells and demonstrated live cells after maturing five days. Additionally, following the initial deposition, cells appeared to spread across fibers to later form tubular-like structures (Figure 3).

The carbon nanotubes originally were added to provide more structural stability to the CA fibers for the cell growth, but they were found to be unnecessary. The CA mat with 0% w/v carbon nanotubes displayed the same cell viability as the CA mat with 0.25% w/v carbon nanotubes and a higher cell viability than the CA mat with 0.5% w/v carbon nanotubes.

Building on this research, in 2012, Gouma's group illustrated the successful growth of bone cells via a CA and nanohydroxyapatite (n-HA) electrospun composite.[11] Hydroxyapatite is the major mineral of natural bone and thus lends itself well to the synthesis of artificial scaffolds for bone repair. Previous efforts by other researchers revealed that ceramic–polymer composite systems suffered from poor dispersion and agglomeration of the ceramic powder when attempting to make artificial scaffolding. However, the employment of nanotechnology, and specifically electrospinning, helped to overcome these barriers.

The experiment performed by Gouma's group included an electrospun CA and n-HA composite mat. The mat

Electrospinning for environmental remediation applications

In addition to biomedical applications, electrospinning can help support the overall health of our planet through environmental remediation applications, such as filtration and photocatalysis.

Regarding filtration applications, in 2011, Gouma's group fabricated mats from cellulose acetate (CA) for oil absorption.[a] The mats were able to absorb about thirty times their weight in oil.

When creating the oleophilic mats, Gouma's group discovered the mats were also super water repellant even though CA is normally hydrophilic. Seven years later, in 2018, the group finally determined why.[b] The process of electrospinning roughened the surface and decreased the stretching of the hydroxyl bonds in CA, leading to the change from hydrophilicity to hydrophobicity.

Regarding photocatalysis applications, in 2014, Gouma's group used electrospinning to process mats of copper oxide and copper tungsten oxide nanowires.[c] The electrospun mats featured a chain structure of nanocrystals with low angle boundaries that acted as photocatalysts to clean water using sunlight. Unlike most photocatalysts that only respond to ultraviolet light, these blankets responded to the entire solar spectrum.

Remarkably, the mats could reduce BTEX levels to under concentrations needed for drinking water. BTEX are a group of chemicals that can affect the kidney, liver, and blood systems. Moreover, as the mats broke down the chemicals in the water, they prevented BTEX from volatizing into the air with water evaporation, thereby reducing overall emissions.

References

[a]P. Gouma and J. Lee, "Fiber mats coated with nanogrid visible spectrum photocatalysts," *Supplement to the Australian Official Journal of Patents* 2014, **28**(3): 462.

[b]F. Mikaeili and P. I. Gouma, "Super water-repellent cellulose acetate mats," *Scientific Reports* 2018, **8**(1): 12472.

[c]P. I. Gouma and J. Lee, "Photocatalytic nanomats clean up produced water from fracking," *Translational Materials Research* 2014, **1**(2): 025002. ■

then was seeded with osteoblasts (i.e., cells that grow bone tissue) and left to mature for up to 14 days. After maturity, the seeded osteoblasts were observed to have used the electrospun fibers as anchoring points, and that allowed new apatite minerals to form on the fibers (Figure 4).[11] Ultimately, the research showed that electrospinning is a promising candidate in the synthesis of bone scaffolds for repair and growth.

In recent years, many other groups have employed electrospinning for biomedical advances. For example, in 2023, Zhang et al. published a review detailing how the random mesh and high porosity of electrospun mats can facilitate the healing of wounds.[12] Not only can the fibers act as anchor points for cell attachment and growth, but they also can prevent excess water loss and maintain a moist environment for the wound as well as prevent bacteria from entering the wound.

Additionally, electrospun fibers can be made from natural or synthetic polymers and can be loaded with additives for antibacterial or growth properties. For example, Chen et al. electrospun a mat of polyurethane with kaolinite and silver nanoparticles.[13] The mat demonstrated the ability to reduce inflammation and promote collagen deposition to accelerate healing.

Along with wound healing, electrospun mats are being investigated as hemostatic bandages for acute hemorrhage. Many hemostatic cloths and powders employ clays to promote clotting and stop excess bleeding. In 2021, Cui et al. exhibited a mat of PVP fibers loaded with kaolinite clay to suppress massive bleeding.[14] The mat displayed an improved performance on hemostatic time and effect compared to other commercial products. These mats can be a promising tool for prehospital care and may contribute to saving many lives in military conflicts, traffic accidents, and surgical procedures.

Another major application of biomedical electrospinning is for use in drug delivery. The electrospinning process offers a large amount of customization and tunability that is not available in other nanofiber synthesis processes. The produced nanofibers also are well equipped for the sustained and controlled release mechanisms required in drug release materials.

While research in this application is nascent, many review articles have been published explaining the opportunities that electrospinning offers for drug delivery systems. Once such article by Gaydhane et al. thoroughly explains the different drug delivery systems in the human body and how electrospun fibers may perform in each of them.[15]

High-throughput electrospinning

With the many applications and advancements discussed here, one may ask why electrospinning is not more ubiquitous. The main challenge lies with scalability. Conventional lab-scale electrospinning is a very slow process that only fabricates about 0.01–0.1 grams of fibers per hour, which is too slow for industrial-scale performance.

Over the years, several groups have proposed different geometries to increase the fabrication rates of electrospinning. Two popular geometries are multineedle[16,17] and open reservoir.[18,19] While these geometries have shown large increases in fabrication rate, they suffer from yield loss issues detrimental to industrial upscaling.

Regarding multineedle setups, they can exacerbate needle clogging issues seen in conventional single-needle setups. These setups also can suffer from jet-to-jet interactions. Because most geometries call for single electric potentials, electrospun jets positioned too closely can repel one another and impede fibers from depositing onto the collector.

On the other hand, open-reservoir setups, including bowl-edge and bubble setups, employ large open surfaces of the precursor. This open pool can lead to premature drying of the solvent and requires the top layer of the precursor fluid to be repeatedly removed, substantially reducing the fiber production rate. These open reservoirs also can pose a health hazard due to the volume of solvent evaporating and the frequent use of toxic solvents employed in electrospinning.

A handful of companies, such as Elmarco (Liberec, Czechia) and Fluidnatek (Paterna, Spain), have designed very large machines capable of industrial-scale processing. However, these devices are restrictive in terms of usable polymers and solvents, which limits the capability of these machines given new electrospinning innovations. Additionally, these machines have an extremely large footprint, sometimes needing their own dedicated room, and can cost millions of dollars.

Ideally, an electrospinning setup would allow for multiple jets of fibers without risk of clogging or inter-jet interactions and could support the large quantity of an open-reservoir setup without the solvent prematurely evaporating. Such a system was designed in 2014 by Gouma's group (Figure 5).[3,20] This system employed a hollow disk extruder placed within a surrounding drum collector. The hollow disk had 24 short-distance capillary holes around the circumference. When fed with a continuous supply of precursor and electrical charges, the disk produced Taylor cones at all 24 capillary holes for fiber formation. The setup is similar to the bowl-edge geometry developed by Thoppey,[18] but it overcomes the issues of inter-jet interactions and premature solvent evaporation. The 24 capillary holes are carefully spaced to allow for the maximum amount of Taylor cones without overlap and the enclosed disk keeps the precursor from drying out.

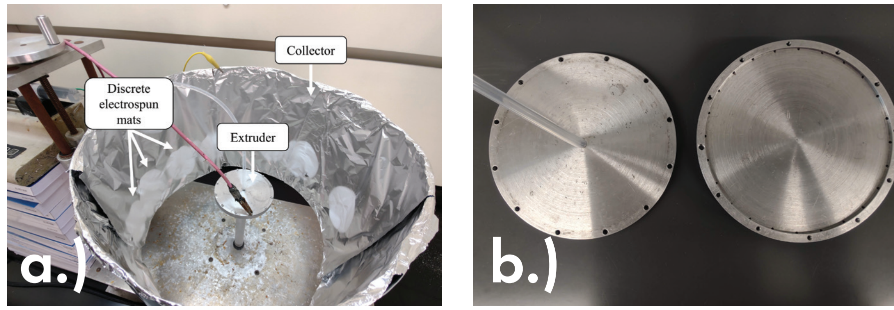


Figure 5. High-throughput electrospinning (HTES) prototype developed by Sood and Gouma in Reference 20. Pictures from Reference 3. (a) HTES prototype extruder and collector electrospinning discrete mats of fibers. b) The top half (left) and bottom half (right) of a hollow disk extruder. The 12 larger holes on top are for screws to attach the two halves. The capillary holes can be seen along the inside ridge of the bottom half.

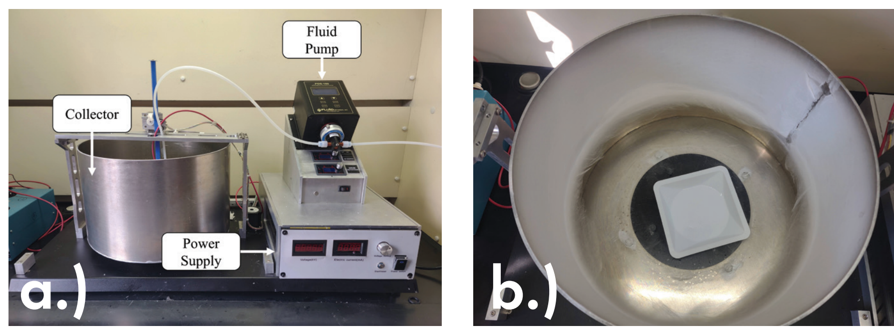


Figure 6. Improved high-throughput electrospinning setup built by The Edward Orton Jr. Ceramic Foundation.[3] (a) Main parts of the electrospinning setup. (b) A continuous fibrous mat electrospun by the system. The white tray at the bottom simply acts as a drip tray.

Initially, this system solely consisted of the novel collector and extruder, with the power and fluid pump supplied through external sources. Additionally, the system would create discrete circular mats that could eventually overlap only if enough precursor was electrospun. Regardless, the system provided a solid proof of concept that left room for growth.

Upon receiving an Accelerator Award from the state of Ohio in 2022, Gouma's group worked with The Edward Orton Jr. Ceramic Foundation to design and fabricate a second iteration that became the first proper and self-contained prototype apparatus (Figure 6).[3] This new system incorporates a power supply and fluid pump, which allows it to be self-contained, and a reasonably small footprint, which allows it to sit on top of a lab bench or within a large fume hood. The latter feature mitigates the need for the installation of dedicated HVAC hookups. The fluid pump also provides for more flexibility in the precursor amounts without being constrained by syringe size, unlike the previously used syringe pump.

Possibly the most impactful addition to the new design is the connection of the collector drum to a small motor, which allows for the collector to slowly rotate during electrospinning. This rotation is critical as it permits the electrospun mat to be a continuous rectangle rather than the separated circles made by the original system, as seen in Figure 6b. Once removed from the collector, the electrospun mat has dimensions of about 36 cm x 119 cm (1.18 ft x 3.90 ft).

The new design supports a fabrication rate that is roughly 15 times greater than that of a conventional, single-needle setup. As such, this current apparatus is ideal for lab-scale high-throughput electrospinning, but the geometry of the setup is also geared to act as a bridge to industrial-level production rates. This extension can be made by enlarging the collector and extruder disk, which would provide for more capillary holes, thereby permitting more jets and a greater rate of fibers per hour on a larger surface area collector. The simplicity of the system also means that a variety of solvents and precursors can be used, unlike the more restrictive industrial-scale machines offered today.

More information about this high-throughput electrospinning apparatus can be found at https://mse.osu.edu/acrl.

Summary

Since the mid-2000s, electrospinning has demonstrated great potential in many biomedical applications, including tissue and bone repair, wound healing, drug delivery, and gas sensing, as well as other health-related fields. Publications focused on electrospinning are growing in number each year as the scientific community finds new innovations and applications for these beneficial mats.

The rapid advancement and growing number of these applications shows an increased imperative for scaled-up electrospinning machinery to promote commercial viability. Various research groups have demonstrated feasible setup constructs. However, many of these proposed setups exhibit design flaws, such as exacerbated clogging or premature solvent evaporation. A few companies have fabricated large machines capable of industrial-scale production, but they also suffer from limited workable solvent and materials, which restricts scientific innovation.

The high-throughput electrospinning system developed by Gouma and her research group is a key advancement in electrospinning technology for biomedical and other applications because it allows for faster lab-scale electrospinning and offers a clear gateway to industrial-scale fabrication rates. The flexibility of the system also provides an avenue to commercial viability for the many inventions listed here. Improvements in high-throughput electrospinning apparatuses may lead to the increased adoption of this versatile processing technique and further innovations in biomedicine and healthcare in the future.

About the authors

Tessa Gilmore is a graduate research associate and Pelagia-Irene Gouma is the Edward Orton Jr., Chair in Ceramic Engineering at The Ohio State University. Contact Gouma at gouma.2@osu.edu.

References

[1]S. Bayda, M. Adeel, T. Tuccinardi, M. Cordani, and F. Rizzolio, "The history of nanoscience and nanotechnology: From chemical–physical applications to nanomedicine," *Molecules* 2020, **25**(1): 112.

[2]F. Adams and C. Barbante, "Chapter 3: History and present status of micro- and nano-imaging analysis," in *Comprehensive Analytical Chemistry*, vol. 69, F. Adams and C. Barbante Eds.: Elsevier, 2015, pp. 67–124.

[3]T. Gilmore and P. Gouma, "Scalable electrospinning using a desktop, high throughput, self-contained system," *Scientific Reports* 2024, **14**: 25844

[4]F. Mikaeili, O. O. Abe, and P.-I. Gouma, "High-throughput electrospinning of biomaterials," in *Additive Manufacturing in Biomedical Applications*, vol. 23A, R. J. Narayan Ed.: ASM International, 2022, p. 0.

[5]K. Sawicka, P. Gouma, and S. Simon, "Electrospun biocomposite nanofibers for biosensing," *Sensors and Actuators B: Chemical* 2005, **108**(1–2): 585–588.

[6]B. Dong, O. Arnoult, M. E. Smith, and G. E. Wnek, "Electrospinning of collagen nanofiber scaffolds from benign solvents," *Macromolecular Rapid Communications* 2009, **30**(7): 539–542.

[7]P. Gouma, K. Kalyanasundaram, and A. Bishop, "Electrospun single-crystal MoO_3 nanowires for biochemistry sensing probes," *Journal of Materials Research* 2006, **21**(11): 2904–2910.

[8]K. M. Sawicka, A. K. Prasad, and P. I. Gouma, "Metal oxide nanowires for use in chemical sensing applications," *Sensor Letters* 2005, 3(1–2): 31–35.

[9]D. Han and P.-I. Gouma, "Electrospun bioscaffolds that mimic the topology of extracellular matrix," *Nanomedicine: Nanotechnology, Biology and Medicine* 2006, **2**(1): 37–41.

[10]D. Han, S. Goldgraben, M. D. Frame, and P.-I. Gouma, "A novel nanofiber scaffold by electrospinning and its utility in microvascular tissue engineering," *MRS Online Proceedings Library* 2004, **845**(1): 222–227.

[11]P. Gouma, R. Xue, C. P. Goldbeck, P. Perrotta, and C. Balázsi, "Nano-hydroxyapatite—Cellulose acetate composites for growing of bone cells," *Materials Science and Engineering: C* 2012, **32**(3): 607–612.

[12]X. Zhang et al., "Advances in wound dressing based on electrospinning nanofibers," *Journal of Applied Polymer Science* 2024, **141**(1): e54746.

[13]G. Chen et al., "Multifunctional electrospun textiles for wound healing," *J. Biomed. Nanotechnol.* 2022, **18**(3): 796–806.

[14]Y. Cui et al., "Robust hemostatic bandages based on nanoclay electrospun membranes," *Nature Communications* 2021, **12**(1): 5922.

[15]M. K. Gaydhane, C. S. Sharma, and S. Majumdar, "Electrospun nanofibres in drug delivery: advances in controlled release strategies," *RSC Advances* 2023, **13**(11): 7312–7328.

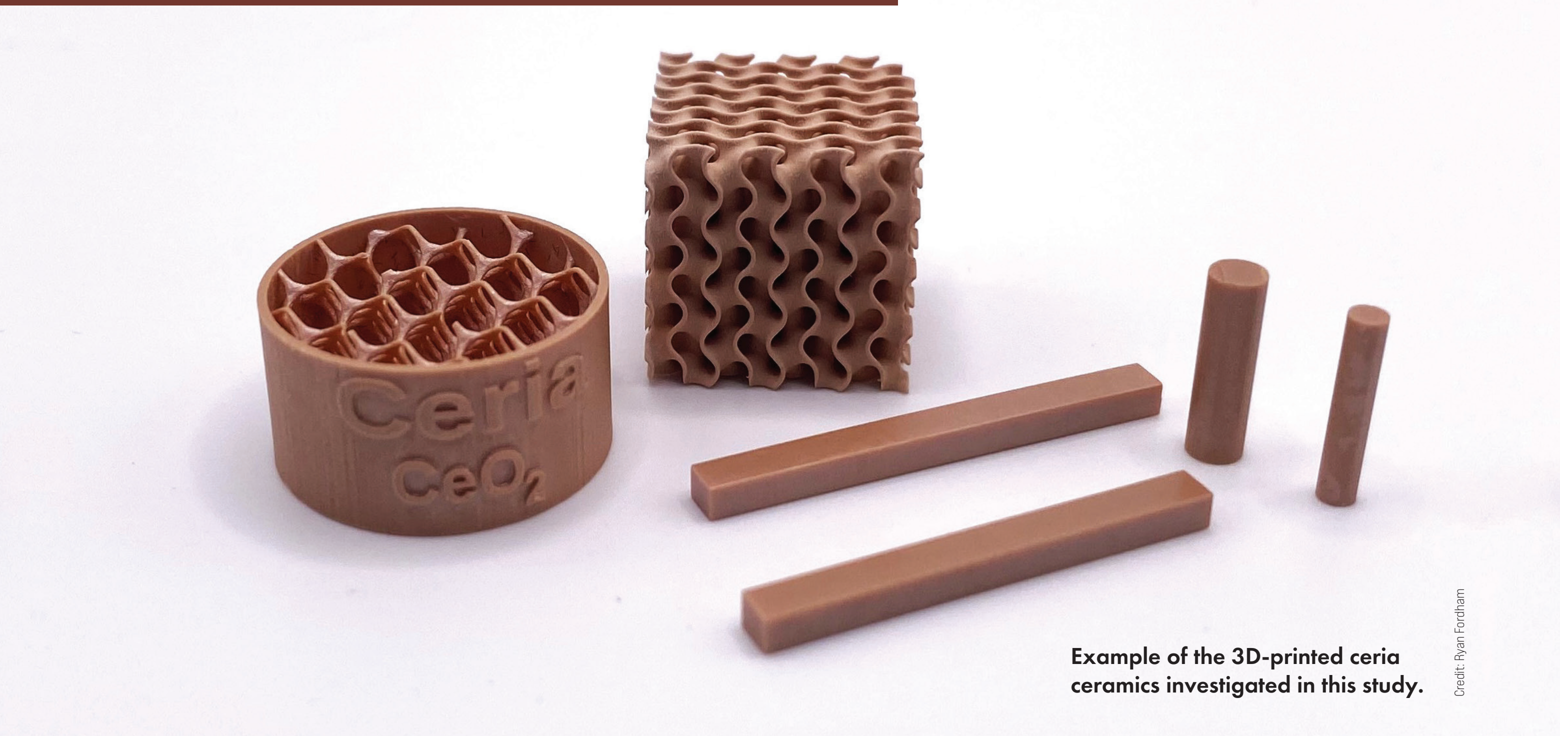
[16]J. Beaudoin É, M. M. Kubaski, M. Samara, R. J. Zednik, and N. R. Demarquette, "Scaled-up multi-needle electrospinning process using parallel plate auxiliary electrodes," *Nanomaterials* 2022, **12**(8): 1356.

[17]Z. Zhu et al., "Nanofibrous membrane through multi-needle electrospinning with multi-physical field coupling," *Materials Research Express* 2021, **8**(7): 075012.

[18]N. M. Thoppey, J. R. Bochinski, L. I. Clarke, and R. E. Gorga, "Edge electrospinning for high throughput production of quality nanofibers," (in eng), *Nanotechnology* 2011, **22**(34): 345301.

[19]Y. Liu and J.-H. He, "Bubble electrospinning for mass production of nanofibers," *International Journal of Nonlinear Sciences and Numerical Simulation* 2007, **8**(3): 393–396.

[20]S. Sood, S. Divya, and P. Gouma, "High-throughput electrospinning of 3D nano fibrous mats," *Journal of Nanoengineering and Nanomanufacturing* 2014, **4**(1): 39–44. ■



Example of the 3D-printed ceria ceramics investigated in this study.

Credit: Ryan Fordham

A study of lithography-based additive manufacturing of ceria ceramics

By Ryan Fordham, S. K. Sundaram, Shawn M. Allan, and Nicholas Voellm

Advances in additive manufacturing have led to a range of techniques to produce ceramics with complex geometries. This case study investigates the printability of ceria with a range of densities and microstructures using the Lithoz CeraFab 8500 system.

Cerium oxide, or ceria, is widely and historically known for its use as an abrasive, particularly to help polish specialized glasses,[1] such as telescope mirrors. But lately, this rare earth metal oxide has gained substantial attention in advanced technological applications as well, including photo- and electrocatalysis,[2,3] fuel cells,[4] and more recently, medicine.[5]

With respect to the medical industry, ceria has several properties of interest. It can absorb ionizing radiation,[6] making it a candidate for radiation shielding in medical imaging and radiation therapy. Ceria is also biocompatible and corrosion resistant,[7] so it can be used as a protective layer on implants, thus helping reduce the risk of inflammation, infection, and implant rejection. Additionally, the catalytic reactivity of ceria can be utilized in multiple medical processes, such as the degradation of pollutants for wastewater treatment or the detoxification of biological systems. Plus, if tailored for high surface area, ceria can adsorb or encapsulate drugs, thereby improving their stability, solubility, and bioavailability for controlled drug release applications.[8]

Various microstructural parameters and the thermal treatment of ceria have a large effect on its physical properties. However, achieving the desired geometry for ceria parts is difficult compared to metals and polymers. Where metals and polymers can be easily machined to achieve appropriate geometry, tolerance, and surface finish, the sensitivity of ceramics to flaws such as cracking, porosity, and crystalline defects makes machining these materials via traditional subtractive methods challenging.[9,10]

Recent advances in additive manufacturing (AM) have led to a range of techniques that can produce ceramics with complex geometries for niche applications. These processes include stereolithography, direct writing, robotic material extrusion, and powder bed fusion.[11] Most AM systems for ceramics require a post-processing step to debind and densify the printed parts. The systems differ in how the printed parts are bound prior to densification.

Digital light projection (DLP) stereolithography is another AM technique that has long been used to additively manufacture ceramics. Compared to traditional stereolithography systems, which use a laser to trace a layer, DLP systems use a projected light source to cure an entire layer at once. Advancements in optics and image projection have allowed DLP systems to give very high lateral resolution while keeping processing times down compared to similarly powered stereolithography rastering laser systems.

The Lithoz CeraFab systems developed by ceramic additive manufacturer Lithoz GmbH (Vienna, Austria) is a subset of DLP stereolithography that has been patented for the proprietary Lithoz binder systems.[12] It employs a lithography-based ceramic manufacturing technique that utilizes a liquid-based, highly viscous photosensitive slurry to produce three-dimensional parts.[9]

The focus of this study was to investigate the printability of ceria with a range of densities and microstructures using the Lithoz CeraFab 8500 system. A parametric investigation was designed and implemented to determine the sensitivity of several processing parameters on the overall printability of ceria and the quality of the printed parts. The variables in the study were the ceramic powder particle size, solid loading of the printable slurry, and sintering temperature. Each parameter was varied at three levels spanning the expected workable range for that variable.

Materials and processing setup

Advanced Abrasives Corporation (Pennsauken, N.J.) supplied ceria powders with advertised purity of 99.95% and advertised particle sizes of 0.5 µm, 1 µm, and 2 µm. The powder was characterized using density measurements, particle size analysis, X-ray diffraction, and scanning electron microscopy to confirm phase, purity, and particle geometry. While the advertised and measured particle sizes for the 0.5 µm and 2 µm powders were fairly close, the 1 µm advertised powder measured an average particle size of 2.00 µm (Table 1).

Table 1. Powder particle size measurements of 0.5, 1, and 2 µm advertised ceria powders.

Advertised particle size (µm)	Measured average particle size (µm)	Standard deviation (µm)
0.5	0.547	0.547
1.0	2.003	0.960
2.0	1.926	0.879

Credit: Ryan Fordham

Slurry development was completed at Lithoz America LLC (Troy, N.Y.). The liquid-based slurry comprised a suspension of ceria powder in a photosensitive resin. The resin was a mixture of photoinitiators, low molecular weight monomers, and dispersants. A combination of a light-emitting diode array and a digital micromirror device was used to selectively polymerize the resin. The printing light intensity was reduced to 300 mJ/cm^2 to avoid overpolymerization.

Grindometer measurements were carried out for each slurry formulation to identify large particles and agglomerates in the slurry. Each particle size batch was then mixed with a proprietary binder system, and the rheology was tracked as the solid loading was increased. Once the slurry reached a loading that caused significant shear thickening, the slurry was deemed unusable. The maximum loading, prior to shear thickening behavior, was used as the medium value for the study. An increase of 2 vol.% and a decrease of 2 vol.% were used for the high and low study values, respectively. Based on the rheology of the slurries for the 0.5, 1, and 2 µm powders, maximum workable solid loadings were 39, 39, and 41.5 vol.%, respectively. It was recommended that the slurry be kept in cold storage to avoid self-polymerization.

Ideal sintering temperature was determined by sintering five cold pressed ceria pellets at increasing temperatures between 1,400°C and 1,600°C. The optimal sintering temperature was found to be 1,450°C. After this determination, a print schedule was prepared to organize the print runs and optimize for printing time. Each print consisted of six cylinders, each 0.5 cm in diameter and 0.25 cm tall. Following 3D printing, the six parts were separated into three pairs and each pair was preconditioned, debinded, and sintered together. The prints were completed at a raised ambient temperature of 29.5°C.

After processing, all ceria samples underwent bulk and surface characterization. Density was measured using the Archimedes immersion method, following the American Standards and Testing Methods standard C20-00. Scanning electron microscopy micrographs were used to analyze the microstructures of the printed samples. Charging occurred on the surface of the lower density samples, and therefore images were not taken at high magnifications for those samples. Grain boundaries were clearly visible and used for grain size measurements.

Variations in sintering schedules, as well as the addition of dopants, such as gadolinium, have been known to affect the reduction of ceria.[13–17] So, X-ray photoelectron spectroscopy was used to measure the fractional oxidation states of cerium in the printed samples sintered at a single selected sintering temperature. From the measured data, no significant variation in cerium oxidation was found between the samples. The small amount of Ce(III) that was found (~5.5%) could be attributed to charging of the samples from the X-ray source or the ultrahigh-vacuum environment during the measurement.

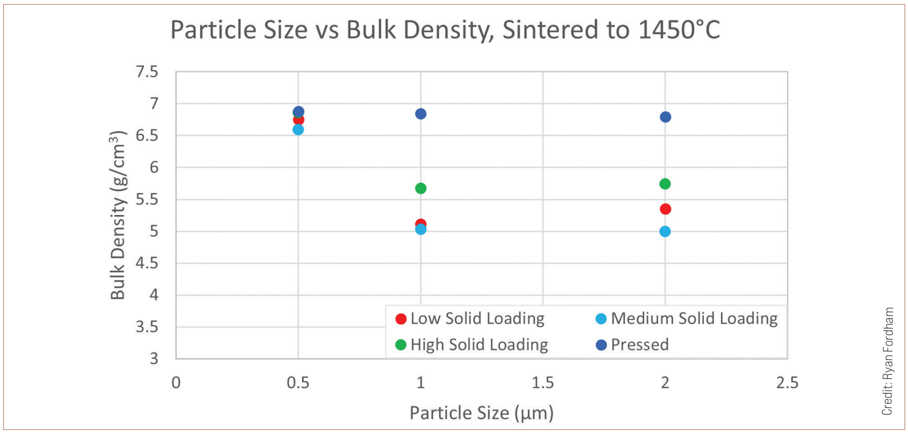


Figure 1. Effect of particle size on the bulk density of ceria sintered at 1,450°C.

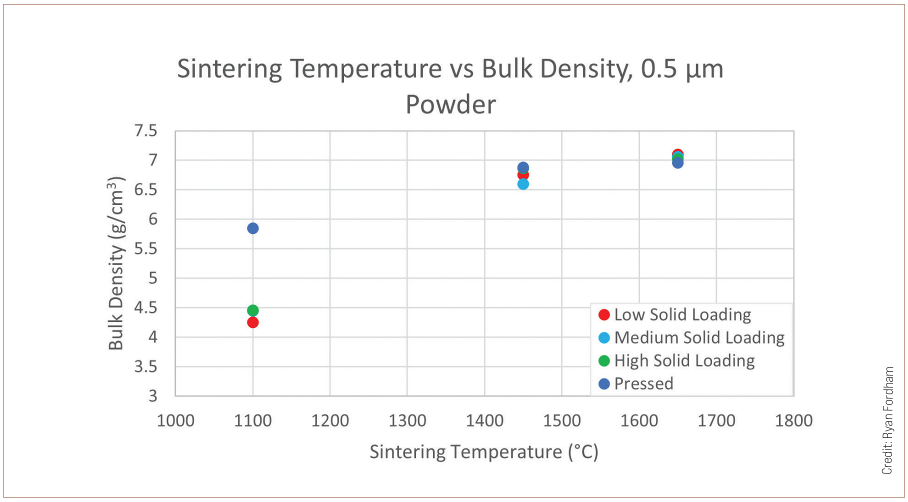


Figure 2. Effect of sintering temperature on bulk density of ceria 0.5 μm particle size.

Results and discussion

Parametric effects on bulk density

Figure 1 shows the effect of powder particle size on the bulk density of printed parts. The bulk density for the pressed pellets was constant between each particle size; however, it increased from about 5.8 g/cm^3 for parts sintered at 1,450°C to about 7.0 g/cm^3 for parts sintered at 1,650°C. In every instance for the printed samples, the 0.5 μm particle size samples sintered to a higher density than the comparable 1 μm and 2 μm samples, and the pressed samples were also significantly higher density than the printed samples when sintered at the low sintering temperature of 1,100°C.

The difference in density between the pressed and printed samples is due to the difference in packing density of the powder prior to sintering. The minimal difference between the density of the 1 μm and 2 μm powder samples also suggests the particle size measurements were accurate, and the 1 μm advertised powder has an actual particle size of about 2 μm.

As expected, the bulk density of each sample increased with sintering temperature (Figure 2). The 0.5 μm powder reached the highest bulk density at about 7.1 g/cm^3, and the 1 μm and 2 μm powders were slightly less dense at a maximum of about 6.7 g/cm^3. The 0.5 μm powder also showed a consistent density between each solid loading, including the pressed samples, when sintered at the medium and high temperatures. The 1 μm and 2 μm printed samples were all found to be less dense than the pressed samples, even at the highest sintering temperature of 1,650°C.

The narrow range of solid loadings chosen for this study had no significant effect on the final parts' bulk density.

Parametric effects on microstructure

No significant changes in microstructure were found with the narrow range of solid loading that was investigated. However, particle size and sintering temperature showed a wide range of porosity and grain size.

Figure 3 shows the effect of particle size and sintering temperature on the microstructure. As expected, the samples sintered at 1,100°C have open pores running through the sample. Small grains are visible, with some coalescing of the particles evident at this low sintering temperature. The samples sintered at 1,450°C show higher density material with visible grain boundaries. Open pores can still be seen throughout the samples printed with 1 μm and 2 μm powders. The samples sintered at 1,650°C show a reduction in porosity and pore size and exaggerated grain growth.

Intragranular porosity was also seen on the surface of the printed parts. This porosity is caused by larger starting grains in the 1 μm and 2 μm powders. As the sintering temperature is increased, the intergranular pores are trapped during the accelerated grain growth and thus becoming intragranular. This porosity is only seen in the 1 μm and 2 μm powder samples sintered at the highest temperature of 1,650°C.

Parametric effects on grain size

Average grain size of the printed samples was strongly dependent on the particle size of the ceria powder used in the slurry as well as the sintering temperature. Because of the higher surface area and therefore higher surface energy of the 0.5 μm powder, these samples consistently had larger grain sizes than the comparable 1 μm and 2 μm powder samples. Solid loading showed an effect on the 0.5 μm powders but there was no significant change in the 1 μm and 2 μm powder samples. As expected, sintering temperature showed a strong positive correlation with average grain size.

Summary and conclusions

In this study, we established the processing parameters for ceria ceramics produced via lithography-based 3D printing. The powder characterization in addi-

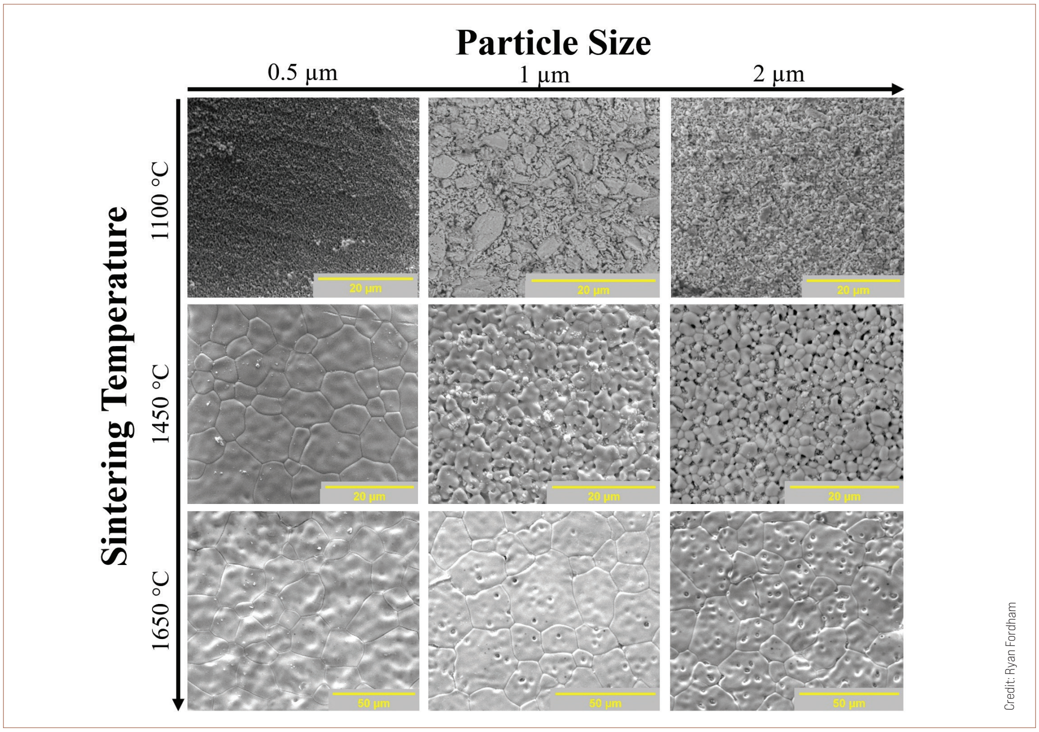


Figure 3. Effect of particle size and sintering temperature on the microstructure of 3D-printed ceria.

tion to the observations made through the sintering study of the pressed pellets were consistent with other conventionally manufactured ceria. Based on the density and microstructure, usable values for particle size, sintering temperature, and solid loading were found for additive manufacturing of ceria.

Powder particle size and sintering temperature were found to have a prominent effect on the bulk density and microstructure of the printed samples. Ultimately, based on the particle sizes investigated in this study, 0.5 µm particle size ceria powder with a slurry solid loading of 41.5 vol.% and sintering temperature of about 1,450°C is recommended for production of high-density ceria ceramics with complex structures and geometries. Further investigations of sintering temperature and time may lead to reduced grain growth while producing a high-density solid. But in any case, these results help enable the advancement of AM of ceria and ceria-containing materials.

About the authors

Ryan Fordham, Shawn M. Allan, and Nicholas Voellm are materials engineer, vice president, and materials technician, respectively, at Lithoz America (Troy, N.Y.). S. K. Sundaram is an Inamori Professor of materials science and engineering at Alfred University in New York. Contact Fordham at rfordham@lithoz-america.com.

References

[1]Z. Zhang et al., "Surface modification of ceria nanoparticles and their chemical mechanical polishing behavior on glass substrate," *Appl. Surf. Sci.* 2010, **256**(12), 3856–3861.

[2]M. Stojmenović et al., "Electrical characterization of multidoped ceria ceramics," *Ceram. Int.* 2013, **39**(2), 1249–1255.

[3]R. J. Gorte, H. Kim, and J. M. Vohs, "Novel SOFC anodes for the direct electrochemical oxidation of hydrocarbon," *J. Power Sources* 2002, **106**(1–2), 10–15.

[4]A. J. Jacobson, "Materials for solid oxide fuel cells," *Chem. Mater.* 2010, **22**(3), 660–674.

[5]F. Pagliari et al., "Cerium oxide nanoparticles protect cardiac progenitor cells from oxidative stress," *ACS Nano* 2012, **6**(5), 3767–3775.

[6]S. Yalcin et al., "Radiation shielding properties of cerium oxide and erbium oxide doped obsidian glass," *Radiat. Phys. Chem.* 2019, **160**: 83–88.

[7]Y. Xiong et al., "Characterization and electrochemical corrosion behavior of biological ceramic coatings on magnesium alloy by micro-arc oxidation," *Journal of Biobased Materials and Bioenergy* 2014, **8**(2): 158–164.

[8]S. Das et al., "Cerium oxide nanoparticles: Applications and prospects in nanomedicine," *Nanomedicine* 2013, **8**(9): 1483–508.

[9]M. Schwentenwein, P. Schneider, and J. Homa, "Lithography-based ceramic manufacturing: a novel technique for additive manufacturing of high-performance ceramics," *Adv. Sci. Technol.* 2014, 60–64.

[10]Z. C. Eckel et al., "Additive manufacturing of polymer-derived ceramics," *Science* 2016, **351**(6268), 58–62.

[11]D. L. Bourell and C. E. R., "Photonics applied: 3D laser printing: Selecting and using materials for additive manufacturing processes," *Laser Focus World* 2016. https://bit.ly/3N7GYG3

[12]H. Johannes et al., "Method for the layered construction of a shaped body," U.S. Patent 10967564B2, March 2016.

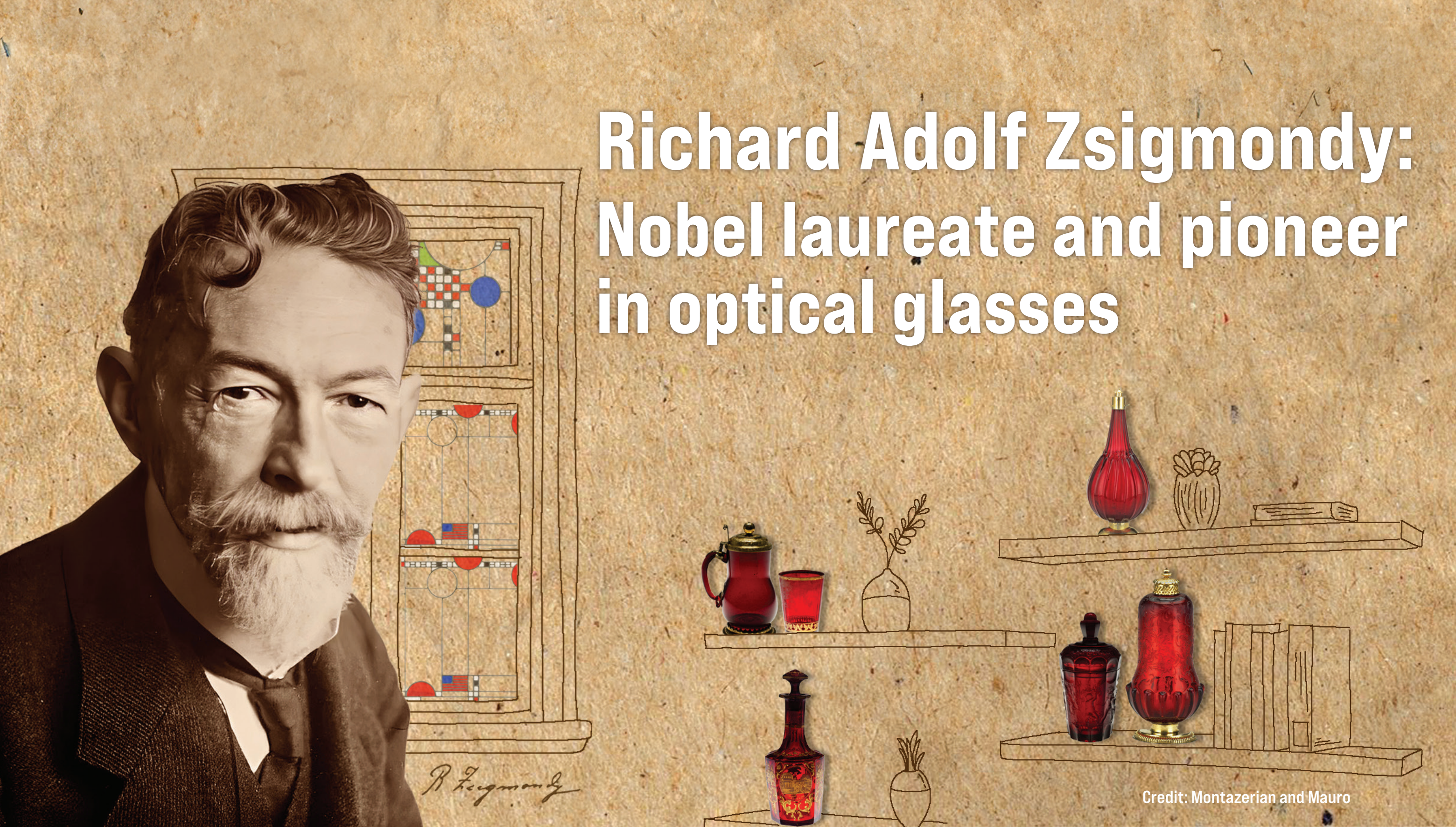
[13]C. Nicollet et al., "Gadolinium doped ceria interlayers for solid oxide fuel cells cathodes: Enhanced reactivity with sintering aids (Li, Cu, Zn), and improved densification by infiltration," *J. Power Sources* 2017, **372**: 157–165.

[14]C. M. Sims et al., "Approaches for the quantitative analysis of oxidation state in cerium oxide nanomaterials," *Nanotechnology* 2018, **30**(8), 085703.

[15]S. M. Ali et al., "Effect of sintering temperature on surface morphology and electrical properties of samarium-doped ceria carbonate for solid oxide fuel cells," *Ceram. Int.* 2015, **41**(1), 1323–1332.

[16]S. Kazlauskas et al., "Effect of sintering temperature on electrical properties of gadolinium-doped ceria ceramics," *J. Mater. Sci.* 2015, **50**(8), 3246–3251.

[17]F. Zhang et al., "Cerium oxidation state in ceria nanoparticles studied with X-ray photoelectron spectroscopy and absorption near edge spectroscopy," *Surf. Sci.* 2004, **563**(1–3), 74–82. ■



Richard Adolf Zsigmondy: Nobel laureate and pioneer in optical glasses

By Maziar Montazerian, John C. Mauro, and Andréa S.S. de Camargo

Austrian chemist Richard A. Zsigmondy was known for his work in colloid chemistry, but his research inspired advancements in optical glasses as well.

Although few Nobel Prizes have been awarded for research in glass science, glass has played a critical role in enabling Nobel-winning discoveries. For example, optical glasses are critical components for seeing both the microscopic world and the greater cosmos, enabling the entire fields of microbiology and modern astronomy.

The sole Nobel Prize recognizing optical glasses was awarded to Charles Kao in 2009 for "groundbreaking achievements concerning the transmission of light in fibers for optical communication," an idea that was reduced to practice by Donald Keck, Robert Maurer, and Peter Schultz at Corning Glass Works (Corning, N.Y.).[1] What is less known is that one of the early winners of the Nobel Prize in Chemistry (1925), Austrian chemist Richard A. Zsigmondy (1865–1929), was also a pioneer in optical glasses because of his work in colloid chemistry.[2]

Zsigmondy was born in Vienna, Austria, on April 1, 1865. He was influenced by the chemistry textbooks of Roscoe-Schorlemmer and Berzelius during his youth. Under the mentorship of professor E. Ludwig from the Medical Faculty in Vienna, he gained basic knowledge in quantitative chemical analysis.

Zsigmondy first studied at the Technische Hochschule in Vienna and then moved to Germany in 1887 to study organic chemistry at the University of Munich under professor W. von Miller. In 1889, he was awarded a doctorate in organic chemistry and remained Miller's assistant until 1891.[2]

From 1891 to 1892, Zsigmondy assisted professor August Kundt at the University of Berlin, and this experience led him to develop a strong interest in inorganic chemistry, specifically the luster colors derived from gold particles in porcelain. After joining the Technische Hochschule in Graz as lecturer, Zsigmondy continued investigating how fine gold particles can impart color to materials, this time in the context of gold ruby glass.

Gold ruby or "cranberry" glass is created by adding gold salts, typically in the form of gold chloride, to otherwise colorless molten glass. The salt is then reduced to gold nanoparticles via the addition of metallic tin to obtain a red color.[3]

During the late 19th century, the nature of this colloidal gold solution was not well understood, so Zsigmondy aimed to elucidate this behavior. These investigations allowed Zsigmondy to gain knowledge of glass and proficiency in producing colored glass, and this expertise brought him to employment at SCHOTT in Jena, Germany, in 1897.

After joining SCHOTT, Zsigmondy continued his studies of colloidal solutions and was responsible for the development of the well-known Jena milk glass, a type of opaque or semi-opaque glass with a white or milky appearance. However, he left SCHOTT in 1900 to focus his scientific efforts on studying colloid chemistry.

In early experiments, Zsigmondy used a glass cube containing dispersed gold colloidal particles as his sample. Sunlight served as the illumination source, and a heliostat was employed to compensate for the movement of the sun relative to the Earth. A glass lens was used to focus the sunlight onto a very small area within the glass cube. The glass cube was then exam-

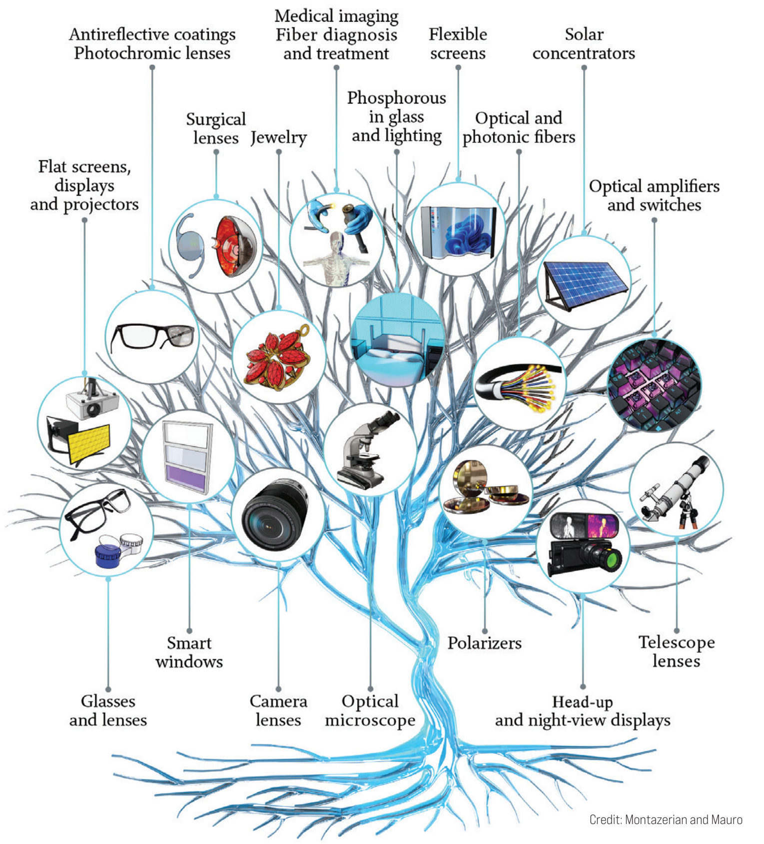


Figure 1. Tree of optical glass applications showing the branching and diverse applications of these materials.

ined using a standard upright light microscope. To ensure that no direct illumination light entered the microscope's optical axis, the optical axis was kept perpendicular to the axis of illumination. Through this setup, Zsigmondy observed the cone of light created by scattering from individual colloidal particles.

Expanding on this setup, Zsigmondy created the concept of the ultramicroscope, a tool that allows for the visualization of particles far smaller than what can be seen using regular optical microscopes. In the ultramicroscope, illumination of samples is done sideways, which allows the light to be scattered rather than simply reflected. This scattering makes the otherwise invisible particles appear as bright points of light against a dark background, allowing for their observation and study even when the particles are smaller than the wavelength of light.[4–7]

Zsigmondy collaborated with physicist Henry F.W. Siedentopf (1872–1940) to develop the ultramicroscope, a process which was facilitated by progress in optical glass at that time. He experimented with this device using different colloids and eventually developed a method for measuring the size of ultramicroscopic colloidal particles, such as the gold nanoparticles in gold ruby glass. This research not only allowed him to explain how particle size influences color and how colloids function, but it also made a significant contribution to the wider domain of materials science, where the meticulous manipulation of material characteristics is crucial for fostering innovation.

As a result of his significant contributions to colloid chemistry, Zsigmondy was awarded the Nobel Prize in Chemistry in 1925. But this research had a lasting impact on glass science as well by catalyzing future advancements in optical technologies, which subsequently influenced later Nobel Prize-winning discoveries. For example, the 2023 Nobel Prize in Chemistry was awarded to Bawendi, Ekimov, and Brus for the discovery and synthesis of quantum dots. Key to this discovery was the ability to observe size-dependent optical effects in glass using nanoscale imaging technologies.[8]

Today, there is significant interest in developing glass-ceramics, particularly in fiber form, that incorporate crystalline phases ranging from quantum dots to nanocrystals for use as gas and chemical sensors. Other glass-ceramic forms, such as films and coatings, are being explored to enhance solar energy harvesting and conversion in photovoltaic cells, solar concentrators, white LED devices, and displays in general. Additionally, glasses containing gold and silver nanoparticles are extensively studied for surface-enhanced Raman scattering and the plasmonic enhancement of emissions from rare earth and other transition metal ions.[9,10] In this context, it is fair to state that Zsigmondy's work was pioneering in these directions.

Other recipients of the Nobel Prize have produced notable advancements in the field of glass research as well, albeit sometimes indirectly. One example is Sir William Ramsay, the recipient of the 1904 Nobel Prize in Chemistry for his discovery of noble gases. He made contributions to the comprehension of gas behavior in glass, which is essential for applications such as vacuum tubes and gas-discharge lamps. His studies were conducted in blown glass apparatuses that he created himself, a skill he learned from his assistant Sydney Young (who was later elected a Fellow of the Royal Society).[11] The main applications of optical glass resulting from Zsigmondy's and others' endeavors are illustrated in Figure 1.

Zsigmondy's contributions illustrate that even during the early 20th century, fundamental glass research could result in the greatest accolades in the field of science. It also emphasizes the crucial significance of glass in facilitating innovative research and technological progress.

In the future, researchers will likely continue building upon Zsigmondy's pioneering work with the development of ultralow-loss glass fibers for quantum communication, next-generation laser glasses, optical glasses for long-term three-dimensional memory storage, and specialty glass lenses for augmented reality applications. And who knows? One of these developments may very well become the next Nobel Prize-winning discovery.

About the authors

Maziar Montazerian is assistant research professor of materials science and engineering at The Pennsylvania State University. John C. Mauro is the Dorothy Pate Enright Professor of materials science and engineering at The Pennsylvania State University. Andréa S.S. de Camargo is professor at Friedrich-Schiller University Jena, Germany, and head of Division 5.6–Glass, at the Federal Institute for Materials Research and Testing in Berlin, Germany. Contact Montazerian at mbm6420@psu.edu.

References

[1]"Charles K. Kao, Biographical," The Nobel Prize. Accessed 27 Sept. 2024. https://www.nobelprize.org/prizes/physics/2009/kao/biographical

[2]"Richard Zsigmondy, Biographical," The Nobel Prize. Accessed 27 Sept. 2024. https://www.nobelprize.org/prizes/chemistry/1925/zsigmondy/biographical

[3]F. Montanarella and M.V. Kovalenko, "Three millennia of nanocrystals," *ACS Nano* 2022, **16**(4): 5085–5102.

[4]B.R. Masters, "Richard Zsigmondy and Henry Siedentopf's ultramicroscope." *In Superresolution Optical Microscopy: The Quest for Enhanced Resolution and Contrast*. Springer, 2020.

[5]"Diamond research," *Nature* 1965, **206**: 139–140.

[6]R. Zsigmondy, "Richard Zsigmondy–Nobel Lecture: Properties of Colloids," The Nobel Prize, 1926. Accessed 27 Sept. 2024. https://www.nobelprize.org/prizes/chemistry/1925/zsigmondy/lecture

[7]"Richard Adolf Zsigmondy," *Wikipedia*. Accessed 27 Sept. 2024. https://en.wikipedia.org/wiki/Richard_Adolf_Zsigmondy

[8]"The Nobel Prize in Chemistry 2023," The Nobel Prize. Accessed 27 Sept. 2024. https://www.nobelprize.org/prizes/chemistry/2023/summary

[9]W.C. Wang, B. Zhou, S.H. Xu, Z.M. Yang, and Q.Y. Zhang, "Recent advances in soft optical glass fiber and fiber lasers," Progress in Materials Science 2019, **101**: 90–171.

[10]Q. Pan, D. Yang, G. Dong, J. Qiu, and Z. Yang, "Nanocrystal-in-glass composite (NGC): A powerful pathway from nanocrystals to advanced optical materials," *Progress in Materials Science* 2022, **130**: 100998.

[11]A.G. Davies, "Sir William Ramsay and the noble gases," *Sci Prog.* 2012, **95**: 23–49. ■

Jonathon Foreman
ACerS journals managing editor

Advances to processing of bioactive and bioinspired ceramics, glasses, and composites

Bioactive ceramic and glass materials have widespread applications in healthcare settings, from dental crowns to tissue scaffolds, among others. But to enable these applications, researchers are exploring ways to process these materials effectively, as demonstrated in this month's Topical Collection, "Advances to processing of bioactive and bioinspired ceramics, glasses, and composites."

In the articles "Perspectives on the impact of crystallization in bioactive glasses and glass-ceramics" and "An insight into the thermal processability of highly bioactive borosilicate glasses through kinetic approach," Montazarian et al. and Chakraborty et al. discuss controlling the crystallization in bioactive glasses and the potential for designing glasses for sinterability and fiber-drawing. Additionally, in the paper "Characterization of biodegradable core–clad borosilicate glass fibers with round and rectangular cross-section," Hongisto et al. explore the biocompatibility of different fiber shapes with potential for in-vivo sensor applications.

Additive manufacturing techniques are assuming a prominent role in fabricating bioactive materials with complex shapes, such as zirconia-based dental prosthetics. In the paper "Effect of inert glass on the physical and mechanical properties of zirconia dental ceramics fabricated by digital light processing," Zhang et al. added inert glass to zirconia toughened alumina (ZTA) processed using digital light processing to improve hardness, toughness, and wear resistance. Meanwhile, in the paper "Digital light processing-based additive manufacturing of orientation-controlled Al_2O_3 ceramics with improved damage tolerance," Wang et al. added texturing platelets and used shearing via doctor blades during digital light processing to improve these properties in alumina.

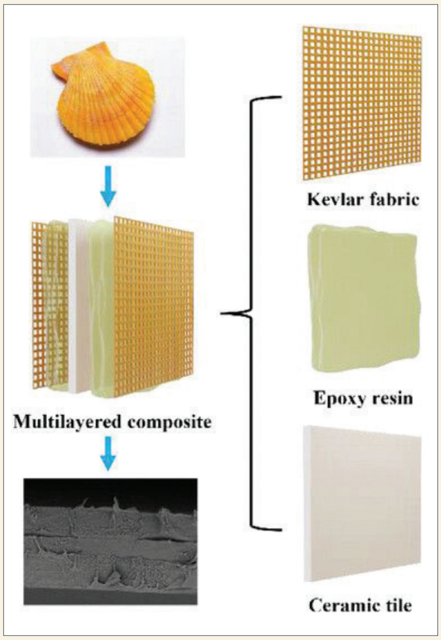
Researchers are exploring other additive manufacturing processes besides digital light processing for biomedical applications. For example, in the paper "Infrared irradiation to drive phosphate condensation as a route to direct additive manufacturing of oxide ceramics," Somers et al. used infrared light with condensation of phosphates to bind oxide ceramics in a layer-by-layer fashion.

Ceramics can also enhance performance and safety of prosthetics made from titanium and other metals. For example, in the paper "The synergistic effect of texture and surface roughness on electrophoretic deposited bioactive glass coating," Yazdani Samani et al. modified the surface of stainless steel to enhance the properties of bioactive glass coatings.

One of the most promising techniques for producing polymer–ceramic composites is cold sintering. In the paper "Cold sintering of bioglass and bioglass/polymer composites," Andrews et al. found that the low temperature (~100°C) of cold sintering enables incorporation of higher amounts of bioactive glass into polymeric polylactic acid while avoiding crystallization.

Safety of bioactive materials is extremely important. Gamma-ray is considered viable for sterilization of polymeric implants. In the paper "Evaluation of the sterilization effect on biphasic scaffold based on bioactive glass and polymer honeycomb membrane," Coquien et al. explored effects of gamma-ray sterilization on bioactive glass-ceramic composites. While the irradiation created defects in the bioactive glass and decreased the molecular weight of the polymer through chain scission, the effects on the physical properties were minimal.

In addition to bioactive ceramics, bioinspired designs of components aim to take advantage of natural structures to enhance mechanical performance among others. For example, in the review paper "Research and application of biomimetic modified ceramics and ceramic composites: A review," Li et al. explain how biomimetic structures can lead to enhanced strength and wear resistance.



Credit: Zhong et al., *International Journal of Applied Ceramic Technology*

Figure 1. Schematic of multilayered porcelain ceramic tile/Kevlar fabric composite with bioinspired shell-like structure processing.

Many production methods for bioinspired structures are being explored. For example, in the paper "Enhanced mechanical properties of porcelain ceramic tile/Kevlar fabric composite with bioinspired shell-like structure," Zhong et al. discuss a low-cost hot-pressing method for producing ceramic/polymer composite tiles inspired by the design of seashells, which were stronger and tougher than pure ceramics of the same thickness (Figure 1).

For more information on the articles discussed above along with others in the Topical Collection "Advances to processing of bioactive and bioinspired ceramics, glasses, and composites," please visit https://ceramics.org/news-publications/journals/collections-on-sustainability. ■

ACERS SHAKES OFF THE VESTIGES OF COVID-19 AS ATTENDEES FLOCK TO MS&T24 IN PITTSBURGH

When the COVID-19 pandemic swept across the world in 2020, the world of scientific conferences was turned upside down. Professional societies scrambled to adopt unfamiliar virtual formats, and almost as quickly, they needed to determine the safest way to hold in-person gatherings again.

ACerS staff and members have worked diligently to navigate this path back to live events. These efforts paid off during the Society's 126th Annual Meeting at the 2024 Materials Science & Technology technical meeting and exhibition, which took place Oct. 6–9, 2024, in Pittsburgh, Pa. More than 2,900 attendees from 59 countries attended the conference and exhibit, including more than 740 students. This attendance outpaced MS&T 2023 attendance by more than 250 and even outpaced MS&T 2019 attendance (pre-pandemic) by nearly 100.

Below are highlights from ACerS 126th Annual Meeting at MS&T24.

STRATEGIC PLAN NEARS FINALIZATION

After a year-long effort, outgoing ACerS president Rajendra Bordia announced that the Society's latest strategic plan is nearing completion during the Annual Business Meeting on Monday, Oct. 7.

Every few years, ACerS conducts a strategic planning process to set goals for the Society. The new plan, which covers the period 2025–2028, will be posted online for members to access in December 2024.

One goal of the new strategic plan is to expand engagement with and support for international members. Several initiatives in this vein have already been implemented. For example, the first ACerS International Chapter in South America was established in Brazil, and the Society now offers reduced dues membership options for professionals and graduate students who currently reside in developing and underdeveloped countries according to the World Bank.

In addition to helping implement the recommendations from ACerS strategic plan, incoming ACerS president Monica Ferraris said her priorities in office will focus on three "Ms": members, meetings, and marketing.

"I am more than honored" to help the Society improve its offerings in each of these areas, Ferraris said during the Annual Meeting.

AWARD LECTURES HIGHLIGHT ADVANCED MATERIAL FUNCTIONALITY AND DESIGN

Every year, humans push the limits on designing materials for ever-more extreme and complex environments, including in space and the body. The award talks at this year's Annual Meeting demonstrated a few of these applications.

The award talks started on Monday morning with the Arthur L. Friedberg Ceramic Engineering Tutorial and Lecture, given by University of California San Diego professor Olivia Graeve. She leads the Xtreme Materials Laboratory at UC San Diego, and she explained the importance of controlling the shape (crystallography) of ceramics to achieve desired material functionality in extreme environments. She dedicated the lecture to the late Joanna McKittrick, who was her undergraduate advisor and then colleague at UC San Diego.

On Tuesday morning, Young-Wook Kim, senior vice president of Worldex Industry & Trading Co., Ltd. and professor emeritus of the University of Seoul, delivered the Edward Orton Jr. Memorial Lecture on "Silicon carbide: The versatile ceramic alloy." He extended the point made in Graeve's lecture about the effect of microstructure on a material's behavior. Specifically, he showed how silicon carbide can be either thermally or electrically insulating or conductive depending on how it is processed.

Later Tuesday morning, two parallel award sessions serendipitously demonstrated the use of glass in different applications. In the first session, University of Adelaide professor Heike Ebendorff-Heidepriem delivered the Cooper Session Distinguished Lecture on the types of glass used in optical fibers. She was followed by this year's Cooper Scholar recipient, student Patrick E. Lynch of Alfred University, who discussed ultrasound-assisted thermal processing of chalcogenide glasses, which are known for their applications in the infrared spectrum.

Meanwhile, a few rooms over, Corning glass development scientist Qiang Fu delivered the Tadashi Kokubo Award lecture on the industrialization of bioactive glass, pulling examples from his own research and discussing remaining challenges. He was followed by this year's Bioceramics Young Scholar recipient, postdoctoral researcher Nicolas Somers of the University of Liège, who talked about using photonic rather than thermal methods to cure 3D-printed bioactive glass.

On Tuesday afternoon, Semiconductor Energy Laboratory president and CEO Shunpei Yamazaki delivered the Rustum Roy Lecture on the development of indium oxide semiconductors to replace silicon electronics. He brought a replica of the first 300-mm indium oxide large-scale integrated wafer, which is expected to enter commercial production within the next few years.

On Wednesday, the last two award lectures took place in the morning and afternoon, respectively. First, University of Delaware professor Chandra Reedy delivered the Anna O. Shepard Award Lecture on the enduring legacy and innovation of Anna Shepard's thin-section petrography approach to archaeological ceramics analysis.

Later, University of Missouri professor Wai-Yim Ching delivered the Robert B. Sosman Lecture on computational modeling of complex materials. Ching was unable to attend the conference in person, and so he submitted his lecture as a recorded presentation. University of Missouri postdoctoral research Puja Adhikari accepted the award on Ching's behalf and paid tribute to his "unwavering work ethic" throughout the years.

EMERGING PROFESSIONALS MIX FUN AND EDUCATION THROUGH TARGETED COMPETITIONS AND EVENTS

As usual, ACerS Annual Meeting featured several targeted events for students and young professionals, which provided them the chance for both fun and learning during the conference. On Sunday, students competed in the annual Undergraduate Student Speaking Contest, which provides students the opportunity to practice communicating their research to a broader audience.

Also that day, the Mentor Mixer gave participants in ACerS' four Mentor Programs the chance to mingle with each other.

On Monday, the Young Professionals Breakfast Club provided members of the Young Professionals Network a chance to mix with ACerS Corporate Partners, building connections and possible job opportunities.

Also that day, the Ceramic and Glass Industry Foundation hosted the IGNITE MSE symposium and career panel luncheon. On Tuesday, a poster session for undergraduate and graduate students took place. This year's poster session winners include

Undergraduate posters

First place: Dylan Burke, University of North Carolina at Charlotte

Second place: Sarah Cole, Boise State University

Third place: Hanyu Pan, Carnegie Mellon University

Graduate posters

First place: Casey Zhang, The Pennsylvania State University

Second place: Prapassorn Numkiatsakul, University of Illinois at Urbana-Champaign

Third place: Fumiya Kimura, Yokohama National University

Also that day, the famous mug drop and disc golf competitions took place. Laura Klusendorf from the University of Illinois Urbana-Champaign took home first place in the mug drop competition, while Josiah Gifaldi and Cole Harsa from Virginia Tech tied for first place in the disc golf competition. Additionally, Kaylyn Courtney from the Colorado School of Mines was announced as having the most aesthetic mug, while Ray Tsai from the University of Illinois Urbana-Champaign was announced as having the most aesthetic disc.

View for more photos from ACerS Annual Meeting at MS&T24 by visiting ACerS Flickr page at https://bit.ly/MST24-Pittsburgh. Pictures from the Awards Banquet can be found there as well. Next year, ACerS 127th Annual Meeting at MS&T25 will take place in Columbus, Ohio, from Sept. 28–Oct. 1, 2025. ■

1. Incoming ACerS president Monica Ferraris, left, accepts the ceremonial ceramic gavel from outgoing ACerS president Rajendra Bordia during the Annual Board Meeting on Monday, Oct. 7.

2. Semiconductor Energy Laboratory president and CEO Shunpei Yamazaki shows off a replica of the first 300-mm indium oxide large-scale integrated wafer during the Rustum Roy Lecture on Tuesday, Oct. 8.

3. ACerS President's Council of Student Advisors held their annual business meeting on the Friday and Saturday before ACerS Annual Meeting at MS&T24. This year's delegates consist of 52 students from 31 universities, representing 10 countries.

4. Finalists of the Undergraduate Student Speaking Contest. From left: David Flores of The Pennsylvania State University took home first place, Ray Tsai of the University of Illinois Urbana-Champaign and Julianne Chen of The Pennsylvania State University tied for second, and Anthony Conte of Rutgers, The State University of New Jersey placed third.

5. Students from the University of Illinois Urbana-Champaign (second row, hands raised) celebrate the survival of their peer Laura Klusendorf's mug after a drop during the competition.

All photos credit: ACerS

UPCOMING DATES

HILTON DAYTONA BEACH RESORT AND OCEAN CENTER, DAYTONA BEACH, FLA.

The 49th International Conference & Exposition on Advanced Ceramics & Composites (ICACC 2025) will provide a platform for state-of-the-art presentations and information exchange on cutting-edge ceramic and composite technologies.

HILTON CITY CENTER, DENVER, CO.

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

HILTON HYATT REGENCY VANCOUVER, VANCOUVER, BRITISH COLUMBIA, CANADA

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

GREATER COLUMBUS CONVENTION CENTER, COLUMBUS, OHIO

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

Find your path with The American Ceramic Society (ACerS)

Material Advantage Student Program
$30 USD

Global Graduate Researcher Network
$30 USD

Associate Membership
$40 USD

**First year complimentary*

Individual Membership
$120 USD

Level up with ACerS

Lifetime
$2,000 USD
Avoid future dues increases and the need to renew each year.

Retired
$40 USD
Available for those who are 65 years or older, have five or more years of continuous ACerS membership, and are retired.

Emeritus
Complimentary
Available for those who are 65 years or older and have 35 or more years of continuous ACerS membership.

Corporate Partnership
Prices vary
Gain exposure to a global community of ceramic and glass professionals, utilize the vast technical resources available, all while supporting your industry.

Learn more *ceramics.org/corporate*

Explore types of membership

Where do you see yourself? ACerS will help you get there!
View a full list of ACerS membership benefits at ceramics.org/memberbenefits.
Sign up for your membership with The American Ceramic Society today at ceramics.org/join.

calendar

Calendar of events

January 2025

26 ★ Introduction to Thermal Spray Coatings: Science, Engineering, and Applications – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla.; https://ceramics.org/course/berndt-intro-thermal-spray-coatings

26–31 49th International Conference and Expo on Advanced Ceramics and Composites (ICACC 2025) – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla.; https://ceramics.org/icacc2025

30–31 ★ Mechanical Properties of Ceramics and Glass 2025 – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla.; https://ceramics.org/course/quinn-mechanical-properties

February 2025

25–28 EMA 2025: Basic Science and Electronics Division Meeting – Hilton City Center, Denver, Colo.; https://ceramics.org/ema2025

March 2025

25–26 60th Annual Greater Missouri Section / Refractory Ceramics Division Symposium on Refractories – St. Louis, Mo.; https://ceramics.org/refractories2025

May 2025

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

June 2025

9–11 ACerS 2025 Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Birmingham, Ala.; https://ceramics.org/clay2025

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

July 2025

8–11 ➨ The 8th International Conference on the Characterization and Control of Interfaces for High Quality Advanced Materials (ICCCI 2025) – Highland Resort Hotel & Spa, Fujiyoshida, Japan; https://ceramics.ynu.ac.jp/iccci2025/index.html

September 2025

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

25–26 ➨ Unified International Technical Conference on Refractories – JW Marriott Cancún Resort & Spa, Cancún, Mexico; https://unitecr2025.com

January 2026

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

April 2026

12–16 ACerS Spring Meeting — Bellevue, Wash.; https://ceramics.org/event/acers-spring-meeting

May 2026

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

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

Ceramic & Glass MANUFACTURING

DECEMBER 2024 • VOLUME 5 • ISSUE 4

PATHS TO COMMERCIALIZATION: BRIDGING THE GAP BETWEEN RESEARCH AND MARKET

WORKING WITH INDUSTRY, ARGONNE BRINGS NEW TECHNOLOGIES TO THE MARKETPLACE

CONTENTS

Ceramic & Glass MANUFACTURING

Vol. 5, No. 4

Executive Director & Publisher
Mark Mecklenborg

Editorial & Production
Lisa McDonald
Editor
lmcdonald@ceramics.org

David Holthaus
Content Editor
dholthaus@ceramics.org

Cyndy Griffith
Graphic Designer

Kerry Burgdorfer
Graphic Designer

Michelle Martin
Production Editor

Customer Service & Circulation
ph: 866-721-3322 **fx:** 240-396-5637
customerservice@ceramics.org

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

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

Editorial & Advertising Offices
The American Ceramic Society
550 Polaris Pkwy., Suite 510
Westerville, OH 43082

The *Bulletin* has a new home!

In January 2025, the *ACerS Bulletin* will move to a new digital home on bulletin.ceramics.org. With this transition, December 2024 is the last issue of *Ceramic & Glass Manufacturing*. All articles from past *C&GM* issues will be available on the new website.

INDUSTRY NEWS

EUROPEAN GLASS MAKER REACHES HYBRID FURNACE MILESTONE

Hrastnik1860, a glass manufacturer based in Slovenia, says it used a hybrid regenerative glass furnace with an increased electric melting share to produce premium glass spirits bottles using hydrogen as the primary energy source. The project aims to increase the energy share of electrical boosting to 40%. The company says that change will enable the production site to reduce its natural gas consumption and related greenhouse gas emissions by more than 50%.

The hybrid regenerative furnace combines the all-electric and regenerative furnace concept. *Credit: Hrastnik1860*

CORNING MUSEUM EXPANDS ITS CENTER FOR ARTISTS AND STUDENTS

The studio lobby, where visitors prepare for their Make Your Own Glass experiences. *Credit: Corning Museum of Glass*

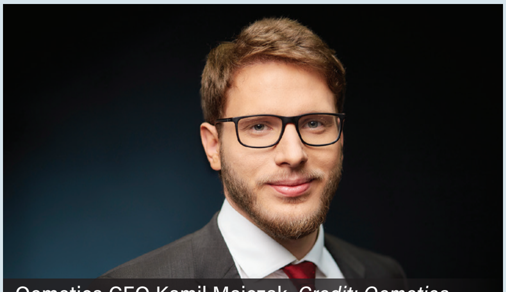
The Corning Museum of Glass inaugurated its new, state-of-the-art studio, expanding the physical footprint of the glassmaking facility for artists and students. The $55.3 million project expands the only facility in North America that can accommodate large-scale works in cast glass, deepens glassmaking education programs for students, and offers expanded residency opportunities. The museum established the studio in 1996 to offer instruction, host residencies, and provide rentals of furnace, kiln, and cold-working spaces and equipment.

SAINT-GOBAIN REFRACTORIES UNIT ACQUIRES CERAMCO

Saint-Gobain Performance Ceramics & Refractories agreed to acquire the assets, technology, and brand from Ceramco, a privately owned company specializing in industrial ceramics. Ceramco, founded in 1997 in Scotland, specializes in manufacturing carbon-bonded and silicon nitride materials used in a range of products, including thermocouple protection sheaths, radiant heater protection tubes, immersion heater protection tubes, and various custom ceramic solutions.

Saint-Gobain Performance Ceramics & Refractories designs, develops, and produces engineered ceramics and refractory products. *Credit: Saint-Gobain*

QEMETICA BUYS PPG'S SILICAS PRODUCTS BUSINESS



Qemetica CEO Kamil Majczak. *Credit: Qemetica*

Qemetica, a chemical producer based in Poland, agreed to buy the silicas products business of Pittsburgh-based PPG for $310 million. The acquisition includes PPG's precipitated silicas manufacturing facilities in Lake Charles, La., and Delfzijl, the Netherlands. In addition, Qemetica will lease silicas manufacturing and research and development operations at PPG sites in Barberton, Ohio, and Monroeville, Pa. The silicas products business employs about 400 people.

Mung Chiang, center, Purdue University president, with Paul Kearns, director of Argonne National Laboratory, and Karen Plaut, Purdue's executive vice president for research. *Credit: Purdue University*

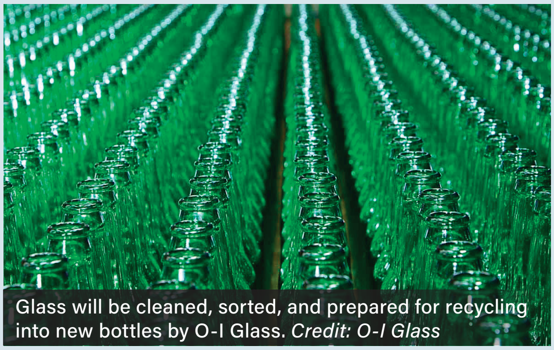
PURDUE AND ARGONNE SIGN COLLABORATION AGREEMENT

Leaders from Purdue University and the U.S. Department of Energy's Argonne National Laboratory signed a memorandum of understanding to promote research between Purdue and Argonne in areas that include microelectronics, quantum information science, materials science, nuclear science and engineering, computing, and energy storage materials and recycling.

DOE FUNDS HEIDELBERG MATERIALS DECARBONIZATION PROJECT

The U.S. Department of Energy's Office of Clean Energy Demonstrations awarded Heidelberg Materials North America's Mitchell Cement Plant Decarbonization Project with $300,000 to begin the first phase. The project is expected to result in the construction and operation of full-scale carbon capture, transport, and storage of approximately 2 million metric tons of CO_2 each year at the company's new cement plant in Mitchell, Ind. The funding builds on prior awards from the DOE for engineering and design work.

The new Mitchell, Ind., cement plant now produces more than triple its previous capacity. *Credit: Heidelberg Materials*



Glass will be cleaned, sorted, and prepared for recycling into new bottles by O-I Glass. *Credit: O-I Glass*

O-I PARTNERS WITH KENTUCKY DISTILLERIES ON RECYCLING

O-I Glass Inc. and multiple distilleries in Louisville launched Kentucky's first dedicated glass recycling program. The $350,000 glass processing initiative is a partnership between O-I Glass, not-for-profit Workwell Industries, and Kentucky distillers including Suntory Global Spirits, Diageo North America, and Pernod Ricard. The initiative aims to process more than 1,200 tons of glass packaging in its first year.

SUPPLIER ALLIANCE FORMED FOR CHIP MAKERS

Taiwan-based E&R Engineering Corp. launched a glass substrate supplier alliance to provide equipment and materials for next-generation advanced packaging with glass substrates to domestic and international customers. The alliance includes Manz AG, Scientech for wet etching, ShyaWei Optronics for automated optical inspection, Lincotec, STK Corp., Skytech, Group Up for sputtering and ABF lamination equipment, and other suppliers such as HIWIN, HIWIN Mikrosystem, Keyence Taiwan, Mirle Group, ACE PILLAR, CHD TECH, and Coherent.

E&R Engineering Corp. established the Glass Substrate Supplier E-Core System Alliance in Taipei, Taiwan. *Credit: E&R Engineering*

PATHS TO COMMERCIALIZATION: BRIDGING THE GAP BETWEEN RESEARCH AND MARKET

By David Holthaus

Basic research often has its beginnings with an elemental wonder at the world around us. In the case of Richard Riman, professor of materials science and engineering at Rutgers, the State University of New Jersey, pondering how crystals grow in caves, how ice crystallizes in beautiful and transparent shapes, and how snow solidifies into ice started him thinking about the kind of work he would like to do as a research professor.

Perhaps there was a way to make ceramics using water instead of high-temperature furnaces, he thought. He studied how engineers densified arctic fields of snow and ice to create airplane landing strips and how shellfish make ceramics at low temperatures. Reviewing the literature, he found work conducted by researchers in Japan using water. However, this approach still required high temperature and high pressure.

Further research found other scientists in Japan using low-temperature densification, compacting materials together with the assistance of water to densify them. But Riman pondered, "What can I do that's really different from what they're doing?"

This pondering led Riman and Vahit Atakan, a former Rutgers doctoral student, to invent an energy-efficient technology that harnesses largely low-temperature, water-based reactions. Called hydrothermal liquid-phase densification, the technology creates bonds between materials at low temperatures.

Riman used this densification process to create a range of ceramic composite materials. But during a mid-career sabbatical from Rutgers, he began thinking about how to use this technology for the common good.

"I went through this whole life evaluation process," he says. "I asked myself, 'Have you made a real difference in what your research has done?'"

He had published numerous research papers, made many presentations to professional organizations, and even licensed technologies to corporations. But these collaborations never made it to commercial production.

Around the time hydrothermal liquid-phase densification was invented, Riman met people in the venture capital community who were investigating laboratory research in search of investment opportunities. One was Bill Joy, a computer engineer, venture capitalist, and cofounder of Sun Microsystems, a Silicon Valley technology company.

Riman's technology has been used to make more than 30 different materials, including concrete that stores carbon dioxide. *Credit: Cameron Bowman, Rutgers University*

At the time, Joy was a partner in Kleiner Perkins Caufield & Byers, the storied Silicon Valley venture capital firm. With Joy and others at Kleiner Perkins steering the densification process toward commercialization, they formed a company called Solidia Technologies in 2008 focused on commercializing the technology for the concrete and cement industry, a huge global market.

Originally based in Piscataway, N.J., and now based in San Antonio, Texas, Solidia Technologies markets eco-friendly cement and concrete for construction and infrastructure. Riman and colleagues demonstrated that they could make a material that costs the same as conventional Portland cement, with the same strength and durability, and reduce the carbon footprint of the materials by up to 70%.

Earlier this year, the company entered a technology licensing arrangement with

CalPortland Co., one of the largest building materials producers in the Western U.S., for patents that enable up to a 50% reduction in the carbon footprint of cement and concrete. CalPortland also purchased some laboratory and plant assets from Solidia.

Penn State's partnership with Bormioli Luigi will focus on scaling up LionGlass to create bottles for luxury beauty products. From left to right: Brittney Hauke, doctoral student; Titus Reed, doctoral student; Elif Akman, doctoral student; Elizabeth Aichele, undergraduate student; Andrea Marostica, Bormioli Luigi; Elisa Biavardi, Bormioli Luigi; Nicholas Clark, postdoctoral scholar; John Mauro, Penn State professor. *Credit: Michael Owen, The Pennsylvania State University*

Teaming with investors like Riman did is just one way to commercialize research. The process of commercialization can transform scientific discoveries into new products and services, drive economic growth and job creation, generate revenue that can be reinvested into further research, and potentially lead to breakthroughs that can solve real-world problems.

There are many examples of research from ceramic and glass laboratories being successfully transitioned to commercial products. Among them are advanced materials developed for dental applications, which companies such as Zurich-based Nobel Biocare and Basel-based Straumann have commercialized into dental implants and crowns. Ceramics suitable for ballistic protection due to their extreme hardness and lightweight properties have been commercialized for use in body armor and vehicle armor. Also, carbon-composite ceramics are now used in high-performance applications, such as jet engines and spacecraft.

PARTNERSHIPS WITH INDUSTRY

Like Riman, addressing the global problem of climate warming was also a driving force behind professor John Mauro's research into inventing and engineering a new family of glass at The Pennsylvania State University.

By far, the predominant type of glass produced around the world is soda lime silicate glass. It is used for windows in homes and offices; for automobile windshields; and for tableware, jars, and beverage packaging. The production of soda lime silicate glass produces millions of tons of carbon dioxide every year, largely because of the energy required to heat furnaces to the high temperatures needed to melt this glass. In addition, both the soda ash and limestone used to make soda lime silicate glass are carbonate, and they both decompose into oxides and release carbon dioxide during the glass melting process.

"Soda lime silicate is ubiquitous, and it has not changed in a very long time, and it is responsible for the lion's share of the CO_2 output of the glass industry," Mauro says. "So, if we want to be serious about reducing the carbon footprint of the glass industry, we need to do something about soda lime silicate glass."

There are few who are more qualified to do that than Mauro. During his 18-year career at Corning Inc., he co-invented Gorilla Glass, the thin, light, damage-resistant material now used in a wide variety of display technologies, personal electronic devices, and optical communications globally. After his stint at Corning, he brought his expertise to Penn State in 2017, where he is a professor of materials science and engineering.

In the university environment, Mauro was free of the profit-driven incentives of the corporate world and able to focus on passion projects. This academic freedom allowed him and his students to experiment with developing a glass that could serve as an environmentally friendly alternative to soda lime silicate glass.

Through these experiments, "We designed a glass called LionGlass that significantly lowers the melting temperature and eliminates the use of carbon batch materials," Mauro says.

LionGlass, named after Penn State's Nittany Lion mascot, is not based on the age-old mixture of quartz sand, soda ash, and limestone. Instead, it is based on phosphate materials and has a lower melting point than soda lime silicate glass. These two factors mean LionGlass has the potential to cut the carbon footprint of glass making in half, Mauro says.

LionGlass also has the added benefit of improved damage resistance compared to soda lime silicate glass. This benefit means that the glass can take a lot more stress before it cracks, "which means that the mechanical performance is better," Mauro says, and allows for "thinner walled glass products instead of having thick-walled glass jars." That design change could further reduce the carbon footprint by lowering the carbon emissions used to transport the glass.

With its intellectual property protected by patents, Mauro and Penn State are pursuing another path to commercialization—partnerships with industry. Mauro and his lab have built partnerships with corporations that include glass manufacturers and customers of the glass industry, and they are working with industry to tests the limits of LionGlass to see how it can be used in the real world.

SCALING UP

After securing the patents for Penn State, the next key step was getting the word out to companies about the new process. Penn State's marketing group was instrumental in that, as several news outlets and trade publications published stories. The marketing effort resulted in meetings with nearly 50 companies to review the technology under confidentiality agreements, Mauro says.

In September 2024, the Penn State researchers announced they had secured their first corporate partner, a move toward bringing the ecofriendly alternative to the marketplace. The partnership is with Bormioli Luigi, an Italian glassmaker that specializes in producing high-end packaging for fragrance, cosmetics, and tableware. The company will work with Penn State to perform research and development with the goal of scaling up, manufacturing, and ultimately commercializing LionGlass.

The partnership will focus on using LionGlass to create bottles for luxury beauty products such as cosmetics and perfume. By focusing on a smaller, high-end market, the company can fine-tune the glass and determine the feasibility of scaling it up further for other uses, the company says.

In the lab, LionGlass is made in small batches using crucibles placed in high-temperature furnaces. But to produce LionGlass at an industrial scale, it will need to be melted in large batches inside massive furnaces and formed using molds, something that is still being tested with the new family of glass. The first year of the partnership will be dedicated in part to testing the feasibility of using the molding technique with LionGlass in Bormioli's existing manufacturing infrastructure.

"We are working closely with them to get this glass ready for pilot scale manufacturing," Mauro says. "That will hopefully take place next year, and it will demonstrate the ability to melt this at a large scale. It will also provide some prototypes that they can pass along to their customers to get their feedback, and it will also provide a much larger amount of samples that we can use for further testing."

The Penn State team is starting with a high-end specialty market such as cosmetics because, Mauro says, "They are higher margin, and also because they are willing to, I think, take a chance on new technology like this." The next likely step, he says, will be to test the technology in the high-end spirits packaging sector. Ultimately, they plan to test it in flat glass, which requires a more complicated technology to produce.

"We want to show that this innovation is compatible with the process for making architectural glass," Mauro says. "So, we're in discussions with a couple of companies about that."

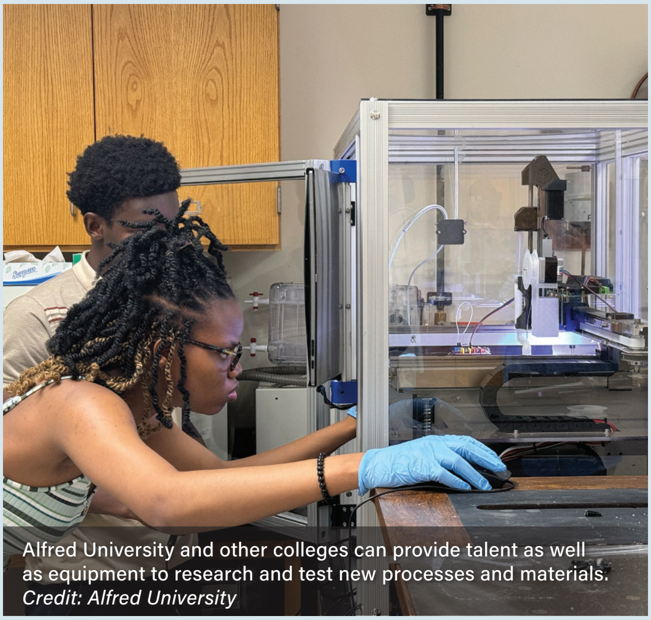
WORKING WITH ACADEMIA

Mauro and his team have the benefit of the resources of a large, state-supported university as they work toward commercializing their invention. But smaller universities, such as Alfred University, can also work with industry to move research from the lab to the marketplace.

Alfred University's Center for Advanced Ceramic Technology (CACT) is one of 15 industry centers located across New York state created to speed technology transfer from universities to the marketplace. The CACT works with firms from New York by providing financial support to offset short-term analytical programs as well as sponsor research, internships, and workforce development programs. For New York companies, the typical cost-share support ranges from 20–30%. The Center also works with out-of-state firms but, as a state-funded program, cannot apply a cost share to those projects.

Alfred, with an undergraduate enrollment of only about 1,500, does not have a dedicated office of technology transfer, nor does it invest in patenting, says David Gottfried, director of the Center for Advanced Ceramic Technology. Supporting patent applications, maintaining them, and defending them can be expensive.

"It's almost better to treat them as trade secrets rather than as published patents when you're working in a lot of these materials because with patents you're just putting your formulations and other things out into the open, and that doesn't really make a whole lot of sense," Gottfried says.



Alfred University and other colleges can provide talent as well as equipment to research and test new processes and materials. *Credit: Alfred University*

Alfred University's Center for Advanced Ceramic Technology uses a model called SWIFT to work with industry that reduces transaction time. *Credit: Alfred University*

Alfred uses a model employed at the University at Buffalo, called UB SWIFT, where SWIFT stands for Sponsorship With Industry-Focused Terms. The approach is an option to sponsor research through an agreement that includes preferred licensing terms for intellectual property that results from the project.

Gottfried says the approach allows both entities to set research and licensing terms at the project planning stage, providing financial certainty for both parties, eliminating ongoing and costly negotiations, and drastically reducing transaction time.

"It's all about getting intellectual property into the hands of industry, where they will commercialize it and produce value," Gottfried says.

Gottfried explains that if a company licenses a technology or utilizes a technology that was developed through its work with the Center, it can have an exclusive right to use the technology and generate $25 million of royalty-free revenue. Beyond that, a very small royalty accrues to Alfred University.

"It makes agreements with an industrial partner very easy on everyone and also extremely low-cost in terms of any payments back to the University in the form of royalties," he says.

The Center also works with Alfred's $7.75 million Ceramic Research, Education, and Technology Enterprise (CREATE), which focuses on supporting industry's needs to develop and commercialize additive manufacturing and printed ceramics and glass, as well as solutions for ceramic machining and surface finishing.

Additionally, Alfred is a source of talented people, faculty, staff, undergraduate, and graduate students who are interested in hands-on experience and can provide talent to the industry, Gottfried says. Industry can also make use of the university's equipment to research and test new processes and materials to avoid tying up production equipment to do that. For example, Alfred is acquiring a large glass furnace that can handle a 200-pound melt, significantly larger than the small crucibles it has worked with in the past.

There are several paths to commercializing basic research that can lead to breakthroughs that solve real-world problems, advancements in technology, and revenue that can support jobs and further research. Whatever the path, the ultimate goal is to translate scientific knowledge into practical applications that bridge the gap between research and markets, benefit society, and help ensure that scientific advancements have an impact on everyday life.

WORKING WITH INDUSTRY, ARGONNE BRINGS NEW TECHNOLOGIES TO THE MARKETPLACE

By Jared Sagoff

Jared Sagoff is a public information officer at Argonne National Laboratory. This article was originally published on the Argonne National Laboratory website and can be found at https://www.anl.gov/feature-stories. Republished with permission.

Over the decades, the U.S. Department of Energy's (DOE) Argonne National Laboratory has worked to create a portfolio of discoveries that have everyday use. Today, working with industry to make them available is one of Argonne's key objectives. Argonne works with companies of every shape and size, from Fortune 100 titans to startups just getting off the ground.

"We have the ability to make a difference all along the value chain," says Megan Clifford, Argonne's associate laboratory director for science and technology partnerships and outreach.

Former X-ray physicist Greg Halder has seen firsthand how the laboratory has put an increasing emphasis on its industrial partnerships. Halder left Argonne in 2015 to obtain his M.B.A. at the University of Texas. When he returned to the laboratory in 2017, he noticed a strengthened commitment in the laboratory's work with industry.

"All of a sudden, there were a number of things that appeared while I was gone, including large-scale centers specifically devoted to bringing new industrial partners to the lab," Halder says.

Halder now helps support one of these centers, the Argonne Collaborative Center for Energy Storage Science (ACCESS). ACCESS seeks to disseminate the laboratory's extensive collection of battery breakthroughs through agreements with companies looking for the next energy discovery that will reshape everything from transportation to grid storage.

Argonne's ReCell Center is a collaboration of industry, academia and national laboratories to advance recycling technologies along the battery life cycle for current and future battery chemistries. *Credit: Argonne National Laboratory*

The laboratory's long history of energy storage commercialization dates to the trailblazing nickel–manganese–cobalt (NMC) cathode material developed at Argonne in the late 1990s and early 2000s. For an invention like the NMC cathode to traverse the long path from an atomic-scale breakthrough to powering a new vehicle requires partnership.

"The NMC material was originally a basic science breakthrough," Halder says. "Now, it is the dominant chemistry found in many different electric vehicle batteries today from a range of different manufacturers. It's all thanks to the ability of Argonne and industry to work together to develop a game-changing innovation."

"By working together, Argonne and its industry partners enable the successful development of useful technologies," Clifford adds. "National laboratories like Argonne work hand in hand with many different industrial partners to advance technologies that can make a difference in our everyday lives."

As companies describe their needs, Argonne offers a customized set of capabilities and intellectual property that can address their challenges.

"Laboratories like Argonne offer a unique nucleus of capabilities and expertise that power the kinds of basic discoveries on which most, if not all, of the technologies we use today are based," Halder says. "Industry wants something that will immediately solve a real-world challenge as an application, and it's our goal to find as many ways as we can of bridging that gap."

One way that companies make use of Argonne technology is through licensing agreements, in which the rights to intellectual property that has been patented are transferred for a period of time, either exclusively or non-exclusively, to various companies. Companies that have acquired the rights to the NMC cathode battery material, for instance, include GM, LG Chem, and BASF.

There are many other ways companies can do work with—or at—the laboratory. Cooperative research and development agreements (CRADAs) fund researchers at Argonne to do work in conjunction with scientists from industry. Through these cooperative agreements, many companies have discovered that the DOE national laboratories offer unique expertise and research centers they cannot find anywhere else.

"Frequently, companies see Argonne as a place where they can come to do research working alongside world-class experts and using unparalleled facilities," Clifford says.

"Our relationship with Argonne goes beyond providing safe and reliable power that enables their critical work," says Gil Quiniones, CEO of ComEd. "Access to great minds and advanced technology is also a unique benefit of working with a prestigious national lab like Argonne. In the latest example, we are partnering on a study that is helping us to learn more about climate change so we can bring innovative technology to the grid and ensure clean and resilient energy for all customers."


Users from industrial companies use the high-powered X-rays provided by Argonne's Advanced Photon Source for research. *Credit: Argonne National Laboratory*

Some examples of significant CRADAs recently undertaken between Argonne and industry include topics such as engine design with Caterpillar or manufacturing fiber materials like those found in medical masks with 3M.

"We have found great value in partnering with Argonne," says Adrienne Lotto Walker, vice president, chief risk and resilience officer at the New York Power Authority. "We are leveraging Argonne's hyperlocal climate modeling and infrastructure resilience expertise to better assess how our assets and business may be affected by climate change and extreme weather. Being proactive on this front is critical to our ability to deliver for our customers."

The advantage of a national laboratory is that it maintains state-of-the-art large-scale science facilities that would be too expensive and cumbersome for an individual company to operate on its own. Examples at Argonne include the Advanced Photon Source (APS) and the Argonne Leadership Computing Facility, both DOE Office of Science user facilities. By applying for time on the laboratory's world-renowned supercomputers or X-ray beams, among other facilities, companies have access to experiments and simulations that would otherwise be beyond their grasp.

In some cases, companies such as Eli Lilly contract with the laboratory to use the laboratory's beamlines for proprietary research. Other times companies will make use of the laboratory's existing or past research to develop new medicines, treatments, or drugs that can help save lives. Recently, the APS was used by Pfizer researchers to support their development of new antiviral drugs, including Paxlovid, used to fight COVID-19 infections.

Sometimes, research at the laboratory forms the foundation for the launch of new companies. This launch happens when a researcher decides to take entrepreneurial leave to commercialize technology they have worked on over the course of their careers. One of these companies, Advanced Diamond Technologies, was spun off to commercialize diamond coatings. In 2019, the company was acquired by mechanical seal company John Crane.

Additionally, in the past five years, Argonne has been home to Chain Reaction Innovations, a Laboratory-Embedded Entrepreneurship Program supported by DOE in which startup companies are given a two-year runway of mentorship and resources, including facilities and experts from Argonne. In this two-year period, these companies advance their deep-tech innovations, build their enterprises and secure venture capital.

"Chain Reaction Innovations has been instrumental in the success of new businesses. We've supported 35 startups to date in the program, which has led to new, clean technologies and more than 434 new jobs and counting," Clifford says.

By strengthening the connections between Argonne and its industry partners, Clifford believes that the laboratory's pivotal discoveries can ultimately have a more transformative impact on society.

"There are things that national laboratories do extraordinarily well, and there are things that industry is the leader in," she says. "By combining our strengths and working together, we can move those next game-changing innovations to market to make a profound impact on people's lives and the world we live in."

ADVERTISERS INDEX

DECEMBER 2024 • VOLUME 5 • ISSUE 4

ADVERTISERS

VOLUME 5

Ceramic & Glass MANUFACTURING

Issue	Theme
April 2024	Nanomaterial manufacturing: Scale-up and commercial production
June/July 2024	Tips for establishing and expanding your business
September 2024	ESG trends in ceramics and glass
December 2024	Commercialization of academic and national lab R&D

JOIN THE GROWING RANKS OF OUR CORPORATE PARTNERS!

ceramics.org/corporate

As of October 2024

DIAMOND PARTNERS

Corning Inc.
Harrop Industries Inc.
Imerys
Mo-Sci LLC
Saint-Gobain
Superior Technical Ceramics

SAPPHIRE PARTNERS

AGC
Allied Mineral Products
Almatis Inc.
Blasch Precision Ceramics
Bosch grow platform LLC - Bosch Advanced Ceramics
CeramTec GmbH
CoorsTek
HarbisonWalker International
Harper International
I Squared R Element Co., Inc.
Kyocera International Inc.
Lithoz America LLC
McDanel Advanced Material Technologies LLC
Specialty Glass LLC
Trans-Tech
Zircar Ceramics Inc.

CORPORATE PARTNERS

3DCeram Sinto
AdValue Technology LLC
Advanced Energy Minerals
Akcoat
Akron Porcelain & Plastics Co.
Alteo
AluChem Inc.
American Elements
APC International Ltd.
Applied Ceramics
Applied Research Center
Associated Ceramics & Technology Inc.
Astral Material Industrial Co., Ltd.
AVS Inc.
BCC Research
Bekeson Glass LLC
Boca Bearings Co.
Bomas Machine Specialties Inc.
Borregaard
Bullen Ultrasonics Inc.
Capital Refractories Limited
Carbo Ceramics
Carborundum Universal Ltd.
Centorr Vacuum Industries
Ceramco Inc.
Ceramic Color & Chemical Mfg. Co.
Ceramiseal LLC
CeraNova Corp.
Cerion Nanomaterials
Chase Nedrow Industries
Chiz Bros: Refractory and Insulation Specialists
Christy Minerals
CM Furnaces Inc.
Comadur SA
Covia
Deltech Inc.
Deltech Kiln and Furnace Design LLC
Digital Press Inc.
Dorst America Inc.
Du-Co Ceramics Co.
Eirich Machines Inc.
Elan Technology
Elcon Precision LLC
Elkem ASA
Endicott Clay Products Co.
Equipceramic S.A.
Exothermics Inc.
Ferro-Ceramic Grinding Inc.
Fineway Ceramics
Fiven ASA
Fraunhofer Institute for Ceramic Technologies and Systems
Free Form Fibers
Fritsch Milling and Sizing, USA Inc.
Fusion Ceramics Inc.
GCA
GE Global Research
GeoCorp Inc.
Gleeble
Górka Cement
Haiku Tech Inc.
Henry Brick
Hindalco Industries Ltd.
Höganäs Germany GmbH
Horiba Scientific
Inmatec Technologies GmbH
Innex Innovative Industries
International Ceramic Engineering
Ivoclar Vivadent AG
J. C. Steele & Sons Inc.
Jadco Manufacturing Inc.
James R. Glidewell Dental Ceramic Inc.
Japan Fine Ceramics Center
Japan Fine Ceramics Co., Ltd.
Karlsruhe Institute of Technology
Keith Co.
Keystone Space Collaborative
Kopp Glass Inc.
Korea Institute of Industrial Technology
Kyanite Mining Corp.
Kyocera AVX Components Corp.
Kyocera Corp.
Laeis GmbH
Larkin Refractory Solutions
Lingl Installation & Service Co., Inc.
Lucideon
Magneco/Metrel Inc.
Materials Research Furnaces LLC
Mohr Machinery Services LLC
Murata Mfg. Co., Ltd.
Nabaltec AG
Netzsch Instruments North America LLC
Netzsch Premier Technologies LLC
Nexceris
Niokem Inc.
Niterra Co., Ltd.
O'Keefe Ceramics Inc.
OptiPro Systems
Orbray Co., Ltd.
O-I Glass Inc.
Oxy-Gon Industries Inc.
Pacific Clay Products Inc.
Pacific Industrial Development Corp.
Paul O. Abbe
Petroceramics
Plibrico Co., LLC
Powder Processing & Technology LLC
PRCO America Inc.
PremaTech Advanced Ceramics
QML Inc.
Rath
Rauschert Co., Inc.
Refractory Minerals Co., Inc.
Refractron Technologies Corp.
Refratechnik North America Inc.
Reno Refractories Inc.
Resonac America Inc.
RHI Magnesita
Samuel Packaging Systems Group
Sandia National Laboratories
Sauereisen Inc.
Selee Corp.
Semiconductor Energy Laboratory Co., Ltd.
Shoei Chemical Inc.
Sigma Advanced Materials
Silicon Carbide Products Inc.
Sinaptic Technologies
Sintx Technologies
SK Fine Co., Ltd.
SPT Roth Ltd.
Sumitomo Chemical Co., Ltd.
Sunrock Ceramics
Surmet Corp.
Swindell Dressler International Co.
TevTech LLC
The Edward Orton Jr. Ceramic Foundation
The Institute of Refractories Engineers
Thermcraft
Toto Ltd.
Triangle Brick Co.
Ube America Inc.
UES Inc.
UL Research Institutes
U.S. Borax
Vesuvius USA
Vishay Dale Electronics dba Vishay Centerline
Washington Mills
WesBond Corp.
Xiamen Innovacera Advanced Materials Co., Ltd.
Xinxing Electronic Ceramics Co., Ltd.
Zircar Zirconia Inc.
Zircoa Inc.

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

The Center for Advanced Ceramic Technology (CACT)

Supporting the needs of the technical ceramics & glass sectors for over thirty years

Through CACT, industrial partners gain access to the resources and expertise needed to advance research and boost their bottom line.

As the only institution in the country to offer glass science degrees through PhD, and one of only three institutions dedicated to ceramic engineering, CACT links firms to Alfred's unique capabilities to solve challenges addressing a wide range of analytical and applied technical research areas, including:

Materials: Additive Manufacturing; Bioceramics; Carbon-based composites; Electronic ceramics; Energy storage materials; Fuel cell materials; Glass; Metal-Ceramic composites; Optical Materials; Polymers; Structural ceramics; Ultra-High Temperature ceramics; Whitewares.

Modeling: Microstructure; Atomistic structure of glass/ceramics; Defect behavior; Transport behavior; Multiscale modeling; Multiphysics modeling.

Processing: Ceramic powders; Engineered nanoparticles; Specialty glass processing; Nanoscale fabrication; Thin/Thick film coatings; Tape casting; Hot/cold isostatic pressing; Specialized sintering capabilities; Sol-gel processing (glasses, powders, films); Traditional ceramic processing.

Properties/Characterization: Electrical properties; Structural analysis; Mechanical behavior and fracture; Optical properties; Biocompatibility; Surface behavior and catalysis; Thermal properties; Spectroscopy.

CACT Center for Advanced Ceramic Technology

New York State College of Ceramics at Alfred University

classified advertising

Career Opportunities

Business Services

custom finishing/machining

custom/toll processing services

firing/melting/drying

maintenance/repair services

laboratory/testing services

AD INDEX

DECEMBER 2024

AMERICAN CERAMIC SOCIETY bulletin

DISPLAY ADVERTISERS

AdValue Technology	www.advaluetech.com	11
Alfred University	www.alfred.edu/CACT	33, 60
American Elements	www.americanelements.com	Outside back cover, 17
Bomas	www.bomas.com	53
Centorr Vacuum Industries Inc.	www.centorr.com	11
Deltech Inc.	www.deltechfurnaces.com	Inside back cover
Gasbarre Products	www.gasbarre.com	53
Harrop Industries Inc.	www.harropusa.com	Inside front cover
I Squared R Element	www.isquaredrelement.com	55
L&L Special Furnace	www.llfurnace.com	17
Lithoz	www.lithoz.com	18
Mo-Sci LLC	www.mo-sci.com	3
OptiPro	www.optipro.com/optisonic	25
Oxy-Gon	www.oxy-gon.com	15
Paul O. Abbe	www.pauloabbe.com	25
Plibrico	www.plibrico.com	23
Rauschert	www.rauschert.com/en	23
Resonac	www.resonac.com	15
TevTech LLC	www.tevtechllc.com	19
Thermcraft	www.thermcraftinc.com	21
Trans-Tech	www.trans-techinc.com	22
Washington Mills	www.washingtonmills.com	21
UNITECR	www.Unitecr2025.com	7
Zircar Ceramics	www.zircarceramics.com	6
The American Ceramic Society	www.ceramics.org	40, 45, 48, 59

CLASSIFIED & BUSINESS SERVICES ADVERTISERS

Advanced Ceramic Technology	www.advancedceramictech.com	61
Bomas	www.bomas.com	61
Centorr/Vacuum Industries Inc.	www.centorr.com	61, 62
Edward Orton Jr. Ceramic Fdn.	www.ortonceramic.com/testing	62
Harrop Industries Inc.	www.harropusa.com	62
PPT - Powder Processing & Technology LLC	www.pptechnology.com	61
PremaTech Advanced Ceramic	www.PrematechAC.com	61
Quality Executive Search	www.qualityexec.com	61
Rauschert Technical Ceramics Inc.	www.rauschert.com	61
Spectrochemical Laboratories	www.spectrochemicalme.com	62
Zircar Ceramics Inc.	www.zircarceramics.com	61
Zircar Zirconia Inc.	www.zircarzirconia.com	61

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 Jessica Sly
Guest columnist

Dissolution dynamics: Understanding fast-dissolving glasses for biomedical use

Glass is traditionally viewed as chemically inert, and many compositions are designed to emphasize durability and corrosion resistance.[1] In the medical world, however, glasses can be used as biocompatible scaffolds that release therapeutic ions important for the growth of new tissue.[2,3] In this application, dissolution of the glass is encouraged for positive results.

Various techniques exist to investigate the durability and dissolution behavior of glasses. However, current techniques have some limitations.

Static dissolution is a common technique for understanding glass dissolution behavior because the experimental setup is relatively simple. In this method, either powdered (ASTM C1285) or monolithic (ASTM C1220) glass can be used to evaluate the dissolution rate.[1] However, the assumption that geometric surface area does not change throughout the measurement often results in error, especially for fast-dissolving glass compositions, such as borate-based systems.[3] Additionally, it is critical to ensure that the ions released from the glass do not have a significant impact on the dissolution rate throughout the duration of the study. Again, this consideration is especially relevant for fast-dissolving glass systems.

An alternative technique for measuring the dissolution rate of a glass is the single pass flow through (SPFT) method (ASTM C1662).[4] With this approach, a flow rate is specified to provide continuous solution flow through a reaction cell, which contains either powdered or monolithic glass. The outflow fluid is collected and measured to determine the concentration of ions released into solution over time. Although there is less concern for any background concentration to influence results using the SPFT technique, there is still worry regarding surface area change. In fact, it is theorized that the fast flow rate of new solution experienced in the SPFT technique promotes greater surface area change compared to static methods.

To overcome the challenges relating to surface area assumptions, scanning electron microscopy, optical profilometry, and mass loss measurements can help to characterize the surface area evolution. It is also good practice to consider the morphological differences when testing various samples because fine glass particles will generally exhibit faster dissolution compared to bulk samples due to increased surface exposure to the liquid.

In addition to understanding the dissolution behavior of the glass, the environment in which the glass is dissolved is highly important in dissolution testing. Many standard measurements on glass durability are done in water. However, for bioactive applications, simulated body fluid (SBF) is commonly used as the solution to emulate conditions in which

Credit: Jessica Sly

Figure 1. Modified aluminoborate glass melt for glass dissolution testing at The Pennsylvania State University.

the glass is expected to perform. Currently, a variety of SBF solutions are utilized, which can make it difficult to compare results across studies. To advance dissolution practices for bioactive glass compositions, a standard formula for SBF will have to be established.

As a member of John Mauro's group at The Pennsylvania State University, I am working to evaluate these techniques and others to help establish standardized testing methodologies for fast-dissolving glasses. By establishing better methodologies, we can take full advantage of the potential of bioactive glasses in healthcare.

References

[1]Thorpe, C. L. et al., "Forty years of durability assessment of nuclear waste glass by standard methods," *Npj Mater. Degrad.* 2021, **5**: 61.

[2]Shearer, A., Montazerian, M., Sly, J. J., Hill, R. G. and Mauro, J. C. "Trends and perspectives on the commercialization of bioactive glasses," *Acta Biomater.* 2023, **160**: 14–31.

[3]Abodunrin, O. D., Mabrouk, K. E. and Bricha, M. "A review on borate bioactive glasses (BBG): effect of doping elements, degradation, and applications," *J. Mater. Chem. B* 2023, **11**: 955–973.

[4]ASTM C1662-18: Standard practice for measurement of the glass dissolution rate using the single-pass flow-through test method. https://www.astm.org/c1662-18.html

Jessica Sly graduated with a B.S. in materials science and engineering from Washington State University and is now pursuing a Ph.D. in materials science and engineering at The Pennsylvania State University. She is part of professor John Mauro's group and works on understanding dissolution mechanisms of aluminoborate glasses. Jessica enjoys running, gardening, and exploring all that Happy Valley has to offer. ■