AMERICAN CERAMIC SOCIETY

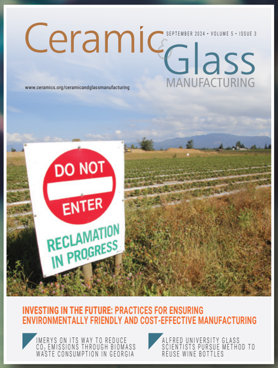
bulletin

emerging ceramics & glass technology

SEPTEMBER 2024

Glass waste solutions:
Current trends, emerging markets, and new technologies

New issue inside:



ACerS Awards of 2024 | Approaches to energy and resource efficiency

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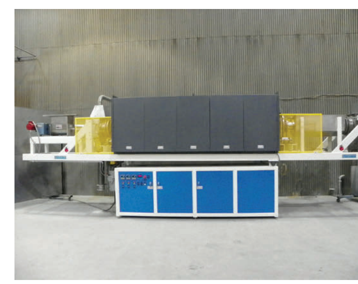

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As seen on *Ceramic Tech Today*...

Credit: Business Insider, YouTube

From pollution to pigments—Appalachian community turns mine waste into marketable product

Rural Action, an Appalachian-based nonprofit, aims to fund the remediation of water affected by acid mine drainage by selling pigments made from iron oxide extracted from the affected waterways.

Read more at www.ceramics.org/mine-pollution-pigments

Also see our ACerS journals...

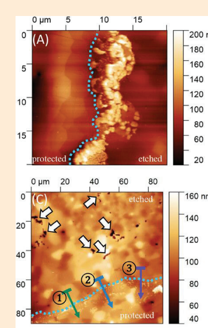
These articles were submitted for the ACerS Journals Rising Stars initiative. They are but a few of the outstanding papers authored by current graduate students and published in our four journals.

Correlative characterization of plasma etching resistance of various aluminum garnets
By C. Stern, C. Schwab, M. Kindelmann, et al.
Journal of the American Ceramic Society

Engineering grain boundary energy with thermal profiles to control grain growth in $SrTiO_3$
By V. Muralikrishnan, J. Langhout, D. P. Delellis, et al.
Journal of the American Ceramic Society

Chromium-substituted bismuth titanate–niobate exhibiting superior piezoelectric performance for high-temperature applications
By Q. Wang, E. M. Liang, and C. M. Wang
Journal of the American Ceramic Society

Selective laser sintering and spark plasma sintering of (Zr,Nb,Ta,Ti,W)C compositionally complex carbide ceramics
By L. Trinh, Z. Hua, K. Bawane, et al.
Journal of the American Ceramic Society



Credit: C. Stern et al., *JACerS*

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

Read more at 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.

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ACSBA7, Vol. 103, No. 7, pp. 1–64. All feature articles are covered in Current Contents.

letter to the editor

Setting a course for change: An invitation to the 'Sustainable Horizons' symposium at MS&T24

To the editor:

In a pivotal moment for our world, where decisions on sustainability and climate change resonate far beyond the immediate future, it is imperative to adopt a comprehensive strategy to address the intricate and interconnected challenges at hand. As scientists and engineers operating at the forefront of this global struggle, we bear the responsibility not only to advance technology and apply scientific knowledge but also to actively contribute as conscientious stewards of our planet for the well-being of future generations.

Our nontechnical symposium titled **"Sustainable Horizons: A Symposium on Collective Action for a Resilient Future,"** which will take place at ACerS Annual Meeting at MS&T in October 2024, strives to serve as a focal point for exploring effective ways in which our collective efforts, both as members of professional organizations and educators, can contribute to solutions.

Notably, a recently established consortium named the International Alliance of Societies for a Sustainable Future (SFS Alliance) has initiated collaborative efforts between several professional societies, including ACerS, to recognize, communicate, and actively work to counter the sustainability crisis. This symposium represents a significant stride in ACerS' commitment to the SFS Alliance, which you can learn more about in the sidebar "SFS Alliance: Current activities and future plans."

Unlike conventional technical programs, which highlight the latest technological advancements, this symposium is conceived as a dynamic forum. It provides a platform for individuals to exchange ideas, showcase initiatives, garner feedback from like-minded professionals, and gain insights into diverse approaches employed within institutions and professional societies, all geared toward advancing a sustainable future.

The inaugural symposium will focus on four main topics:

1. **Outreach to a broader audience**: Discussing strategies to disseminate knowledge on sustainability to a broader audience, including K–12 educators and the general public.
2. **Socio-ecological transformation**: Examining the societal and individual roles in driving socio-ecological transformation toward sustainability.
3. **Sustainability in the workplace**: Exploring sustainable practices across diverse work environments, from industry settings to university and government laboratories.
4. **Other topics in the spirit of the broad approach**: Encouraging presentations on a wide array of topics that align with the overarching theme of sustainability.

A list of presentations approved so far for the symposium can be found at https://bit.ly/SustainableHorizons2024.

By fostering dialogue and collaboration across these diverse topics, the symposium aims to be a catalyst for transformative change. Together, we endeavor to pave the way for a more sustainable and resilient future, recognizing that our collective actions today shape the legacy we leave for generations to come.

Sincerely,

Rishabh Kundu,[a] Alp Sehirlioglu,[b] and Jürgen Rödel[a]

[a]Institute of Materials Science, Technical University of Darmstadt, Darmstadt, Germany

[b]Department of Materials Science and Engineering, Case Western Reserve University, Cleveland, Ohio

To learn more about the upcoming "Sustainable Horizons" symposium and how to participate, contact the authors at

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SFS ALLIANCE: CURRENT ACTIVITIES AND FUTURE PLANS

The International Alliance of Societies for a Sustainable Future (SFS Alliance), formally established in December 2023, aims to recognize, communicate, and actively work to counter the sustainability crisis. To this end, the SFS Alliance has initiated collaborations with societies from both the materials and social science worlds, and it plans to extend these partnerships to include societies from the life sciences and natural sciences as well.

Current communications are facilitated through webinars, symposia hosted by the involved societies, and publications plus comments in various scientific journals. Recordings of past webinars can be found on the German Society for Materials Science YouTube webpage at https://www.youtube.com/@MatWerkMedia.

From July 2024, the SFS Alliance started conducting joint workshops with its partner societies to disseminate specific recommendations for sustainable business practices. These guidelines cover a range of topics, including the organization of more sustainable conferences, environmentally responsible travel practices, efficient operational strategies, and effective outreach communications. The recommendations soon will be made available on the alliance's website.

Learn more about the SFS Alliance and how to get involved by visiting https://sfs-alliance.org/home.

DOE Transmission Interconnection Roadmap sets targets for hooking clean energy up to the grid

Many discussions involving clean energy focus on the deployment of infrastructure to generate and store energy from solar and wind projects. But for these projects to contribute to the overall energy ecosystem, the generated energy must be transmitted to where it is needed. And connecting clean energy to the electrical grid is an often-underappreciated challenge.

For one, many parts of the grid are not equipped to handle the additional power generated by clean energy projects. So, more transmission and distribution lines need to be built before connecting these projects to the grid.

Even when grid capacity is not an obstacle, the traditional algorithms and configuration settings used for power conversion do not always play nicely with clean energy systems. So, grid infrastructure needs to be adapted to work with the new inputs.

In April 2024, Lawrence Berkeley National Laboratory released a report stating that nearly 2,600 gigawatts of generation and storage capacity are actively seeking grid interconnection, which represents an eight-fold increase since 2014. More than 95% of this demand comes from zero-carbon projects, such as solar, wind, and battery storage.

To address this backlog and ensure a smoother path for future interconnections, the Biden Administration through the U.S. Department of Energy launched the Interconnection Innovation e-Xchange (i2X) project in June 2022. This project, funded by the Bipartisan Infrastructure Law, brings together partners across government and industry to develop solutions for faster, simpler, and fairer interconnection of clean energy resources while boosting the reliability, security, and resiliency of the electric grid.

In October 2022, DOE announced that experts from the Wind Energy Technologies and Solar Energy Technologies offices, Pacific Northwest National Laboratory, National Renewable Energy Laboratory, and Lawrence Berkeley National Laboratory would collaborate with participating i2X organizations to develop a 5-year roadmap outlining solutions to speed up interconnection and clear the existing project backlog.

On April 17, 2024, DOE released the proposed roadmap. It includes four target metrics for 2030 that can be measured using publicly available data:

- Decreasing average time from interconnection request to interconnection agreement for completed projects to less than 12 months.
- Lowering the variance of interconnection costs for all projects to less than $150 per kilowatt.
- Increasing completion rates for projects that enter the facility study phase to greater than 70%.
- Eliminating annual North American Electric Reliability Corporation disturbance events involving unexpected tripping of inverter-based resources that are not identified in analysis due to inaccurate models.

Credit: Kenueone, Pixabay

Connecting solar and wind power projects to the electrical grid faces numerous challenges. A new roadmap outlines solutions to make this process easier.

To achieve these target metrics, DOE called attention to several funding opportunities that support the implementation of solutions outlined in the roadmap. For example,

- The Grid Innovation Program provides $5 billion for fiscal years 2022–2026 to support projects that use innovative approaches to transmission, storage, and distribution infrastructure.
- DOE's Solar Energy Technologies Office and Wind Energy Technologies Office released a $10 million funding opportunity for analytical tools and approaches to accelerate interconnection.
- The Loan Programs Office, through the Title 17 Clean Energy Financing Program, seeks to finance energy infrastructure projects, including transmission infrastructure investments.

With the transmission roadmap now complete, DOE is working on a companion roadmap that focuses on the distribution grid. DOE expects to release a draft of this roadmap soon. ■

Hydrogen train record raises expectations for sustainable transportation

Hydrogen fuel cell technology has lagged behind the development and adoption of battery–electric automobiles due in part to higher fabrication costs and the lack of a robust fueling network, both key factors to consider when designing smaller passenger vehicles.

However, fuel cells hold an edge in heavy-duty long-haul applications, where vehicles are expected to travel long distances with tons of cargo and stop only a few times for fast refueling.

Several automobile manufacturers are beginning development of hydrogen-powered semitrucks, but rail companies are farther along in this journey, with hydrogen-powered trains in service in several European countries and some prototypes undergoing testing across Asia.

Hydrogen-powered trains will soon make their debut in the United States as well thanks to a partnership between California's San Bernardino County Transportation Authority (SBCTA) and Swiss manufacturer Stadler Rail AG.

In 2019, SBCTA and Stadler signed a contract to manufacture the first two-car hydrogen-powered passenger trains to operate in the U.S. Stadler debuted the train, called FLIRT H2, at InnoTrans 2022, and in October 2023 and February 2024, the California Department of Transportation signed additional multimillion-dollar contracts with Stadler for more FLIRT H2 trains.

The FLIRT H2 hydrogen-powered train has undergone extensive testing in Switzerland, but a recent test in Colorado made headlines for setting a new Guinness World Record. During this test, which took place in March 2024, the train traveled 1,741.7 miles (2,803 kilometers) for more than 46 hours without stopping to refuel or recharge.

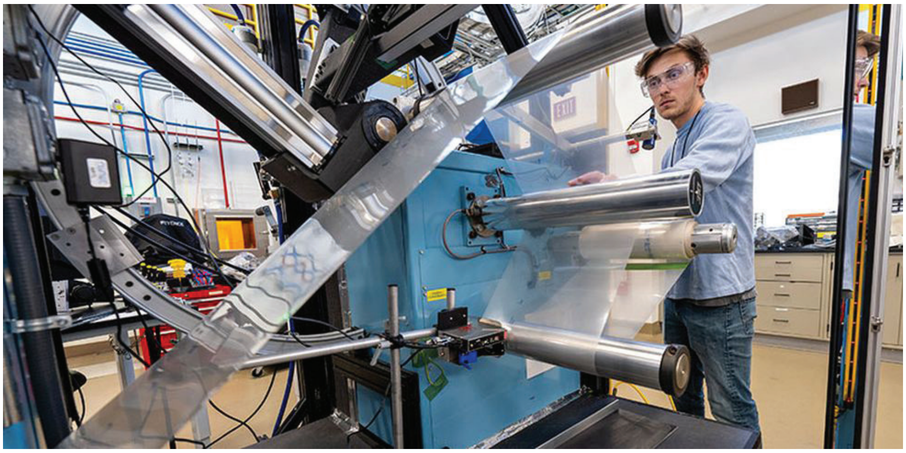
Though the ideal conditions of the test would be difficult to replicate in everyday operations, "This [test] is a monumental achievement," says Ansgar Brockmeyer, executive vice president of marketing and sales at Stadler, in a press release. ■

High-throughput manufacturing of hydrogen technologies

Research on hydrogen technologies fired up in the last year, with companies around the world testing the potential of this alternative fuel. But even as these tests yield promising results, upscaling this technology so it can be adopted by industry faces many challenges along the entire supply chain, from production and storage to transport and use.

The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has led efforts in the United States to address these challenges. For example, the HydroGEN Advanced Water Splitting Materials Consortium, launched in 2016, advances the scientific understanding of hydrogen production through electrolysis. The H2NEW Consortium, launched in 2020, aims to identify the materials and manufacturing processes that will enable production of affordable and durable electrolyzers.

In October 2023, NREL scientists Huyen N. Dinh and Bryan Pivovar presented an update on these consortiums at the Research and Development 20 Conference in Japan. Their report, which is available at https://www.nrel.gov/docs/fy24osti/87654.pdf, demonstrated the success of these consortiums in advancing hydrogen technology.



Credit: Werner Slocum, NREL

The National Renewable Energy Laboratory's roll-to-roll web line is used for research of in-line quality control monitoring techniques for battery, electrolyzer, and fuel cell materials.

With the science and tools for hydrogen production validated, the next step is a transition to mass manufacturing of hydrogen technologies. This step will be tackled by the new Roll-to-Roll (R2R) Consortium, which NREL announced on March 25, 2024.

The R2R Consortium consists of NREL, Argonne National Laboratory, Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, and Sandia National Laboratories. The laboratories plan to use roll-to-roll processing to enable high-throughput manufacturing of hydrogen fuel cells and water electrolyzers.

Corporate Partner news

Centorr Vacuum Industries celebrates its 70th year in business

The year 2024 marks Centorr Vacuum Industries' 70th year in business. Today's Centorr is the combination of two companies: Vacuum Industries, founded in 1954 in Somerville, Mass., and the Centorr Furnace Company, founded in 1962 in Suncook, N.H. The two companies merged in 1989 in new facilities in Nashua, N.H.
https://vacuum-furnaces.com

Covia completes separation of energy and industrial businesses

Covia Holdings LLC announced the completion of the separation of its Energy and Industrial businesses. Covia Solutions will remain focused on industrial markets and will be headquartered in Independence, Ohio, while Covia Energy LLC will operate as a stand-alone company based in The Woodlands, Texas.
https://www.coviacorp.com/news-releases

Orbray Co., Ltd. announces new management plan, headquarters

Orbray Co., Ltd. plans to conduct an initial public offering in 2029 amid renovations for a new headquarters and factory. These management plans are expected to help improve employee working conditions and benefits while supporting the growing company.
https://orbray.com/magazine_en/archives/3787

Resonac announces new US–JOINT consortium

Resonac Corporation announced a new consortium of 10 partners called US–JOINT to collaborate on next-generation semiconductor packaging in Silicon Valley. The companies include Azimuth, KLA, Kulicke & Soffa, Moses Lake Industries, MEC, ULVAC, NAMICS, TOK, TOWA, and Resonac.
https://am.resonac.com ■

Roll-to-roll processing is a fabrication method that embeds, coats, prints, or laminates varying applications onto a flexible rolled substrate material as that material is fed continuously from one roller on to another.

Roll-to-roll processing has the potential to increase efficiency, reduce waste, and improve the cost of hydrogen technology production. But there are challenges related to materials synthesis, coating, drying, and quality control that must be addressed to scale the process for industry adoption.

"The consortium's activities will focus on understanding the science of the manufacturing processes themselves to achieve target rates, yields, and product quality," says Scott Mauger, R2R Consortium director and senior scientist at NREL, in the NREL press release.

In addition to conducting internal research at the laboratories, the R2R Consortium plans to support industry efforts through cooperative research and development agreement projects. More details regarding this aspect of the consortium can be found at https://www.nrel.gov/hydrogen/r2r-crada-call.html. ■

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Global markets for environmental remediation technologies

By BCC Publishing Staff

The global market for environmental remediation technologies was valued at $82.5 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 7.1% to reach $124.5 billion by 2028.

Environmental remediation is the removal of pollution or contaminants from the water, soil, and air. Removal can take place through either destruction or separation of the pollutants from the environment. Generally, a few treatment approaches are consolidated because no single method can remediate an entire contaminated site. Furthermore, geographical differences impact the approaches used. For example, regions with rocky soils may require different technologies to remediate contaminated groundwater than areas with sandy soils.

Although technological developments and adoption of new technologies are generally slower in the environmental remediation market than in other industries, this market is mature due to longstanding environmental regulations in various countries. As sustainability becomes a broader topic of public discussion, companies continue to focus on product innovations and low-cost strategies to increase their share of the market. Emerging technologies for environmental remediation include

- **Bioremediation**: This approach relies on living organisms to clean up contaminated sites. This method can involve introducing microorganisms that degrade specific pollutants or using plants to absorb and remove contaminants from the soil and water.
- **Chemical reduction and oxidation**: This approach involves converting hazardous pollutants to less toxic or less hazardous contaminants through chemical reduction and/or oxidation processes. Nanoparticles are being explored as reactants in this process.
- **Electrokinetic remediation**: This technology uses an electric field to drive the movement of ions and water in contaminated soil and thereby removes heavy metals and other pollutants from the soil.
- **Steam stripping**: This method moves volatile contaminants from water to air. To vaporize volatile and semivolatile pollutants, steam is injected into the soil through an injection well. Vacuum extraction is then used to remove the contaminated vapor steam. Through condensation and phased separation processes, the pollutants are captured.
- **Ultraviolet oxidation**: This technology uses ultraviolet radiation, ozone, or hydrogen peroxide to detoxify or destroy organic pollutants as water flows into the treatment tank. Chlorine gas and dechlorinated materials are the reaction products.

In addition, the U.S. Federal Remediation Technologies Roundtable offers interactive "decision support" software tools that can be incorporated into a structured decision-making process for environment site clean-up. The tools support multiple functions, such as data acquisition, spatial data management, modeling and cost estimating. View the full list of tools at https://www.frtr.gov/decisionsupport.

North America accounted for 33.5% of the global market for environmental remediation technologies, followed by Europe (28.7%) and Asia-Pacific (20.6%). North America has a large and mature market for these technologies due to the region's long history of industrial development and the presence of many contaminated sites. In contrast, in Europe and Asia-Pacific, the market is influenced by rapidly expanding industrialization.

Table 1. Global market for environmental remediation technologies, by application, through 2028 ($ millions)

Application	2022	2023	2028	CAGR % (2023–2028)
Oil and gas industry	13,810.0	4,916.4	21,937.3	8.0
Landfill and land development	12,232.7	13,289.5	20,165.6	8.7
Mining and forestry	12,382.3	3,257.6	18,669.3	7.1
Manufacturing	11,314.5	12,067.7	16,670.3	6.7
Chemical production and processing	9,476.8	10,021.5	13,252.1	5.7
Agriculture	8,529.9	8,952.3	11,411.2	5.0
Automotive	6,545.9	7,012.5	9,899.3	7.1
Other applications	8,257.5	8,893.2	12,576.4	7.2
Total	83,549.9	88,410.9	124,581.4	7.1

About the author

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

Resource

BCC Publishing Staff, "Global markets for environmental remediation technologies," BCC Research Report ENV006E, March 2024. https://bit.ly/BCC-March-2024-remediation ■

SOCIETY DIVISION SECTION CHAPTER NEWS

Welcome new ACerS International Brazil Chapter

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

Chapter officers
Chair: **Dachamir Hotza**, Federal University of Santa Catarina
Treasurer: **Agenor De Noni Jr.**, Federal University of Santa Catarina
Secretary: **Douglas Gouvea**, University of São Paulo

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

ACerS International Southwest India Chapter organizes symposium

The ACerS International Southwest India Chapter, along with the Indian Ceramic Society Karnataka Chapter, Electrochemical Society of India, and Visvesvaraya Technological University, Karnataka, is organizing "Green Energy Materials Meet (GEM Meet) – 2024," a two-day International Symposium on Ceramics & Advanced Materials for Green Energy Value Chain. The symposium will take place from Sept. 23–24, 2024, in Bangalore, India. For more information, visit the Chapter's webpage at www.ceramics.org/sw-india-chapter. ■

ACerS International Spain Chapter participates in SECV conference

The ACerS International Spain Chapter participated in the annual Conference of the Spanish Ceramic and Glass Society, which welcomed around 180 people to Zaragoza, Spain, from June 11–14, 2024. Chapter chair Arnaldo Moreno served as one of the co-organizers of the event.

The Chapter sponsored a symposium at the conference titled "Current Advances in Additive Manufacturing of Glass and Ceramics: Processing Routes, New Feedstocks, and Applications." One keynote lecture and 12 papers were presented in the symposium. ■

María Canillas from Universidad Politécnica de Madrid gave a talk on fabricating multi-component microelectronic devices via laser deposition and sintering.

Notice: Do you qualify for Emeritus membership?

If you will be 65 years old (or older) by Dec. 31, 2024, and will have 35 years of continuous membership in ACerS, you are eligible for Emeritus status. Note that both criteria must be met. Emeritus members enjoy waived membership dues and reduced meeting registration rates. To verify your eligibility, contact Vicki Evans at vevans@ceramics.org. ■

FOR MORE INFORMATION:

ceramics.org

Central Ohio Section members enjoy clay throwing event

For the second year in a row, members of ACerS Central Ohio Section attended a clay throwing event at the Hands-On Art Barn in Galena, Ohio. The instructor, Matt, helped everyone throw clay on the potter's wheels, and each member created several small clay objects, be that bowls, cups, or vases. Everyone returned a week later to glaze their pieces and turn them into works of art. ■

Dayton/Cincinnati/Northern Kentucky Section attend Dayton Dragons game

On June 16, 2024, ACerS Dayton/Cincinnati/Northern Kentucky Section held their annual Dayton Dragons baseball game outing in collaboration with the local sections of the American Chemical Society and the Society for the Advancement of Materials Processing and Engineering. The event was a success, with excellent attendance, good food and drink, and networking within the local ACerS Section and with other scientists and engineers in the area. ■

Attend your Division business meeting at MS&T24

Seven of ACerS Divisions will hold executive and general business meetings at ACerS Annual Meeting at MS&T24 in Pittsburgh, Pa. General business meetings will be held Monday or Tuesday in the David L. Lawrence Convention Center. Plan to attend to get the latest updates and to share your ideas with Division officers.

Monday, Oct. 7
Electronics Division: Noon–1 p.m.
Engineering Ceramics Division: Noon–1 p.m.
Bioceramics Division: 2–2:30 p.m.
Energy Materials and Systems Division: 4:30–5:30 p.m.

Tuesday, Oct. 8
Glass & Optical Materials Division: 11 a.m.–Noon
Basic Science Division: Noon–1 p.m.

Wednesday, Oct. 9
Art, Archaeology & Conservation Science Division: 2–2:20 p.m. ■

MEMBER HIGHLIGHTS

Volunteer Spotlight: Maria Juenger

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

Maria Juenger is the L.B. (Preach) Meaders Professor of Engineering in the Fariborz Maseeh Department of Civil, Architectural, and Environmental Engineering at the University of Texas at Austin. Juenger received a B.S. in chemistry and Spanish from Duke University and Ph.D. in materials science and engineering from Northwestern University. After completing her Ph.D., she was a postdoctoral researcher in civil engineering at the University of California, Berkeley, before coming to UT Austin.

Juenger's teaching and research focus on materials used in civil engineering applications. She primarily examines chemical processes in cement-based materials, including phase formation in cement clinker, hydration chemistry of cements and supplementary cementitious materials, and chemical deterioration processes in concrete. Her current research efforts emphasize the interaction of cement-based materials with the environment, such as the capacity of cementitious materials to produce or remove airborne and waterborne pollutants.

Juenger is an ACerS Fellow, and she delivered the 2024 Della Roy Lecture titled "The road to sustainable cement." She is also a Fellow and current vice president of the American Concrete Institute.

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

ACerStudent Engagement: Pattiya Pibulchinda

Pattiya Pibulchinda is a Ph.D. student studying materials science and engineering at Northwestern University and serves as chair of the ACerS President's Council of Student Advisors (PCSA) Professional Development Committee.

"Being part of PCSA has allowed me to engage with professionals and peers, especially through organizing webinars and symposiums. I'm thrilled to see how our networking events create spaces for sharing diverse ideas and positively impacting others."

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

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Ceramic Tech Chat: Sergei Kalinin

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

In the June 2024 episode of Ceramic Tech Chat, **Sergei Kalinin**, Weston Fulton Professor of materials science and engineering at the University of Tennessee-Knoxville, shares how his development of advanced scanning probe microscopy techniques led to an interest in machine learning and describes some of the benefits, limitations, and challenges of adopting machine learning for materials research.

Check out a preview from his episode, where he discusses some of the challenges that come with using machine learning to tackle big data problems.

"The vast majority of machine learning algorithms are not causal. You have features and targets, but you can flip targets and features it is still a legitimate machine learning problem. As a result, the best majority of the machine learning methods that rely on big data can be useful under certain scenarios, but they're no substitute for human intuition, decision making, and generally planning. So they can help, but they cannot take over the human role for the time being."

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

AWARDS AND DEADLINES

Nomination deadlines for Division awards: Sept. 25, 2024

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

Division	Award	Deadline	Contacts	Description
BSD	Roland B. Snow Award	September 25	Klaus van Benthem benthem@ucdavis.edu	Presented to the Best of Show winner of the Ceramographic Exhibit & Competition, which is an annual poster exhibit to promote the use of microscopy and microanalysis in ceramics research.

Recognize your excellence: The case for self-nomination in awards

We know our members are leaders and innovators deserving of recognition. But do successful materials professionals simply wait to be recognized? The answer is no. Instead, they take proactive steps to ensure their hard work and stellar performance are acknowledged. One effective step that members can take is through self-nomination for awards or requesting colleagues to nominate them.

Why pursue awards?

- **Reflection:** The application process allows you to reflect on your skills, career progress, and achievements, helping you identify areas for improvement.
- **Recognition:** Winning awards distinguishes you from others, builds credibility, and can help establish you as an expert in your field.
- **Support:** Seeking nominations fosters strong relationships with senior colleagues, building a supportive professional network.

Benefits of self-nomination

Contrary to popular belief, self-nomination and seeking support letters from colleagues do not solely benefit the nominee. This process also helps raise awareness of high-quality work within the community, encouraging a culture of recognition and support.

Strategies for successful nomination

To increase your chances of a successful nomination, it is crucial to prepare thoroughly. For example,

1. **Review award requirements:** Understand what the award committee is looking for.
2. **Compile supporting information:** Gather both quantitative and qualitative data that highlight your achievements.
3. **Request detailed support letters:** Ask trusted colleagues to provide comprehensive letters that reflect your contributions accurately.

Applying for multiple awards can also increase your chances of recognition. Remember, most awards committees keep nominations on file for up to five years. If you do not win initially, review and update your submission for the following year, possibly adding new support letters to strengthen your application.

ACerS: Honoring excellence in ceramics and glass

ACerS is proud to be the professional home to global leaders in the ceramics and glass community. Recognizing those who distinguish themselves within our community is a privilege we hold in great respect. So, take the initiative, ask for support, and let your excellence shine.

We particularly encourage nominations for deserving candidates from underrepresented groups, including women, minorities, industry scientists and engineers, and international members.

FOR MORE INFORMATION:

ceramics.org/members/awards

CERAMICANDGLASSINDUSTRY FOUNDATION

CGIF's Materials Science Classroom Kit featured in PBS's 'Curious Crew'

By Ryan Schwieger, CGIF intern

The Ceramic and Glass Industry Foundation (CGIF) Materials Science Classroom Kit lessons were recently featured on the PBS show "Curious Crew," hosted by Rob Stephenson.

"Curious Crew" is an award-winning educational PBS series produced by WKAR in East Lansing, Mich. Each episode dives into a different topic of science, with Stephenson and a crew of students conducting experiments to showcase concepts in a fun and engaging way to get students excited and curious about the world around them.

"I love working with inquisitive kids," says Stephenson, a previous recipient of the Presidential Award for Excellence in Science Teaching (2006) and Michigan Teacher of the Year (2009–2010). "When I'm working with inquisitive kids, their energy feeds me, and gets me really excited about inquiry and phenomenon-based instruction and really starting to do authentic science."

The episode, titled "Materials Science," dives deeply into the science behind materials, including ceramics, glass, composites, and metal alloys. During the episode, Stephenson and his team of students thoroughly tested the CGIF kit lessons titled "How Strong is Your Chocolate?" and the "Candy Fiber Pull," as well as other lessons. The last section of the episode highlighted career opportunities within the materials science field. During this segment, students were given a tour of Michigan State University's School of Packaging, showcasing the work that engineers do to create effective packaging.

"I love, love, love, seeing the profound impact that we are having, even in my own region, walking into a school, getting mobbed by kids recognizing me from Curious Crew, and have them share with me their favorite activity, their investigation," says Stephenson.

Credit: Robert Stephenson, PBS

Rob Stephenson, center, stands with his team of student on the PBS hit show "Curious Crew."

The show has been a hit on PBS, garnering thousands of views worldwide. Stephenson also received two 2020 Michigan Regional Emmy Awards for his work on the show.

CGIF's collaboration with Stephenson enables more students to explore the world of materials science, especially those based around ceramics and glass.

Watch the episode at https://bit.ly/Curious-Crew-Materials-Science.

Collaborations such as this one are one of the many ways that the CGIF continues to foster involvement and awareness of the ceramics and glass industry, which would not be possible without the help from all our donors. If you would like to become a donor or continue to show your support, please visit https://foundation.ceramics.org/give. ■

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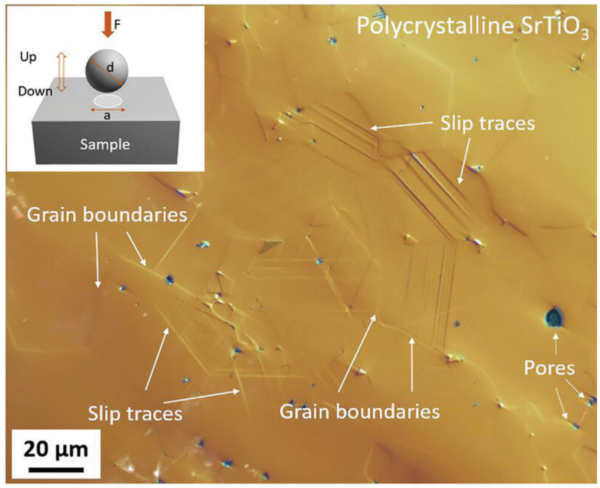
Near-surface dislocation mechanisms allow room-temp deformation of polycrystalline ceramics

In a recent open-access paper, researchers in Germany used cyclic Brinell indentation to explore how dislocation mechanisms near and along the surface of polycrystalline strontium titanate allow it to successfully deform without fracture at room temperature.

According to the von Mises or Taylor criterion, which is used to predict yielding of materials under complex loading, polycrystalline materials need to have at least five independent slip systems to plastically deform without fracture. Anything less would result in dislocations piling up along the grain boundaries and initiating cracks.



Credit: Okafor et al., Journal of the American Ceramic Society (CC BY 4.0)

Optical microscope image highlighting the slip traces induced by Brinell indentation (inset) on a polycrystalline strontium titanate sample at room temperature.

In many ceramics, such as strontium titanate and most rocksalt-structured ceramics, there are six physically distinct slip systems at room temperature, but only two of them are independent. As such, effective slip transmission cannot take place at room temperature.

Fewer independent slip systems do not necessarily condemn a material to fracture, however. The von Mises or Taylor criterion was developed with the movement of interior grains in mind. But along the surface of a polycrystalline material, dislocations can avoid piling up through various mechanisms, so the von Mises or Taylor criterion can be relaxed.

Before testing polycrystalline samples, the researchers first performed cyclic Brinell indentation on single-crystal strontium titanate samples. Because single crystals have no grain boundaries, a better understanding of the basic dislocation slip trace patterns can be gained prior to examination of the more complicated polycrystalline system.

Based on these experiments, which used testing parameters established in an earlier publication, the researchers discovered that cyclic indentation trigged several dislocation multiplication mechanisms, namely cross slip and Frank-Read sources, irrespective of surface orientation. In other words, indentation increased the number of dislocations in the sample, which helped accommodate the loading.

These multiplication mechanisms occurred in the polycrystalline samples as well. However, during the first indentation cycle, the researchers found that the movement and generation of dislocations along and within two grain boundary features, namely ledges and triple junction pores, were the main mechanisms promoting plasticity and preventing fracture. This finding is "counterintuitive to most brittle ceramics at room temperature," the researchers write, because grain boundaries and pores often contribute to rather than mitigate fracture.

The researchers expect these findings on the dislocation-enabled deformation mechanisms of polycrystalline strontium titanate to be transferrable to other ceramics that exhibit room-temperature plasticity. In addition, "...this work may pave the road for future studies on the geometrical contribution and grain size effect on dislocation–GB [grain boundary] interaction," they conclude.

The open-access paper, published in *Journal of the American Ceramic Society*, is "Near-surface plastic deformation in polycrystalline $SrTiO_3$ via room-temperature cyclic Brinell indentation" (DOI: 10.1111/jace.19962). ■

Research News

Specialty optical fibers overcome data transfer challenges of quantum computing

University of Bath physicists developed specialty optical fibers to cope with the challenges of data transfer expected to arise in the future age of quantum computing. Modern cable networks use optical fibers with solid cores. In contrast, the specialty fibers fabricated at Bath have a microstructured core consisting of a complex pattern of air pockets running along the entire length of the fiber. The pattern of these air pockets allows the properties of light to be manipulated and so can create entangled pairs of photons, change the color of photons, and even trap individual atoms inside the fibers. For more information, visit https://www.bath.ac.uk/announcements.

AI-based method speeds predictions of materials' thermal properties

Researchers led by Massachusetts Institute of Technology developed a machine-learning framework that can predict the phonon dispersion relation, a key property of heat dispersion in materials, up to 1,000 times faster than other artificial intelligence-based methods. Traditionally, this property is calculated using graph neural networks, which are not flexible enough to efficiently predict an extremely high-dimensional quantity such as the phonon dispersion relation. The researchers instead used a virtual node graph neural network, which enables the output of the neural network to vary in size so it is not restricted by a fixed crystal structure. For more information, visit https://news.mit.edu.

Hardness breakthrough: New experimentally synthesized carbon nitrides may rival diamond

In a recent groundbreaking study, researchers from numerous universities across Europe reported that they synthesized four covalent carbon nitrides with hardness values comparable to either cubic boron nitride or diamond.

Diamond stands supreme among naturally formed materials in terms of hardness. However, scientists have continually aimed to overcome this natural limit through synthetic fabrication of different carbon- and nitrogen-based materials.

Since 1989, carbon nitrides have captured the attention of many research groups due to theoretically predicted potential for extreme hardness. Specifically, carbon nitrides featuring three-dimensional frameworks of CN_4 tetrahedra are expected to have a hardness greater than or comparable to diamond.

Yet over the past three decades, attempts to synthesize these carbon nitrides using a variety of methods resulted in only a single success in 2016. In that study, researchers obtained a fully saturated sp^3-hybridized carbon nitride (the CN compound) in a diamond anvil cell laser-heated to 7,000 K at pressures of more than 55 GPa. However, this compound was unstable below pressures of 15 GPa and could not be recovered at ambient conditions.

In the new study, the researchers successfully recovered four covalent carbon nitrides at ambient conditions. The four covalent carbon nitrides include the previously synthesized CN composition (*oP*8–CN), two with the C_3N_4 composition (*tI*14–C_3N_4, *hP*126–C_3N_4) and one with the CN_2 composition (*tI*24–CN_2). All the compounds feature 3D polymeric structures in which carbon and nitrogen atoms are fourfold and threefold-coordinated, respectively.

To create these covalent carbon nitrides, the researchers first synthesized the samples using different precursors at pressures between 70 to 140 GPa and temperatures above 2,000 K. In all cases, synthesis of the carbon nitrides was performed in laser-heated diamond anvil cells at their target pressure. After opening the diamond anvil cells and exposing the samples to air, high-quality synchrotron single-crystal X-ray diffraction data could still be collected at ambient conditions, which means the nitrides' crystallinity and high-pressure crystal structures were preserved.

In addition to high hardness values, the four covalent carbon nitrides exhibited high thermal conductivity and energy density, wide bandgaps and insulating properties, second-order harmonic generation, and possible tunability of photoluminescence via defects. Plus, the compounds *tI*14–C_3N_4 and *tI*24–CN_2 can exhibit piezoelectricity due to their non-centrosymmetric structures.

In a University of Edinburgh press release, first author Dominique Laniel, a Future Leaders Fellow at the University of Edinburgh, says the researchers were at first "incredulous" to have produced materials that researchers were dreaming of for the last three decades. But now with their existence confirmed, "These materials provide strong incentive to bridge the gap between high pressure materials synthesis and industrial applications," he says.

The open-access paper, published in *Advanced Materials*, is "Synthesis of ultra-incompressible and recoverable carbon nitrides featuring CN_4 tetrahedra" (DOI: 10.1002/adma.202308030). ■

Toward a better way of releasing hydrogen stored in hydrogen boride sheets

Tokyo Institute of Technology researchers showed that hydrogen stored in hydrogen boride sheets can be efficiently released electrochemically by simply dispersing the sheets in an organic solvent and applying a small voltage. The Faradaic efficiency of this process, which measures how much electrical energy is converted into chemical energy, was more than 90%. These findings suggest hydrogen boride sheets could be a convenient way to store and transport hydrogen, which is a necessary part of building out a robust hydrogen fuel network. The researchers now plan to investigate the rechargeability of the hydrogen boride sheets after dehydrogenation. For more information, visit https://www.titech.ac.jp/english/news/2024/068477. ■

Cross-cultural study provides insight into how pottery forms change across communities

An international group of researchers led by Kobe University in Japan investigated the roles that community and individuality play in pottery design through a unique cross-cultural experiment.

Archeologists have defined two major mechanisms to explain the similarities and differences in community-specific art styles:

- **Selective transmission of information.** This mechanism is modeled after the theory of biological evolution, in which small errors are introduced unintentionally when existing patterns are copied. Over time, these errors will accumulate and result in a new, distinct pattern within the given community.
- **Culture-specific biased transformation.** This mechanism involves making purposeful changes to an existing pattern based on an individual's biases. When these biases are shared in a population, community-specific variations of artifacts can persist.

These two mechanisms are not mutually exclusive and may both contribute to a community's nonrandom divergence from standard patterns.

To better understand how these mechanisms and other factors interact to result in community-specific variations, the researchers tasked 21 professional potters from three different cultural backgrounds (French, Hindu Indians, and Muslim Indians) with reproducing unfamiliar model shapes.

The potters, who each had more than 10 years of experience, were instructed to use pottery wheels and two different quantities of clay (0.75 and 2.25 kg) to make four different shapes: cylinder, bowl, sphere, and vase. No dimensions for the shapes were provided; the potters were only told to reproduce the shapes and throw vessels with the thinnest walls possible. Each potter used the pottery wheel most familiar to them: Hindu potters used high-inertia flywheels driven by sticks, Muslim potters used low-inertia kick wheels, and French potters used electric wheels.

The shaping process was captured with video cameras, and both the final shape as well as the vessel's shaping process were mathematically analyzed in several ways. Changes occurring during the initial preformed stage up to the final form were examined.

For each shape produced, both the forming process and final product showed variations, confirming that each individual potter had their own unique wheel-throwing method. However, potters from different communities produced vessels with more shape variations than within communities. Differences between communities include

- Hindu Indian potters made elongated barrel-like shapes during forming, and these intermediate shapes were taller than the final products. The final shape was shorter and wider with a sharp curve at the height where the diameter is largest.
- Muslim Indian potters produced a more gradual elongation, and the intermediate shapes were not much taller than the final products. This group produced vessels the fastest and had thicker walls compared to the other groups.
- French potters initially prepared disk-like flat preforms, and the final vessels tended to have wider bottoms compared with those produced by the other two groups.

Credit: Kobe University, YouTube

Researchers led by Kobe University investigated how potters from different cultural backgrounds formed basic shapes. (Left) Hindu Indian potters use high-inertia flywheels driven by sticks to shape their products, (center) Muslim Indian potters use low-inertia kick wheels, and (right) French potters use electric wheels.

Despite the same quantity of clay being used to produce the shapes, the final products also varied in dimension across potters in the different communities. Furthermore, analysis showed that

- Each potter had their own preferred preformed shape, which eventually evolved into different final shapes. The range of individual variation was largest at the initial stage.
- Significant degrees of difference were present within each community, where individual potters followed different forming processes to reach the final shape, which was more consistent than the preformed shape.
- Differences between individual potters within one community were smaller than the differences between communities, making it possible to identify a product's community of origin.
- The final product could also be identified as to which individual potter made it.

The researchers conclude by noting that this study "adds to the growing realization that we should explore theories that assign greater complexity to individual humans, as this is necessary for providing thorough explanations of skill learning and craftsmanship."

The open-access paper, published in *PNAS Nexus*, is "Cultural attraction in pottery practice: Group-specific shape transformations by potters from three communities" (DOI: 10.1093/pnasnexus/pgae055). ■

Dairy residues on Neolithic pottery show that ancient Europeans relied on cheese from multiple species

University of York researchers led a study that suggests early farmers used dairy products from different animals to make cheese, thereby reducing the products' lactose content.

Archaeologists have repeatedly shown that dairy products were an essential part of late Stone Age diets, yet they have also shown that most Neolithic Europeans were lactose intolerant.

The researchers focused this recent study on ceramic vessels found at the site of Sławęcinek, Poland, which belonged to the historically significant Funnelbeaker culture. The Funnelbeaker culture, also known as Trichterbecherkultur (TRB) in German, existed in north-central Europe during the fourth millennium BCE (about 4000 BCE to 3000 BCE). This culture, which extended from the Netherlands to Poland and from Germany to southern Sweden, is considered one of the first in the area to transition from being hunter-gatherers to relying on farming and livestock.

The Funnelbeaker culture is named after their signature funnel-shaped ceramics. At the Sławęcinek site, a TRB settlement was discovered in 2016 with many ceramic vessels and fragments. Of those ceramics, some had a characteristic white mineralized residue on the inside, spurring the researchers to examine them for evidence of dairy.

The study concentrates on four ceramic vessels (three flasks and one strainer) as well as four modern replicas. The modern replicas were used in an archaeology outreach event to make cow's milk cheese using ancient techniques. They act as a control to understand how diary processes affect ceramic containers.

Using paleoproteomics, or the analysis of proteins, the researchers characterized both the ceramic vessels and the residue itself to identify which proteins were present. Comparing their results to two large databases of known proteins, the study concluded that all the dietary proteins found were from dairy; none were from meat, plants, or yeast. They also identified proteins from multiple species, including cows, sheep, and goats.

Notably, the proteomic results showed that the ancient residues closely resembled cheese rather than whole milk. The process of turning milk into cheese reduces the lactose content.

"This [finding] reveals that the people of Sławęcinek practiced cheesemaking or another form of curd-enriching dairy processing," says lead author Miranda Evans, Ph.D. student in archaeology at the University of Cambridge, in a press release.

These results also signal an "intensification in milk production," according to the researchers, in contrast to the early Neolithic period where milk was consumed only occasionally within a highly varied diet.

In addition to the protein analysis, the researchers investigated the lipids present in the ceramics with dairy residues, as well as six additional vessels with no visual evidence of dairy. They found that the six additional vessels all had evidence of animal fats and plant oils, and of all the vessels, some even had evidence of mixed usage between dairy, animal fats, and plant oils. The paper concludes that many vessels likely had varying uses throughout their lifetimes, and that discrepancies between the protein and lipid analyses are cause for further study.

The open-access paper, published in *Royal Society Open Science*, is "Detection of dairy products from multiple taxa in Late Neolithic pottery from Poland: an integrated biomolecular approach" (DOI: 10.1098/rsos.230124). ■

Credit: Hans Splinter, Flickr (CC BY-ND 2.0)

Performers at Archeon Museum Park in the Netherlands demonstrate how Neolithic-era people may have created cheese.

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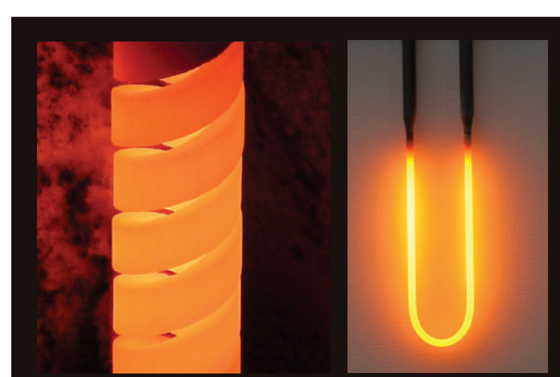

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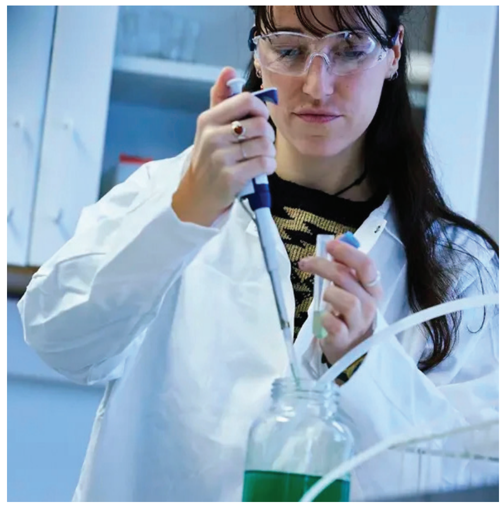
From trash to treasure: Environmentally friendly recovery processes for battery scrap reuse

Two recent studies by researchers in the United States and Sweden, respectively, described new ways to recover materials from spent batteries in a more environmentally friendly manner.



Credit: Henrik Sandsjö, Chalmers University of Technology

Léa Rouquette, Ph.D. student in chemistry and chemical engineering at Chalmers University of Technology, demonstrates a new hydrometallurgy recycling method based on oxalic acid.

Water-based recovery process for anode scraps

In an April 2023 paper, researchers at Oak Ridge National Laboratory and Argonne National Laboratory described a simple yet efficient water-based recovery process for battery anode scraps.

A typical lithium-ion battery anode consists of graphite, conductive carbon, and a binder material (such as polyvinylidene difluoride or styrene-butadiene rubber) coated onto a current collector, typically copper foil. Current recycling methods use either hazardous solvents or high temperatures to dissolve/remove the binder, which can result in the release of toxic gases.

“Therefore, it is important to develop a highly efficient, cost-effective, and environmentally friendly process to directly recycle anode scraps and reintegrate the recovered materials into the battery supply chain,” the researchers write in the paper.

In the recent study, they showed that simply immersing the anode in deionized water completely delaminated the anode films from the copper foils without damaging any components. The recovered films could then be directly reprocessed into slurry and recast as new anodes because the films’ composition was not altered. Testing confirmed that the new anode exhibited electrochemical performance on par with that of the original anode.

The paper, published in *Sustainable Materials and Technologies*, is “Direct recycling and remanufacturing of anode scraps” (DOI: 10.1016/j.susmat.2022.e00542).

Hydrometallurgy goes green: Oxalic acid shows potential as leaching agent

In a September 2023 open-access paper, researchers at Chalmers University of Technology in Sweden described a new hydrometallurgy process that uses oxalic acid as a leaching agent to achieve selective separation during battery recycling.

Hydrometallurgy relies on aqueous solutions to extract and separate metals. Toxic inorganic acids are typically used in this process. However, oxalic acid is an organic acid found in many plants. Not only is oxalic acid considered more environmentally friendly than inorganic acids, but it also has a high potential for industrialization.

Several previous studies investigated the use of oxalic acid as a leaching agent. These studies confirmed its potential to effectively recover various battery metals. But the effect of oxalic acid on aluminum—a difficult metal to remove using the traditional, inorganic acid-based hydrometallurgy route—was not reported.

In the new study, the Chalmers researchers dismantled spent lithium-ion batteries provided by Volvo Cars AB. The nickel–manganese–cobalt cells were then crushed, mechanically sieved, and magnetically separated at temperatures below 50°C to obtain a “black mass,” or a shiny, metallic mixture containing all the valuable metals from the battery.

During the subsequent leaching process, the oxalic acid reacted with lithium, nickel, manganese, and cobalt oxide to form simple oxalate compounds. Aluminum, on the other hand, formed complex oxalate compounds.

Only the lithium simple oxalate and aluminum complex oxalates were soluble. This property allowed them to be selectively dissolved in the leachate, while the other transition metal oxalates remained in the leaching residue.

By optimizing the processing conditions, the researchers successfully leached 98.8% of the lithium and 100% aluminum, while less than 0.5% of cobalt and nickel and 1.5% of manganese were dissolved.

With the cobalt, nickel, and manganese left behind as easily recovered solids, the next step would be to separate the aluminum and lithium in the leachate. The researchers do not believe this separation will be difficult because the metals have very different properties.

The open-access paper, published in *Separation and Purification Technology*, is “Complete and selective recovery of lithium from EV lithium-ion batteries: Modeling and optimization using oxalic acid as a leaching agent” (DOI: 10.1016/j.seppur.2023.124143). ■

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Stretching the limits of auxetic expansion: Tungsten semicarbide nanosheets set new record

In a new record for auxetic materials, researchers at the University of Western Ontario synthesized 2D flakes of tungsten semicarbide (W_2C) than can expand up to 40% under applied strain.

It is difficult to synthesize W_2C because most carbide growth techniques operate close to thermodynamic equilibrium, resulting in the formation of conventional tungsten carbide (WC) instead. To overcome this challenge, the Canadian researchers designed a dual-zone, ultrahigh-vacuum, remote plasma deposition system.

Conventional plasma deposition techniques for thin films and 2D materials involve placing the substrate directly within a plasma chamber and using a gas discharge to provide the energy for material growth reactions. In contrast, remote plasma-assisted techniques extract the plasma from the plasma chamber, and species that travel far enough to reach the substrate are deposited. The remote plasma process allows the growth of tungsten carbides outside of equilibrium thermodynamic conditions.

Using this system, the researchers successfully produced 2D flakes of W_2C. Their achievement depended on identifying the specific deposition conditions for which hydrocarbon precursors (W_2CH_n) can be remotely extracted from the plasma.

First, using optical emission spectra, they investigated how the amount of argon backflow affected the reactor behavior. They determined that if there was no backflow, the amount of exposed tungsten on the surface that can be sputtered was reduced, leading to a large area of WC. For a slightly higher backflow, the rate of decomposition from CH_4 to CH^+ increased proportionally, but a substantial portion of the target's surface still showed WC formation.

At a backflow rate of 3 standard cubic centimeters per minute (sccm), a more uniform texture was observed, which resembled the crystallographic structure of single-layer W_2C. Increasing the backflow to 5 sccm led to a higher deposition rate and flake thickness, but beyond that, the diffusion of W_2CH_n species started to be limited again, thus reducing the deposition rate.

Investigation of the 2D W_2C flakes revealed that these materials exhibited the strongest experimentally observed auxetic behavior observed to date, expanding by up to 40% under applied strain. This expansion is four times more than the previous experimental record observed in 2D black phosphorous.

In addition, the researchers developed a transfer printing method to move the W_2C flakes without damage, which would allow them to be used in mechanically switchable photonics crystals and oscillators.

Credit: Mitch Zimmer, University of Western Ontario

Noah Stocek, Ph.D. student at the University of Western Ontario, looks inside the customized remote plasma deposition system he designed with physics professor Giovanni Fanchini and assembled with postdoctoral fellow Farman Ullah. Using this system, they produced new record-setting 2D auxetic materials.

The paper, published in *Materials Horizons*, is "Giant auxetic behavior in remote-plasma synthesized few-layer tungsten semicarbide" (DOI: 10.1039/D3MH02193A). ■

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Honoring the ACerS

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

The most prestigious of ACerS awards is Distinguished Life Member designation, a recognition bestowed upon only two or three members each year. In 2024, two individuals will receive DLM honors: Lisa C. Klein and Zuhair A. Munir.

The Society will elevate 13 members to Fellow and recognize many more outstanding members with various Society, Division, and Class awards during the ACerS Annual Honor and Awards Banquet Reception on Oct. 7, 2024.

2024 DISTINGUISHED LIFE MEMBERS

Lisa C. Klein

People very rarely end up in the career they imagined pursuing as a child. But Lisa C. Klein is not like most people. "I told my first-grade teacher that I was going to be an engineer. Many years later, when I ran into her again, she said, 'Well, what have you done? Have you become an engineer?' And in fact, I had," Klein says.

Though neither of Klein's parents were engineers, she grew up in a time that placed great emphasis on science. The space race between the United States and the Soviet Union drove discussion and funding for science across the nation, while closer to home, Klein was inspired by field trips to local industrial facilities, such as commodity chemical plants run by DuPont, a major employer in the area.

Klein initially earned a B.S. in metallurgy from Massachusetts Institute of Technology, but it was during her graduate studies in the university's materials science department when she discovered her passion for ceramics and glass, specifically sol-gel processing of these materials.

"I was working on a glass composition that was not very easy to make. It was a sodium aluminosilicate," Klein says. "Rustum Roy had written a paper at the time talking about the sol-gel process, and I thought, 'Oh, that might make it easier to get a uniform glass.'"

Klein's interest in what was at the time a laboratory curiosity has since evolved into more than 250 peer-reviewed publications, patents, book chapters, and edited books on the topic of sol-gel processing and other related glass topics. She is now widely recognized as a leading expert in the field of sol-gel science and engineering, particularly for applications in electrolytes, electrochromics, membranes, and nanocomposites. Her seminal efforts were on display during ACerS Annual Meeting at MS&T22 when she delivered the Arthur L. Friedberg Ceramic Engineering Tutorial and Lecture, titled "From moon rocks to melting gels."

In addition to her groundbreaking work on sol-gel processing, Klein is known for her dedication to the advancement of women in science. She was the first woman to join the Department of Ceramic Science and Engineering at Rutgers, The State University of New Jersey, in 1977, and the university awarded her a Human Dignity Award in 2015 to recognize her work "leveraging opportunities to encourage women, underrepresented minorities, and economically disadvantaged individuals to pursue their aspirations."

Klein originally became a member of ACerS in graduate school. During her more than 50 years as a member, she served the Society in various roles on committees and as an editor of *Journal of the American Ceramic Society* from 1998–2019. In addition to the Friedberg Lecture, Klein has been recognized with the Karl Schwartzwalder-Professional Achievement in Ceramic Engineering Award (1987), the Michigan/Northwest Ohio Section's Toledo Glass and Ceramic Award (2018), and the Darshana and Arun Varshneya Frontiers of Glass Science Lecture (2023).

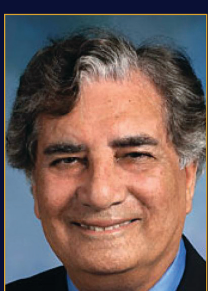
Considering the reach of her career, Klein says people are often surprised to hear that Columbus, Ohio, has been her number one destination over the years. But this revelation demonstrates her long-standing commitment and involvement as a member of ACerS.

Regarding her recent designation as DLM, Klein says she is honored to be recognized by a society that supports its members in so many ways.

"The American Ceramic Society has so many opportunities to get involved, both the publications, the scientific content, the meetings. To me, it is being part of an organization that very much appreciates its members' contributions," she says.

Awards Class of 2024

Zuhair A. Munir



Out of a long career filled with research, awards, and lectures, Zuhair A. Munir gives credit to the many students he has mentored as a source for his success.

"Over decades of teaching and doing research, I have had the good fortune of working with scores of outstanding young students and scholars who contributed immensely to my accomplishments. This honor belongs to them also," says Munir.

Munir spent his student years at the University of California, Berkeley, where he received a B.S. in chemical engineering with honors and a Ph.D. in ceramic engineering. He then taught at San Jose State University and Florida State University before joining the University of California, Davis, where after more than four decades he now holds the positions of Distinguished Professor, Emeritus and Dean, Emeritus.

Munir is world renowned for his work on the use of electric fields in materials processing. In the 1970s, he investigated the effect of electric fields on phase transformations and the formation and mobility of defects in ceramics; he received two National Science Foundation Creativity in Research Awards for this work. Then, in the 1980s, he began studying the role of electric fields on self-propagating high-temperature synthesis (SHS) reactions, including work in microgravity aboard NASA's "Vomit Comet." In the 1990s, he added spark plasma sintering (SPS) to his list of research topics when he acquired an SPS facility at UC Davis, the first in the Western Hemisphere. He also studied field effects on electromigration, dissolution in liquid metals, annealing of point defects, and crystallization of metallic glass.

Munir has shared his research with the community through several ACerS publications, including an invited feature article on SPS for *Journal of the American Ceramic Society* and an invited feature article on SHS in the *ACerS Bulletin*. The latter article was translated and published in a Chinese journal, and the Chinese government then invited him for a month-long visit to give lectures on SHS at major universities and research institutes in the country.

Munir has received numerous awards for his pioneering work on SHS and SPS, including the Medal of Honor at the Fourth International Symposium on SHS, the Gold Medal from the Russian Academy of Science, the Prometheus Award from the National Institute of Materials Science in Japan, and the UC Davis Prize. He also has had several events organized in his honor, including a symposium at the 10th Pacific Rim Conference on Ceramic and Glass Technology, a workshop at the University of Valenciennes in France, and the Fourth International Workshop on Spark Plasma Sintering (plus its proceedings book). In addition, for his work on synthesizing dense nanocrystalline cubic zirconia, Munir received the Nano 50 Award, which recognizes technologies "most likely to impact the state of the art in nanotechnology."

Munir has volunteered with ACerS in several capacities, including as co-organizer for eight International Conferences on Advanced Ceramics and Composites as well as the International Symposium on Combustion and Plasma Synthesis. He co-edited four books in the "Ceramic Transactions Series" and served as associate editor of *Journal of the American Ceramic Society*. He also was a member of several Society committees.

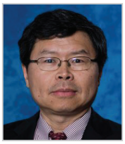
"It is with a great sense of humility and gratitude that I acknowledge the recognitions I have received from ACerS over the years: the W. David Kingery Award, the James I. Mueller Memorial Award, the John Jeppson Award and Medal, and the Outstanding Educator in Ceramic Engineering Award," says Munir. "But with this honor of Distinguished Life Membership, I feel a special sense of gratitude because it provides a fitting milestone for my work and for my association with our Society." ■

The 2024 Class of Fellows

Victoria Blair is research materials engineer serving the U.S. Army Combat Capabilities Development Command at the U.S. Army Research Laboratory. She received her B.S. in ceramic engineering and Ph.D. in ceramics from Alfred University. She has been an ACerS member since 2007 and is a member of the Basic Science Division. Blair has served on multiple committees within ACerS, including the Member Services Committee, Strategic Planning and Emerging Opportunities Committee, Educational and Professional Development Council, and the Young Professionals Network. She currently serves as the President's Council of Student Advisor's mentor-at-large. In 2021, she received the Du-Co Ceramics Young Professional Award and the Robert L. Coble Award for Young Scholars.

Willard Cutler is division vice president and commercial technology director at Corning Incorporated. He received a B.S. in materials science and engineering from the University of Utah and a Ph.D. in materials from the University of California, Santa Barbara. He has been an ACerS member since 1988 and is a member of the Basic Science Division.

Edward Gorzkowski, III, is branch head of the Multifunctional Materials Branch at the U.S. Naval Research Laboratory (Washington, D.C.). He earned his B.S. and Ph.D. degrees in materials science and engineering from Lehigh University. Gorzkowski is the current chair of the Electronics Division, as well as a member of the Basic Science and Energy Materials and Systems Divisions. He is a founding member and previous co-chair of the Washington, D.C., Maryland, and Virginia Section. He co-organized the Electronic Materials and Applications conference in 2022 and 2023, and he served as a symposium organizer for sessions at EMA, MS&T, and PACRIM conferences both present and past. He has also served on the ACerS Book Subcommittee and is former chair of the Young Professionals Network. He received the 2015 Du-Co Young Professionals award, a 2018 Best Paper award for *Journal of the American Ceramic Society*, and a 2020 Richard M. Fulrath award.



Kevin Huang is South Carolina SmartState Endowed professor and director at the University of South Carolina. He received his Ph.D. in physical chemistry from the University of Science and Technology Beijing. Huang has been an active ACerS member since 2010 in the Basic Science, Electronics, and Energy Materials and Systems Divisions, in addition to the ACerS Carolinas Section.

Emanuel Ionescu is deputy director and head of the Department of Digitalization of Resources at Fraunhofer IWKS, Germany. He is also an adjunct professor in materials and earth sciences at TU Darmstadt. He received his Ph.D. in inorganic chemistry from the University of Bonn, Germany. Ionescu served as secretary of the ACerS International Germany Chapter from 2018–2021. In 2022, he was recognized with the ACerS Global Star award.

Kang Lee is senior research scientist at NASA–John H. Glenn Research Center. He originally joined NASA Glenn Research Center in 1990 after postdoctoral training at the University of Pennsylvania and returned in 2016 to continue his work in environmental barrier coatings. He is a member of the Engineering Ceramics Division and has been involved with ACerS through organizing conference symposiums and delivering invited lectures.

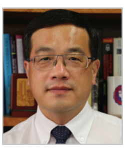
Navin Manjooran is chairman of Solve, a technology and research services company addressing energy, industry, medical, and infrastructure challenges. He received a B.Tech. in metallurgical engineering from the National Institute of Technology, India, an M.S. in materials science and engineering from the University of Florida, and a Ph.D. in materials science and engineering from Virginia Tech. He has been an ACerS member since 2003 and is a member of the Glass & Optical Materials, Bioceramics, and Manufacturing Divisions.

Lalit Sharma is CEO at Mahamana Ceramic Development Organization, India. He received his materials technology and Ph.D. degrees in ceramic engineering from the Indian Institute of Technology Varanasi. Sharma is a member of the Engineering Ceramics Division. He has given invited talks on behalf of ACerS, in addition to serving as former chair of the Global Corporate Achievement Award Committee. He is a recipient of the ACerS Global Star award, Global Ambassador award, and Corporate Environment Achievement award. He currently serves as chairperson of the ACerS International India Chapter.

The 2024 Class of Fellows (continued)

Klaus van Benthem is professor of materials science and engineering at the University of California, Davis. He received his Ph.D. from the Max-Planck Institute for Metals Research, Germany, and completed postdoctoral work at Oak Ridge National Laboratory. He has been an ACerS member since 2010 and is a member of the Basic Science Division.

Gerard Vignoles is professor and head of the ThermoStructural Composites Lab (LCTS, a joint unit with CNRS, CEA, and Safran Group) at the University of Bordeaux. He graduated from Ecole Normale Supérieure (rue d'Ulm, Paris) and joined LCTS as a Ph.D. student. Vignoles has been an ACerS member since 2005 and is a member of the Engineering Ceramics Division. He has organized symposia for the ICACC and Pacific Rim conferences, among others, and he received the ACerS Global Ambassador award in 2020.



Min Wang is professor of mechanical engineering of the University of Hong Kong. He earned his B.Sc. and Ph.D. in materials science and engineering at Shanghai Jiao Tong University, China, and the University of London, U.K., respectively. He has been a member of ACerS since 2009 and is a member of the Bioceramics Division. He actively participates in ACerS organized activities and conferences.

Hui-Suk Yun is head of the Department of Advanced Biomaterials Research at Korea Institute of Materials science and professor of materials science at the University of Science & Technology, Republic of Korea. She received her Ph.D. in materials science and engineering from the University of Tokyo, Japan. Yun is a member of the Engineering Ceramics Division. She is a recipient of the 2021 ACerS Global Ambassador award and 2020 Jubilee Global Diversity award.

Jie Zhang is principal investigator of Shenyang National Laboratory for Materials Science and Institute of Metal Research, Chinese Academy of Sciences, China. She received a Ph.D. in materials science from the Graduate School of the Chinese Academy of Sciences. Zhang has mentored many young researchers and students in ACerS. She has served as a member of the Executive Committee of the Engineering Ceramic Division since 2021, and she now serves as chair-elect of the ECD. She worked as a committee member (2019–23) and chair (2022–23) of the John Jeppson award. She has served as an organizer for the "Advanced MAX/MXENE Phases and UHTC Materials for Extreme and High Temperature Environment" symposium series at ECD's ICACC meetings since 2019, "Global Young Investigator Forum" symposium series at PACRIM, as well as CMCEE conferences. Most recently, she served as the program chair of ICACC 2024. ■

Visit https://ceramics.org/awards/society-fellows to learn more about the 2024 Fellows.

THE AMERICAN CERAMIC SOCIETY

2024
ANNUAL HONORS
AND AWARDS BANQUET

126 YEARS OF ADVANCING
THE CERAMICS AND GLASS COMMUNITY

Monday, Oct. 7 at MS&T24

6–6:30 p.m. Reception

6:30–10 p.m. Dinner and awards

Grand Ballroom,
Omni William Penn Hotel

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

Tickets must be purchased by **noon on Sept. 27, 2024**.

Society Awards

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

Katherine T. Faber, DLM, FACerS, is Simon Ramo professor of materials science at California Institute of Technology, Calif.

Her research interests include the field of materials science, particularly in the study of brittle materials, ceramic composites, and cultural heritage science.

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

Kwang Ho Kim is Distinguished Professor in the School of Materials Science and Engineering, Pusan National University, Republic of Korea.

His work focuses on the design, synthesis, and evaluation of the hybrid interfaces that form between two different bulk materials.

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

Amanda R. Krause is assistant professor of materials science and engineering at Carnegie Mellon University, Pa.

Her current focus is engineering microstructures and grain boundaries to improve the mechanical performance and degradation response of ceramics used in extreme environments.

RICHARD AND PATRICIA SPRIGGS PHASE EQUILIBRIA AWARD honors authors who made the most valuable contribution to phase stability relationships in ceramic-based systems literature in 2023.

"The MgO–TiO_2–SiO_2 system: Experiments and thermodynamic assessment," *Journal of the American Ceramic Society* 2023, **106**(12): 7704–7727.

Maria Ilatovskaia, Forschungszentrum Jülich GmbH, Germany

André Treichel, Friedrich-Schiller-Universität Jena, Germany

Olga Fabrichnaya, Institute of Materials Science, Technical University Bergakademie Freiberg, Germany

ROSS COFFIN PURDY AWARD recognizes authors who made the most valuable contribution to ceramic technical literature in 2022.

"Digital light processing stereolithography of hydroxyapatite scaffolds with bone-like architecture, permeability, and mechanical properties," *Journal of the American Ceramic Society* 2022, **105**(3): 1648–57

Francesco Baino, Politecnico di Torino, Italy

Giulia Magnaterra, Politecnico di Torino, Italy

Elisa Fiume, Politecnico di Torino, Italy

Alessandro Schiavi, INRIM Istituto Nazionale di Ricerca Metrologica, Italy

Luciana-Patricia Tofan, Institute of Science and Technology, Austria

Martin Schwentenwein, Lithoz GmbH, Austria

Enrica Verné, Politecnico di Torino, Italy

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

Eeshani Godbole is research scientist at GE Research in Niskayuna, N.Y., where she works on developing high-temperature ceramic materials for aerospace engines.

Her dissertation focused on advanced multiphase rare earth aluminate zirconates as candidate coating materials to promote more predictable and consistent coating based on calcium–magnesium aluminosilicate reactions against a range of deposit compositions. An integrated process using experiments and thermodynamic modeling tools was used to accelerate coating design.

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

Judy Jeevarajan is vice president and executive director of the Electrochemical Safety Research Institute at UL Research Institutes, Ill.

With more than 27 years of experience in the area of batteries and a primary focus on the lithium-ion chemistry, she specializes in battery safety research, including safety trends in aged lithium-ion cells and modules, thermal runaway propagation in lithium battery systems, characterizing fire and fire suppressants for lithium-ion batteries, and consumer battery safety.

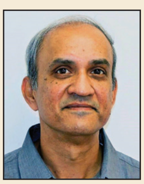
Society Awards (continued)

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

Tessa Davey is UKAEA Reader in nuclear materials at the Nuclear Futures Institute at Bangor University in Wales, U.K.

Davey was the first international chair of ACerS President's Council of Student Advisors. She received the ACerS Global Ambassador Award in 2017 for her leadership and continues to serve students through the ACerS Mentor Program.

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



Sanjay Sampath, FACerS, is Distinguished Professor of materials science at Stony Brook University and director of the Center for Thermal Spray Research.

Sampath has for 30 years focused intensely on applying scientific discipline to the technology and commercialization of thermally sprayed ceramic coatings and functional multilayers. His efforts changed the fundamental landscape of spray materials and coatings from an empirical practice with limited capabilities to a robust and reliable technology, enabling the production of designer coatings and functional multilayers.

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

Rebecca Welch is a Ph.D. candidate in materials science and engineering at The Pennsylvania State University.

In addition to coordinating STEM demonstration nights for K–12 students through her university, Welch serves as club advisor for the local Society of Women Engineers section, which includes organizing mentorship workshops, guest lecturers, and club outreach events for middle schools in the surrounding area.

Elizabeth Tsekrekas, previously a Ph.D. candidate in glass science at Alfred University, is now a postdoctoral researcher at Savannah River National Laboratory.

Tsekrekas performed tempered glass demonstrations for K–12 students through her university and the Ceramic and Glass Industry Foundation. ■

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

Paolo Colombo, FACerS is professor of materials science and technology at the University of Padova, Italy, where he earned a degree in chemical engineering and later a diploma in glass engineering.

Colombo is president of the International Ceramic Federation; Academician of the World Academy of Ceramics; Academician of the European Academy of Sciences; Fellow of The Institute of Materials, Minerals, and Mining; and Fellow of the European Ceramic Society.

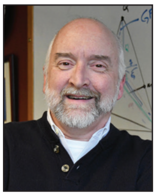
ECERS-ACERS JOINT YOUNG PROFESSIONAL AWARD recognizes individuals who foster international cooperation between The American Ceramic Society and the European Ceramic Society, in demonstration of both organizations' commitment to work together to better serve the international ceramics community.

Tessa Davey is UKAEA Reader in nuclear materials at the Nuclear Futures Institute at Bangor University in Wales, U.K.

After joining ACerS President's Council of Student Advisors in 2014, Davey went on to serve as the council's first international chair. She has served on 13 ACerS committees and co-organized eight symposia at international conferences. ■

Class Awards

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



William Carty, FACerS, is McMahon Professor at Alfred University. He earned B.S. and M.S. degrees in ceramic engineering from the University of Missouri-Rolla, and a Ph.D. in materials science from the University of Washington.

Carty has taught most, if not all, of the ceramic engineers who graduated from Alfred University since the mid-1990s. His close ties to industry often inform and guide the content of his courses, which makes the information very useful for students who ultimately seek careers in industry. He also uses creative teaching techniques that draw from popular media, such as allowing students to make one phone call during an exam in the style of the game show "Who Wants to be a Millionaire?"

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

Dragan Damjanovic, FACerS, is professor emeritus at the Swiss Federal Institute of Technology in Lausanne, Switzerland. He earned a B.S. in physics from the University of Sarajevo and a Ph.D. in ceramics from The Pennsylvania State University.

Damjanovic's research focuses on fundamental and applied investigations of the piezoelectric, ferroelectric, and dielectric properties of a wide range of materials, with a focus on emergent electromechanical phenomena in complex materials. He has twice received, together with his colleagues, the Edward C. Henry Best Paper Award from ACerS' Electronics Division.

Richard M. Fulrath Symposium and Awards

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

U.S. industrial: **Valerie Wiesner**, NASA Langley Research Center

U.S. academic: **Jennifer Rupp**, Massachusetts Institute of Technology

Japanese industrial: **Shuichi Funahashi**, Murata Mfg. Co.

Japanese industrial: **Kazuyoshi Izawa**, Kyocera Corporation

Japanese academic: **Ichiro Fujii**, University of Yamanashi

Corporate Environmental Achievement Award

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

JFC JAPAN FINE CERAMICS CO.

Japan Fine Ceramics Co., Ltd. (JFC) was established in 1984 as a public–private joint venture and later became a wholly owned subsidiary of JGC Corporation in 1992.

In the last few years, the company has developed and produced Si_3N_4 substrates with high thermal conductivity for electric vehicles, which are expected to help reduce carbon emissions by combatting degradation of the power components.

ACerS Award Lectures

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

Olivia Graeve, FACerS, professor, University of California, San Diego

"Materials for extreme (and space) environments: Crystallography and properties"

Her area of research focuses on the design and processing of new materials for extreme environments, including extremes of temperature, pressure, and radiation.

EDWARD ORTON JR. MEMORIAL LECTURE

Young-Wook Kim, FACerS, professor, University of Seoul, Republic of Korea

"Silicon carbide: The versatile ceramic alloy"

Kim has made seminal contributions to the field of microstructure control as well as mechanical, thermal, and electrical properties of dense and porous silicon carbide ceramics. He has also contributed to the processing of electrically conductive silicon carbide ceramics.

ACerS FRONTIERS OF SCIENCE AND SOCIETY RUSTUM ROY LECTURE

Shunpei Yamazaki, president and CEO, Semiconductor Energy Laboratory, Japan

"Proposal of oxide ceramic LSI device for putting the brakes on global warming accelerated by AI-age computers"

Yamazaki has devoted his life to the research and development of semiconductors and energy storage devices, and he invented a nonvolatile memory device in 1970 using a silicon floating gate with a control gate, currently known as a "flash memory."

BASIC SCIENCE DIVISION ROBERT B. SOSMAN AWARD AND LECTURE

Wai-Yim Ching, FACerS, University of Missouri

"The role of computational modeling in complex materials"

His research and publications cover diverse disciplines, such as condensed matter physics, ceramics and glasses, chemistry, biology, materials science, engineering, medical science, geophysics, and earth science.

GLASS & OPTICAL MATERIALS DIVISION ALFRED R. COOPER AWARD SESSION

COOPER DISTINGUISHED LECTURE PRESENTATION

Heike Ebendorff-Heidepriem, professor of photonic materials and optical fibers, University of Adelaide, Australia

What is the best glass material for optical fibres—soft glass or silica? It depends

2024 ALFRED R. COOPER YOUNG SCHOLAR AWARD

Cooper Scholar:

Patrick E. Lynch, Alfred University

Accelerated relaxation of chalcogenide gasses via thermo-ultrasonication

2024 ALFRED R. COOPER YOUNG SCHOLAR AWARD RUNNERS UP

Cooper runner up:

Julianne Chen, The Pennsylvania State University

LionGlass™: A zinc aluminosilicophosphate (ZASP) glass that reduces carbon emissions by 65%

Cooper runner up:

William Fettkether, Iowa State University of Science and Technology

Structure–property relations in the $60Li_2S + 30SiS_2 + xLiSbO_3 + (10-x) LiPO_3$ glass system

Cooper runner up:

Daniel Wiedeman, University of Central Florida

Solution-based processing of $Ge_2Sb_2Se_4Te_1$ phase change material for optical applications

Cooper runner up:

Kyungmin Yu, Seoul National University

Subsolidus phase diagrams of the In_2O_3–SnO_2–ZnO system at 1,400 and 1,500 °C and new ternary $In_2Sn_2Zn_2O_9$ phase

Check www.matscitech.org for latest updates.

Glass waste solutions: Current trends, emerging markets, and new technologies

By Collin Wilkinson, Arron Potter, and Gabrielle Gaustad

Glass punch set produced by Remark Glass (Philadelphia, Pa.) based on recycled liquor bottles.

Credit: Rebecca Davis, Remark Glass

Glass recycling is, in principle, the perfect closed-loop process. The material can be continuously and completely recycled in theory, so only a small amount of raw materials would be needed to account for the systematic loss of material during processing of new products, such as production of fine powders during crushing.

In practice, though, glass recycling is often hampered by diverse factors, including low collection rates, increased comingling and contamination of recycled goods, and shifting economics such as labor and fuel costs. While the European Union has done a commendable job addressing these challenges, achieving an average 76% recycling rate for glass containers in 2018,[1] the United States has struggled, reporting an average recycling rate of just 31.3% for the same year.[2]

In this article, we will examine the factors that prevent U.S. companies and communities from adopting a more robust recycling ecosystem. We will then discuss a model of the glass recycling system in New York state to better understand the flow of waste glass and identify some solutions that can help address the current recycling challenges.

Challenges to recycling

Many factors contribute to the lack of glass recycling in the United States, but almost all trace their origins to economics: Recycling must be profitable for companies to invest in its setup and maintenance. Unfortunately, the way that glass is typically collected in the U.S. prevents profitable glass recycling from the very start.

In general, glass recycling systems send post-consumer glass products, such as bottles and jars, to material recovery facilities (MRFs). These facilities either sort and clean waste glass themselves or pass it to a secondary processor, if financially worthwhile. Ideally, after sorting and cleaning, the glass is returned to a furnace and turned into new containers or fiberglass.[3]

The use of waste glass (cullet) reduces the need for raw materials in glass production. As a result, the carbon dioxide emissions that come from converting carbonate precursors to oxide glass are mitigated, thereby decreasing the embodied energy and carbon profile of the new glass products.[4]

In contrast to many European Union countries, most waste collection systems in the U.S. are based on single-stream recycling, meaning consumers mix all their recyclables together in one bin. Such a system reduces transportation costs and increases collection rates, but it places a burden on MRFs to sort all these recyclables.

Compositionally, most consumer glasses vary little. However, to MRFs, even small amounts of impurity or contaminants within and alongside these glasses makes a big difference. The most valuable glass is clear, colorless, free of organics (e.g., glue or paper), and free of fine particulates.[5] Colorless clarity indicates the glass has minimal transition metal content, i.e., the substances used to give glass its color, and so allows for improved control over the chemistry of new melts. Additionally, glass with low organic and fine particulate content experiences reduced bubble formation during reprocessing. Unfortunately, by its nature, single-stream recycling results in post-consumer glass mixed with organics and tricolor (clear, green, and brown) glass waste with a wide range of particle sizes, making the job of the MRF more complicated.

Any tricolor stream could theoretically be transformed into pure single-stream feed stock for new glass melts, but the work, capital, and time required varies greatly based on the waste stream. Even the highest quality streams often require significant startup capital for sorting and automation due to challenges inherent to glass itself. Unlike other material streams, such as plastics, metals, and paper products, glass cannot be compacted and baled for ease of transport. It also breaks into small pieces that end up in other material streams and cause issues with MRF handling equipment. As a result, many recycling facilities will only invest if they are sure of an end market and a steady stream to process.

Some waste streams are so contaminated with metals or organics that it is unlikely the comingled glass will ever make its way into high-quality products. Instead, it is more cost effective to send this glass to landfills or use it as "landfill cover," an acceptable end-of-life stream in many states, including Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, and Rhode Island.[6,7]

In addition to post-consumer glass waste streams, the construction and demolition industries generate waste glass from flat glass used in buildings. The production of flat glass requires materials of even higher quality than that of fiberglass or bottle glass, reducing manufacturers' flexibility with input materials. Some flat glass manufacturers have programs to use recycled materials.[8] But this process is difficult and slow growing, leaving post-industrial glass a critical, largely unaddressed problem with no clear solution.

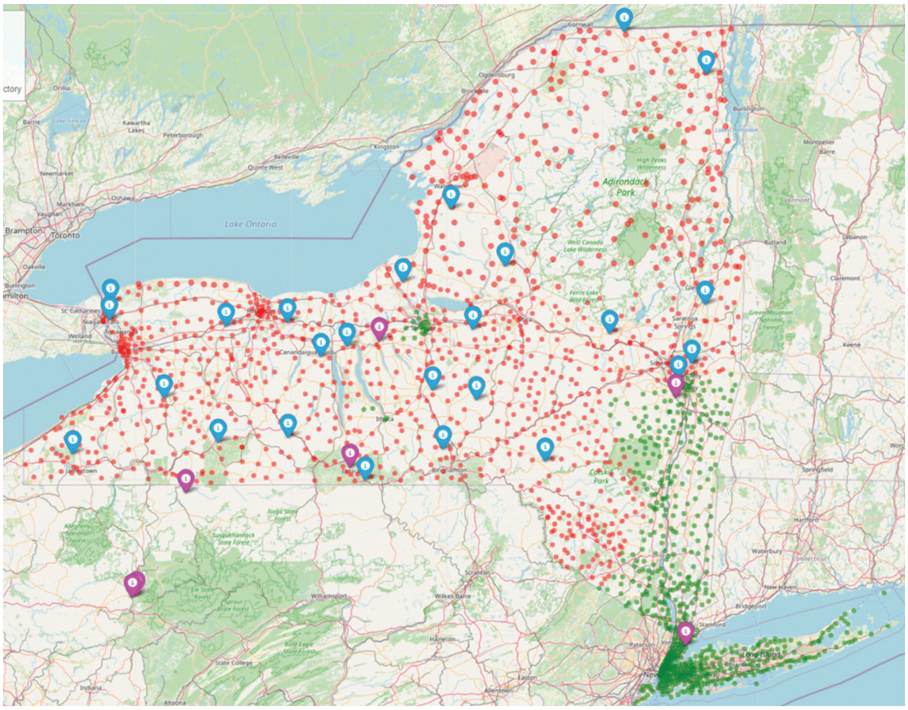
Besides post-consumer and flat glasses, which largely conform to a narrow range of chemical compositions, specialty glasses with diverse compositions have the potential to form a large waste stream in the future. Specialty glasses can be found in applications such as kitchen and labware, electronic displays, wind turbine blades, photovoltaic modules, and emerging glass-based battery technology.[5,9] As the U.S. pushes to decarbonize, the use of these specialty glass technologies is sure to expand quickly, requiring new recycling streams to handle this waste. The sidebar "Photovoltaic glasses and challenges to end-of-life disposal" provides a deeper look at one of these emerging specialty glass markets.

Modeling glass recycling in New York state

To identify solutions that can help address the current recycling challenges, Alfred University recently partnered with the New York State Department of Environmental Conservation (NYSDEC) to model the flow of waste glass in New York state.

New York is one of 10 bottle bill states, meaning there is a deposit on each glass container sold for beer and soda. Consumers can reclaim the deposit by returning the containers, thus improving return rates and ensuring a cleaner waste stream. New York also contains several glass manufacturers within state borders, meaning its intrastate recycling infrastructure positions it as a microcosm of the United States at large. These factors, in addition to New York's current glass recycling rate of 50%, make the state an excellent proving ground for new innovations.

To understand the flow of waste glass in New York state, we developed a simple source/sink model in which consumers are treated as the "source" of glass waste.[10] To account for geospatial variation, we assume that post-consumer glass waste is generated proportional to the population, which is determined based on zip code. Meanwhile, the two "sinks" in the model indicate where the glass ends up: at an MRF or the landfill. In the former case, the value of creating new glass products must be higher than the processing and transportation costs to make the process profitable. Notably, the model uses an estimated 70% glass recovery rate from MRFs, though the real recovery rate may be lower. In the latter case, the glass only needs to be moved once, which is economically advantageous. But it requires a tipping fee to be deposited in the landfill, which cannot be economically recovered.



Credit: Deniz Saadatpour

Figure 1. Green dots represent zip codes where recycling is economically favored, and red dots represent locations where landfilling is more affordable. Blue markers show landfill locations and purple markers represent factories.

Performing this analysis of the lowest cost option for each zip code resulted in a map that shows where and why recycling is economically favorable (Figure 1). Though this model only accounts for purely economic factors and omits social factors, such as consumer opinion on recycling in each zone, the results align well with reports from the NYSDEC.

The model found that large population centers in Western New York, such as Buffalo, Rochester, and Syracuse, have no economic way to deal with their glass besides landfilling because, despite sufficient nearby MRFs, they lack an end market. Even in places where recycling would be expected, such as Long Island, the introduction of a new landfill can easily undercut the recycling rate due to the high cost of transportation.

Varying the input parameters further confirmed the impact that transportation costs have on the overall recycling rate in New York state (Table 1). A small decrease in transportation costs can lead to a significant increase in the feasibility of recycling by effectively increasing the radius of recyclability around factories. However, these costs are largely inflexible, and if anything, likely to increase in the future due to fuel and regulatory costs. Landfill tipping fees are likely to rise in coming years as well due to increased demand for landfilling and added regulation as landfill capacity decreases. An artificial increase in tipping fees for recyclable materials is likely infeasible, as it would require waste to be organized and would encounter significant political resistance.

Based on these findings, one way to improve glass recycling in New York state is to create more efficient MRFs that process glass at recovery rates higher than 70%. This approach has been a subject of ongoing research for the last few decades, and recent innovations are detailed in the next section.

Of course, not every MRF needs expensive sorting technology if they cannot guarantee a return on investment. This reality leads to another solution for improving glass recycling rates in New York state: creating a new glass sink. New end-use destinations, such as bottle redemption centers, or markets, such as construction filler materials, offer a double advantage, both by increasing the value of glass as demand rises in these alternative outlets as well as reducing transportation costs. Plus, if the new sink leverages newer technologies or high-quality waste streams, this improved efficiency will be reflected in lower processing costs.

Table 1. Predicted benefits and feasibility of each proposed change in the model.

Action	Possible benefit (70% MRF efficiency)	Associated challenge	Feasibility ranking
Decrease transportation cost	~0.7–2.1%	Technology/Policy	Low
Build a new MRF	~1%	Economics	Low
Increase the tipping fee	~1–4%	Economics/Policy	High
Build a new glass factory	~4%	Economics	Low
Create a new glass sink	~4%	Technology	High
Decrease processing cost/increase value of glass	~3.5–7%	Technology	Medium
Making MRFs perfectly efficient (More recycled glass is cleaned and processed for factories)	21%	Technology	Low

Recent innovations in MRFs

Our models suggest that the largest gains in glass recycling rates can come from improving MRF efficiency. Specifically, finding ways to reduce contamination during single-stream recycling will be the key, as most reuse applications require cullet with low impurities.

Diverting more glass to bottle collection facilities separate from other municipal solid waste is the most straightforward way of reducing contamination. But within the MRF itself, several techniques exist to separate glass and nonglass materials (Figure 2).

PHOTOVOLTAIC GLASSES AND CHALLENGES TO END-OF-LIFE DISPOSAL

Glass recycled from end-of-life photovoltaic (PV) panels will become increasingly significant in coming years. However, three major factors differentiate PV waste glass from traditional consumer waste glass: availability, composition, and separability.

Availability

At present, PV waste glass accounts for a very small quantity of overall glass waste. This makes the use of recycled cullet from such material difficult, as supply remains low and inconsistent. But as more panels begin to fail around their expected lifetime of 25–30 years, PV waste will become increasingly relevant.

As installed PV capacity quickly expands, waste material generated by end-of-life modules will naturally follow, increasing cumulatively to a projected 7.5–10 million metric tons by 2050 for the United States alone and 60–78 million metric tons globally.[a] This increase equates to an additional 0.5–1 million metric tons of waste per year. For context, the total amount of recycled glass in the United States was just 2.8 million metric tons in 2018.[b]

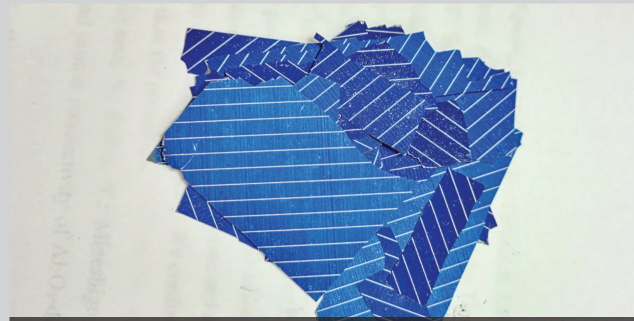
Composition

Most modern solar panels are crystalline silicon covered with a patterned, tempered, low-iron (~120 ppm) soda-lime silicate glass, though thin-film cadmium telluride panels are gaining market acceptance. In principle, the consistency and clarity of PV waste glass cuts the cost of high-purity raw materials and eliminates the need for sorting of clean cullet by color, thus improving the marketability and price of such material.[c]

For example, whereas fiberglass insulation production requires (comparatively) little control over the color or iron content of incoming cullet, architectural glass manufacturers require cullet with low iron content and negligible coloration. If recycled PV glass meets the more stringent requirements of the architectural glass manufacturers, that glass would command a significantly higher price than mixed-color glass with high impurity content. Furthermore, as the amount of available material increases, this glass might also be able to be directly reused in the production of new solar cell cover glass.

Another benefit of having high-purity cullet available is furnace longevity. Raw batch materials are corrosive to furnace refractory, so introducing cullet to flat glass and specialty glass production, especially in locales where cullet usage is low, could provide additional value.

Unfortunately, most currently installed PV glasses contain antimony as a fining agent and decolorant.[d] Antimony oxidizes the small amount of residual iron content to improve transmission of the near-infrared wavelengths absorbed by silicon. For PV glass sheets produced by rolling, antimony is an effective solution to improve performance of the glass. If recycled into glass produced on a float line, however, the antimony can enter the tin bath and cause deleterious interactions.



Example of clean pieces of silicon extracted from discarded solar panels using thermal delamination.

Credit: Arron Potter

Thankfully, with the advent of PV technologies that do not require high transparency in the near-infrared range, such as the cadmium telluride thin films mentioned earlier, new glass will not need to contain antimony and so this danger can be avoided.

Separability

In practice, PV waste glass is difficult to remove from the other solar cell components without significant contamination.[e] A crystalline silicon solar cell is composed of five major layers, from bottom to top: plastic backing sheet, usually polyvinyl fluoride (PVF); a crosslinked ethyl vinyl acetate (EVA) encapsulant; the silicon wafer itself; another layer of the same EVA encapsulant; and finally, the glass cover sheet. The silicon wafer is coated with an aluminum rear conductor, silicon nitride surface coating, and a screen-printed silver grid, with soldered copper interconnects between cells.

The efficacy of EVA as an encapsulant creates some difficulty in delaminating the solar cells, which tend to swell under solvent dissolution or thermal delamination, the two major avenues being pursued for intact delamination of solar cells. This behavior means that most techniques for recycling PV glass are either costly or result in cullet contaminated with pieces of the other materials present in the system, if not also residual organic content.[f]

These contaminants can affect reuse in multiple ways. For example, silver and copper are strong colorants in soda-lime glass, while lead and tin pose major environmental and health hazards. These metals also can pool at the bottom of furnaces and cause significant damage. Additionally, if the fluorinated polymer backing sheet remains in the cullet, its decomposition produces hydrofluoric acid fumes.[g] As a result, the separability with current technology remains low and as such the value of PV scrap is low.

Recently, solar panel recycling methods were reviewed by Crespo et al.[h] They compared the three leading proposed methods to recycle panels: thermal delamination, mechanical separation, and solvents. All three methods faced major financial or technical challenges, but thermal delamination appeared to show promise. However, any technologically viable approach remains limited by the purity, and therefore value, of the materials recovered. ■

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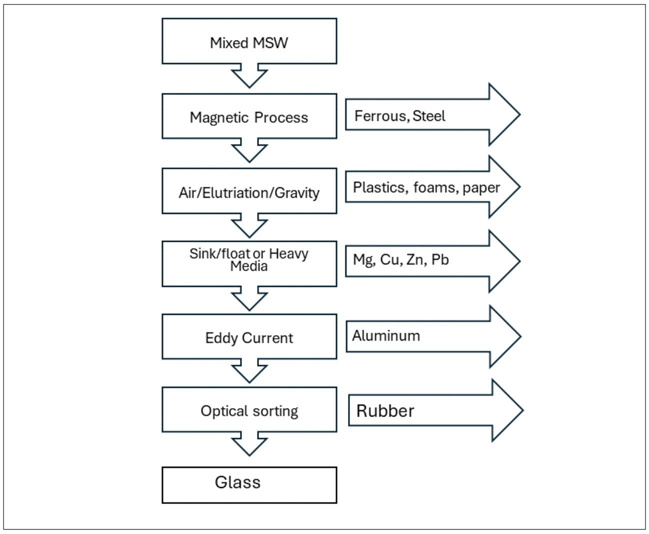


Credit: Gabrielle Gaustad, Alfred University

Figure 2. Schematic of a common scheme for glass separation from municipal solid waste streams.

Besides manually sorting by hand, most MRFs take advantage of gravity or air-based sorting techniques, such as windsifting, air-knives, elutriation, winnowing, and air columns. Conveyor belt systems often use suction to pull off lightweight materials, such as paper, plastic, low-density rubbers, and foams. For metallic products, a magnet or eddy current can separate ferrous and nonferrous metals from the mixed stream.

Recent decreases in both computing and sensor costs have improved adoption of a variety of optical and color sorting techniques,[11] which can sort materials into streams with more than 95% purity. Computers analyze images of each scrap based on specified color ranges and then direct them to different feeds. Robotics also have potential in this area,[12] but current high costs prevent widespread adoption.

Though many traditional end-use applications of glass require the material to be of high purity, some emerging markets for glass waste, such as aggregates for concrete, can tolerate low-quality glass cullet very well. The new demand that comes from developing these alternative markets can increase the glass waste's value. Some of these emerging markets are described in the following section.

Emerging markets for recycled glass waste

New markets for recycled glass waste ideally will have several features, including the option for local use to reduce transportation costs, stability, and growth so they can accept large volumes of glass waste, and minimal requirements for additional processing or large remelt facilities to incorporate the glass back into the new product. Major emerging markets for waste glass are shown in Table 2 and described in more detail below.

Foam glass is one promising emerging market for waste glass. This porous construction material, which is created by heating a mixture of crushed or granulated glass and a blowing agent, such as carbon or limestone, is known for being lightweight and strong with good thermal and acoustic insulating properties.

Foam glass was first created almost 100 years ago.[13] It has always been popular in Europe as a low-cost insulation material due to tighter environmental regulations and geographic restrictions, but it has only recently gained popularity in the U.S. Foam glass manufacturing can take even highly contaminated waste glass and create a quality end product with minimal additional additives. For example, the waste-based foam glass created by AeroAggregates (Eddystone, Pa.) was used to reconstruct a destroyed section of I-95 near Philadelphia, Pa. Though this end application of waste glass is unlikely to be circular, it provides an alternative avenue for glass waste that would otherwise be landfilled.[14]

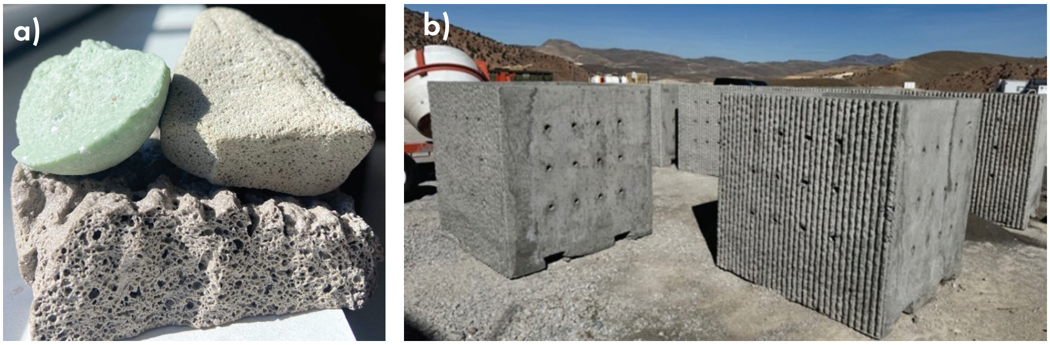
Companies have started to leverage glass foams' inherently high surface area to expand beyond the traditional application of insulation. For example, Growstone from Aeroaggregates is used as a high-performance soil aeration material. SilicaX (Spokane, Wash.), one of Alfred University's partners, is working to convert waste glass into a foam aggregate with high resistance to oceanic corrosion (Figure 3a), which can be used to create improved concrete retaining walls. Large coupons of these materials are being produced and sank into the Long Island Sound (Figure 3b).

Foam glass as water filtration has shown promise as well,[15] but it competes with simple materials, such as woodchips or charcoal, for low-level filtration or activated carbon and zeolites for high-end filtration. It is also unclear how much processing is needed to make glass into good filtration media.

Table 2. Some alternative uses for waste glass and their associated feasibility.

Application	Commercial status	Amount of glass required	Challenges
Cullet to glass factories	Commercialized	High	The amount of glass that technoeconomically can be used as cullet
Foam glass	Commercialized	High	Transportation
Pozzolan or aggregates	Commercialized	Medium	Grinding/safety: small mistakes can lead to concrete failure
Water filtration	Not commercialized	Medium	Hard data is missing

Waste glass can also serve as a pozzolan for cementitious materials.[16] Concrete consists of cement, water, and aggregate, and replacing some of the cement with a supplementary cementitious material can help reduce concrete's embodied carbon. Recent studies have found that, despite historical challenges with alkali silicate reaction, glass can be used as a supplementary cementitious material without any negative results, provided the particle size is fine enough.[17] One company, SQ4D (Patchogue, N.Y.), has



Credit: 3a) Collin Wilkinson; 3b) Philip Galland

Figure 3. a) Images of varying foam glass compositions. The green foam glass (left) is SilicaX's aggregate, while the traditional grey foam glass (top) and experimental foam glass (bottom) were created by Collin Wilkinson's group at Alfred University. b) SilicaX coupons being produced for immersion in the Long Island Sound.

partnered with Alfred University to create specialized forms of these glass additives that can be used to 3D print homes. The only downside of this method is that much like with foam glass, these materials are unlikely to be circular.

Future opportunities

The European Union's high rates of recycling demonstrate that an improved glass recycling system is achievable.[18] However, geographic proximity of sources and sinks remains a major difference between the U.S. and European Union. In the U.S., destinations for recycled cullet have decreased from roughly 40 container glass companies with 112 plants in 1967 to about 17 companies operating 54 plants in 2018.[19] Deploying additional infrastructure—whether collection facilities, processing facilities, or manufacturing centers that require glass cullet—will greatly impact U.S. glass recycling rates.

Because costs are a key driver in U.S. waste management, policy interventions would likely be beneficial as well. For example, in areas with higher landfill tipping fees, recycling rates are typically higher.[10] Strategies aimed at consumers may also improve the quantity and quality of recyclables put in bins destined for MRFs and reduce contamination. These strategies may include curbside feedback to consumers,[20] enhanced labeling of receptacles,[21] and general consumer education aimed at understanding challenges around processing at the MRFs.

Similarly, strategically employed economic development incentive programs would likely also improve glass recycling rates. These initiatives may include programs that fund capital equipment improvements at waste processing facilities or provide incentive programs for collection. Also, states that have passed bottle deposit legislation, or "bottle bills," typically have higher return rates for glass and plastic bottles, and some states are exploring expansion of their bottle bills to include additional container types, such as wine and liquor bottles.

In the end, it will take close collaboration and communication between consumers, researchers, manufacturing, policymakers, and the waste management industry to drive increased glass recycling rates in the United States.

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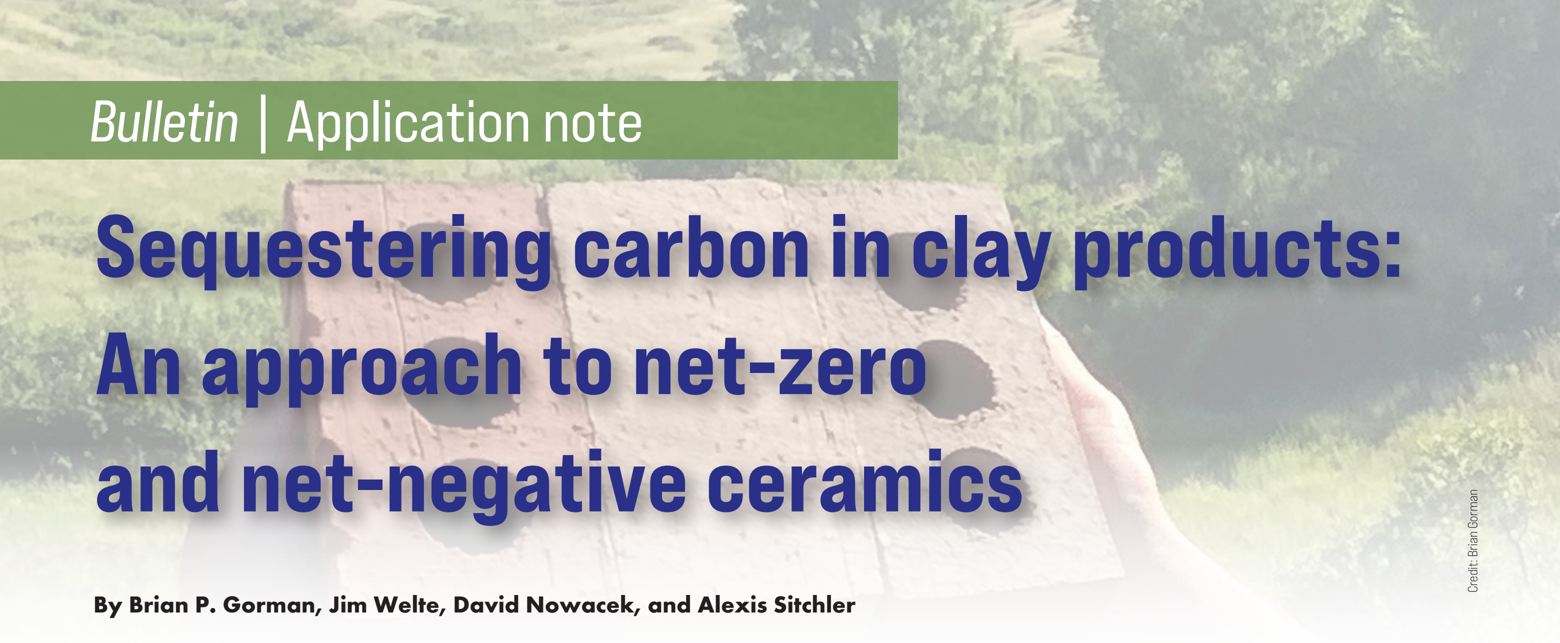

Credit: Brian Gorman

Sequestering carbon in clay products: An approach to net-zero and net-negative ceramics

By Brian P. Gorman, Jim Welte, David Nowacek, and Alexis Sitchler

To keep global temperature from rising more than 1.5°C, we must reduce carbon dioxide emissions by 50 Gtons per year while also removing an additional 10 Gtons per year from the atmosphere by 2050.[1]

Several methods exist to remove CO_2 already present in the atmosphere, but none alone presently can achieve the goal of sequestering 10 Gtons per year. As such, stakeholders in every industry must do their part in lowering CO_2 emissions and enabling sequestration.

This article explores a novel approach the ceramics community can take to help achieve these goals: sequester carbon in clay products.

Mineralizing carbon: A primer

Mineralization can be defined as a chemical reaction in which gases react with solids and/or liquids to produce other nonreactive solids. In the context of mineralizing CO_2, reactions with mafic rocks, such as olivine-rich basalt, to produce carbonate solids is a natural process that geochemists are exploring as a way to sequester CO_2 on a Gton per year scale.[2,3]

This natural process starts when gaseous CO_2 reacts with liquid water to produce carbonic acid. This acidic solution reacts with silicate minerals in mafic rocks to release the rock's alkaline and alkaline earth cations, namely calcium, magnesium, and iron, into the solution. These cations subsequently react with the inorganic carbon species and precipitate solid carbonate minerals such as calcite ($CaCO_3$), dolomite ($Ca,Mg(CO_3)_2$), and siderite ($FeCO_3$).

Throughout the reaction process, mineral dissolution and precipitation reaction rates are heavily dependent upon surface area contact between the solution and solid reactants. Though geologic sources of mafic rocks have some surface exposure, it is nowhere near enough to contribute substantially to the goal of sequestering 10 Gtons per year. Scientists would need to either increase exposure to mafic rocks at Earth's surface through mining or capture and pump the CO_2 underground.

Rather than relying on natural deposits of mafic rock to sequester CO_2, engineering clay products to elicit mineralization reactions may be a more feasible and reliable approach to achieve significant emissions reductions.

Mineralization via clay products

Clay products, such as architectural bricks, pavers, and roof tiles, are a promising high-surface-area solution for carbon mineralization. Approximately 4 billion bricks are manufactured in the U.S. every year. Globally, that number increases to more than 1 trillion bricks per year.

Unfortunately, fired clay products are traditionally felsic, meaning they are rich in aluminosilicates but low in the alkaline and alkaline earth cations of calcium and magnesium. As a result, they do not lead to significant precipitation of carbonate minerals after contact with carbonic acid.

We hypothesized that adding materials rich in mafic minerals to clay products would improve the product's CO_2 uptake by increasing the amount of alkaline and alkaline earth cations, which are necessary ingredients for the mineralization reaction. However, for this sequestration method to be a commercially viable solution, the mineral addition cannot significantly affect the clay product's mechanical properties and appearance.

Industrial trials

We tested the feasibility of this sequestration method by adding 25 wt.% commercially available 70 mesh magnesium-rich olivine to an industrial clay extrusion process for pavers and modular bricks at Summit Brick Co. in Lakewood, Colo. Olivine melts at 1,890°C, so it can be directly incorporated into most clay product manufacturing.

We found that the olivine addition did not affect the manufacturing process. In fact, the olivine aided the drying process as little to no defects were observed in either the dry or green states.

In addition, because the olivine does not absorb water or undergo vitrification during firing, the bricks and pavers containing olivine had slightly less shrinkage. A small color change was observed in some products due to the precipitation of hematite from the natural iron content of olivine during sintering.

X-ray diffraction after sintering showed the presence of olivine remaining in the final product, along with the expected quartz and hematite. Microstructural analyses with scanning electron microscopy (Figure 1a) illustrated the olivine is well dispersed with abundant pore–olivine interfaces.

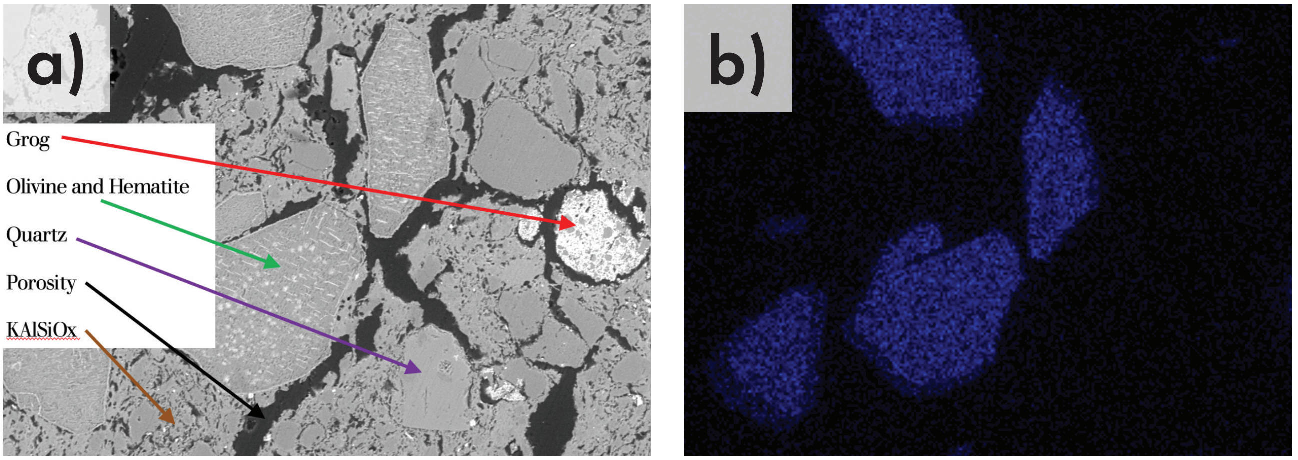

Figure 1. a) Backscattered scanning electron micrograph of the clay brick sintered microstructure. b) Energy dispersive X-ray microanalysis spectral image of the same area illustrating the location of magnesium. Magnesium is retained within the olivine grains, which are well dispersed within the microstructure. Abundant pore–olivine interfaces are also observed. Horizontal field width = 600 mm.

Elemental spectral imaging with energy dispersive X-ray spectroscopy (Figure 1b) showed magnesium remained in the olivine grains and did not diffuse into the felsic matrix phases. Regarding mechanical properties, all bricks and pavers exceeded ASTM standards for compressive strength, water absorption, and freeze-thaw.

Generally, a 2-kg modular clay brick has about 550 grams of embodied carbon.[5] As such, incorporating 31 wt.% olivine into the clay products is necessary to achieve net zero. Based on our tests, at least 40 wt.% olivine should be possible while still meeting ASTM standards. In other words, these materials have the potential to be net-negative because they sequester more CO_2 than is produced during manufacturing.

Considerations of producing net-zero and net-negative clay products

Though the results of the first industrial tests are promising, several considerations must be addressed to enable global scale-up of the process.

First, olivine is not the only reactive mafic material compatible with ceramic manufacturing. Steel slag, metallurgical casting sand, basalt, and fly ash are all potential candidates, and they are all widely available as waste products. Engineered fiberglass may also have potential as an enhanced mineralization material.

Second, several micro- and macrostructural features influence how quickly the clay product sequesters carbon. On the micro level, particle size, volume fraction of porosity, and pore location relative to the mafic particles are all critical to the reaction rates. On the macro level, the installation method (horizontal pavers versus vertical bricks versus roof tiles) affects water exposure. Environmental factors such as humidity, rainfall, and temperature also play a role in sequestration rates.

Initial tests on pavers installed as a driveway in Colorado did not display any degradation in mechanical properties over the course of a year, but micro-Fourier-transform infrared spectroscopy indicated the formation of carbonates within the pores.

Besides material and form factor considerations, the embodied carbon of clay products can be further reduced by using less carbon-intensive production and distribution methods, such as firing in electric kilns and lower carbon transportation.

Summary and outlook

Clay product industries can easily and immediately incorporate mafic materials into their products. Once this solution is implemented, the ceramics community will be well positioned to make a large contribution in the global push toward net-zero and net-negative materials.

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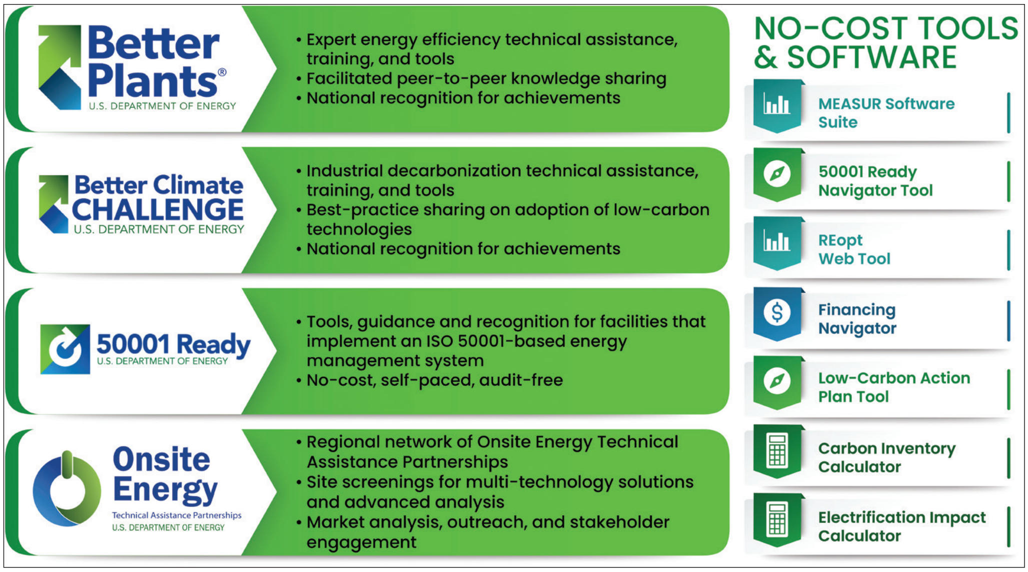


Credit: DOE IEDO

Figure 1. Overview of DOE's programs and resources that support manufacturers in improving energy performance and reducing GHG emissions.

DOE provides targeted technical assistance for manufacturers pursuing energy and resource efficiency

Contributed by the U.S. Department of Energy's Industrial Efficiency and Decarbonization Office

The U.S. Department of Energy (DOE) is committed to providing the industrial sector with resources and funding to support the development of innovative new technologies and processes.

Previously, DOE's Advanced Manufacturing Office was the front door of the department for many manufacturers.[1] This office focused on two main missions: driving innovation in manufacturing technologies, and reducing energy and emissions related to manufacturing. These missions complemented each other in many ways, but as attention in these areas grew, so too did the need for specialization.

In October 2022, the Advanced Manufacturing Office was reorganized into two new offices:[2] the Advanced Materials and Manufacturing Technologies Office (AMMTO) and the Industrial Efficiency and Decarbonization Office (IEDO). For emissions-heavy industries, such as ceramics and glass, the latter office provides research and development funding, technical assistance, and demonstration support to help manufacturers along their journey to reduce emissions and increase resource efficiency.

This article overviews the portfolio of resources applicable to ceramic and glass manufacturers through IEDO,[3] including programs that were portioned into this office during the split and new offerings that were added since then. These programs and resources include energy management support, technology-specific guidance, and in-plant technical assistance (Figure 1).

Better Plants Program

The Better Plants Program is a longstanding initiative that encourages and supports U.S. manufacturing companies to pursue aggressive energy efficiency and sustainability goals. The program continues to work with industrial partners who are committed to reducing their company-wide energy intensity by approximately 25% over 10 years.

As of 2022, more than 280 partners had cumulatively saved more than $11.7 billion in energy costs since 2009 at more than 3,500 nationwide facilities, representing 13.8% of the U.S. manufacturing energy footprint.[4] These savings come from technical assistance, industry networking, and peer-to-peer knowledge sharing.

In-Plant Trainings are one component of the Better Plants Program. These expert-led, multiday workshops—which are offered through both in-person and virtual platforms—train participants to identify, implement, and replicate energy efficiency projects. To date, In-Plant Trainings have been delivered to more than 4,400 participants, which helped them identify more than $66 million in energy efficiency opportunities.

The Better Climate Challenge, another component of the Better Plants Program, encourages partner organizations to commit to reduce portfolio-wide greenhouse gas emissions by at least 50% within 10 years, with energy-intensive industries committing to a 25% reduction.

Finally, the Better Plants Program regularly offers energy and carbon bootcamps tailored specifically for individuals who are relatively new to energy and carbon management. These three- to four-day workshops use extensive hands-on activities to educate attendees on the fundamentals of energy and carbon management while also covering the key aspects of energy efficiency and carbon accounting. Since the bootcamps started in 2022, more than 400 participants from industry have attended these trainings.

Learn more about the Better Plants Program and its various offerings:

- Better Plants Program: https://betterbuildingssolutioncenter.energy.gov/better-plants
- In-Plant Trainings: https://betterbuildingssolutioncenter.energy.gov/better-plants/plant-trainings-inplts
- Better Climate Challenge: https://betterbuildingssolutioncenter.energy.gov/better-climate-challenge
- Energy bootcamps: https://energybootcamp.ornl.gov
- Carbon bootcamps: https://decarbbootcamp.ornl.gov

Collaboration with EPA

IEDO also collaborates with the Environmental Protection Agency's (EPA) ENERGY STAR program to provide new technical assistance opportunities to energy intensive industries. ENERGY STAR works with companies to develop energy management programs by offering instructive partnership programs, energy management guidance, energy program resources, benchmarking and tracking tools, and much more.

EPA's benchmarking tools for industrial plants measure a plant's energy performance and compare it to that of similar plants nationwide, generating an ENERGY STAR score on a scale of 1 to 100. Additional subsectors are included in the program periodically, and tools currently exist for both the container and flat glass manufacturing industries.

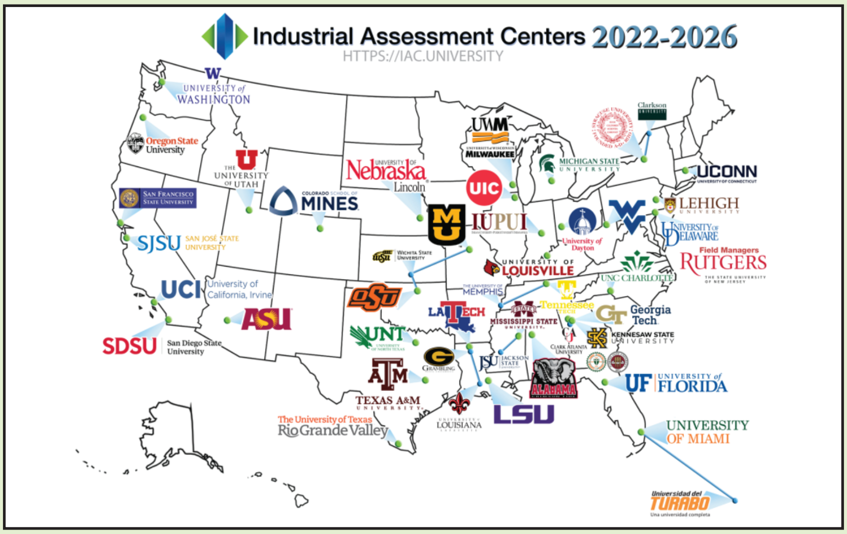
Learn more about EPA's approach to benchmarking industrial energy performance at https://www.energystar.gov/industrial_plants/measure-track-and-benchmark/energy-star-energy.

Industrial Assessment Centers: Tracking the transition to a decarbonized future

DOE's Industrial Assessment Centers (IACs) work with small- and medium-sized manufacturers to increase their energy efficiency and ease their transition to a decarbonized future. The program used to live within DOE's Advanced Manufacturing Office, but in 2022, it transitioned to the newly established Office of Manufacturing and Energy Supply Chains.

IACs now number 37 institutions across the U.S., and several new Centers of Excellence were established in the past several years to develop enhanced capabilities for serving partners. These Centers are located at universities to serve as both a resource to manufacturers and a training ground for the next generation of energy engineers.

To date, IACs have conducted more than 21,000 assessments, which resulted in more than 158,000 recommendations with average annual savings of $139,905.[5] All these activities and more are tracked in a publicly available IAC Database, which is available at https://iac.university/#database. Learn more about IACs and apply for an assessment at https://iac.university.



Credit: Office of Manufacturing and Energy Supply Chains

Figure 2. Map of DOE's Industrial Assessment Centers.

Energy management programs

IEDO encourages a comprehensive company-wide approach to address energy efficiency and emissions reductions. The establishment of an energy management system that is easily understood and implemented across all facilities in a company's portfolio is central to this approach. IEDO helps companies establish such a system through the 50001 Ready and Superior Energy Performance 50001 programs.

50001 Ready

The 50001 Ready program is designed to aid companies in preparing for ISO certification, facilitating the development of an energy management infrastructure that fosters continuous improvement and cost savings. To date, DOE has recognized more than 200 organizations for completion of the 50001 Ready program. This program includes virtual cohorts that benefit from 6–12 months of expert support in 50001 Ready implementation and continues to welcome new industrial members.

Learn more about the 50001 Ready program at https://betterbuildingssolutioncenter.energy.gov/iso-50001/50001Ready. Apply to be a part of the program by emailing 50001Ready@lbl.gov.

Superior Energy Performance 50001

Once a company has adopted an energy management system into their standard routine, they can pursue full ISO certification and then receive advanced recognition for their efforts through the Superior Energy Performance (SEP) 50001 program.

This program validates success through a third-party assessor and provides a tiered platform for recognizing outstanding energy efficiency improvement.

Learn more about the Superior Energy Performance 50001 program at https://betterbuildingssolutioncenter.energy.gov/iso-50001/sep-50001.

Onsite Energy Program

IEDO provides technical assistance, market analysis, and best practices to help industrial facilities and other large energy users increase the adoption of onsite clean energy technologies. Previously, these resources were offered through the Combined Heat and Power program, but starting in January 2024, this program evolved to become the new Onsite Energy Program. This program, which is overseen by IEDO, includes additional national lab resources and expanded expertise into new generation technologies.

A central pillar of the Onsite Energy Program is the Technical Assistance Partnerships (TAPs), or 10 regional centers that provide unbiased, fact-based engineering support and technical assistance to industrial and commercial facilities that can benefit from deploying onsite energy technologies. TAPs help identify opportunities for plants, support project planning, and conduct economic payback analyses.

The technologies covered by the Onsite Energy Program include battery storage, geothermal, solar thermal, combined heat and power, industrial heat pumps, renewable fuels, waste heat to power, fuel cells, solar photovoltaics, wind power, and more.

Learn more about the program at https://betterbuildingssolutioncenter.energy.gov/onsite-energy.

Software tools

IEDO provides support for a range of free open-source software and tools designed to help manufacturers and water treatment plants improve energy efficiency and advance decarbonization efforts. A full list of these tools is available at https://www.energy.gov/eere/iedo/iedo-software-tools. Tools most relevant to the ceramic and glass industries are described below.

Utility tracking and analysis

Resource utilization can be difficult to track, and many companies have their own unique system for managing utilities and calculating the resulting emissions. Released in early 2023, the VERIFI dashboard tool allows for tracking and analyzing of utility data within companies. This no-cost, open-source software provides a common data input platform for utility bills, visual representations of performance, regression analysis, and report-out capabilities at the site and company levels. The software is available online and on desktop and is updated regularly with new features developed from industry experience and feedback from users.

Download the open-source VERIFI dashboard tool on the IEDO Github page at https://ornl-amo.github.io or access the web version at https://verifi.ornl.gov. If you are interested in a demonstration of the tool or desire training on the software, contact BetterPlants@ee.doe.gov.

REopt Web Tool

The Renewable Energy Integration & Optimization (REopt®) web-based tool allows users to evaluate the economic viability of various onsite energy technologies, such as distributed photovoltaics, wind, battery storage, combined heat and power, geothermal heat pumps, and thermal energy storage. It also allows users to estimate how long a system can sustain critical load during a grid outage, as well as identify system sizes and dispatch strategies to minimize energy costs while meeting clean energy goals.

Learn more about the REopt Web Tool at https://reopt.nrel.gov/tool.

Financial Navigator

New financing opportunities can arise through different DOE programs and partnerships with financial institutions. The Financial Navigator tool provides a consolidated portal for learning more about these options that may be applicable for companies or specific projects.

Learn more about Financial Navigator at https://betterbuildingssolutioncenter.energy.gov/financing-navigator.

Case study

IEDO has seen continued success from the ceramics and glass manufacturers that partner with our programs.

Saint-Gobain

Saint-Gobain, an ACerS Diamond Corporate Partner and active Better Plants Partner, continues to improve energy efficiency in their manufacturing facilities. Saint-Gobain was awarded the Better Plants' 2024 Better Project Award for installing more than 180 energy meters integrated with a smart energy management system at its gypsum wallboard plant. Within three months, the system helped identify several opportunities to reduce energy usage and enabled the plant team to scope process changes and projects to address them.

Saint-Gobain was also awarded the 2022 Better Project Award for piloting and installing a new recycling technology that grinds and then captures waste gypsum and paper for reuse, reducing annual landfill waste by 15,000 tons and annual costs by more than $384,000.

Innovation focus

IEDO is leading initiatives in the following areas to help support the growth and sustainability of the U.S. manufacturing ecosystem:

Validation of innovative technology

The Industrial Technology Validation pilot continues to work with both vendors of innovative technologies and manufacturing companies that are interested in deploying these technologies. New case studies are published as the validation process is completed. These studies can be found along with the application to participate in the program at https://betterbuildingssolutioncenter.energy.gov/better-plants/industrial-technology-validation-pilot.

Education and workforce development

U.S. manufacturers benefit from strong training programs for current and future employees. IEDO is committed to furthering the work being done in this field and will have new announcements on this front coming in the second half of 2024. Learn more about workforce development resources from IEDO at https://betterbuildingssolutioncenter.energy.gov/workforce.

Focus on energy-intensive industries

DOE offers a wide array of technical assistance resources including energy and decarbonization assessments, specialized trainings on industrial systems and energy-related topics, and onsite energy assistance. To request technical assistance, please reach out to Robert Lung at robert.lung@ee.doe.gov or Zach Amigone at zachary.amigone@ee.doe.gov.

In addition to resources that help manufacturers adopt existing technologies, IEDO also invests in research and development (R&D) to accelerate the next generation of energy-efficient and industrial decarbonization technologies in the highest emitting sectors. For example, IEDO supports the R&D of technologies that reduce emissions attributed to various aspects of glass manufacturing, including the use of alternative glass feedstocks; overcoming challenges related to electrification and adoption of alternative fuels for process heating; and technologies enabling expanded cullet use.

For more information about IEDO's R&D opportunities, please visit the IEDO website and subscribe to the monthly newsletter at https://www.energy.gov/eere/iedo/industrial-efficiency-decarbonization-office.

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Jonathon Foreman
ACerS journals managing editor

Recycling and reusing ceramics and glass

Reduce, reuse, and recycle are the three Rs of sustainable practice. Of these three actions, reduce is the most straightforward, with the goal of minimizing energy use, raw material consumption, and dead-end waste production. On the other hand, recycle and reuse have multiple facets. For example, in last month's Topical Collection, "Sustainable ceramic and glass raw materials," there were several examples of materials produced for one purpose being "recycled" into raw materials for other purposes. Could this practice be considered reuse? Perhaps.

In this month's Topical Collection, "Recycling and reusing ceramics and glass," we explore some of the nuanced and various factors that must be considered when implementing the other two Rs. For example, inorganic glasses are exemplary of multiple levels of reuse and recycling. Dairies and breweries once frequently made use of glass bottles to deliver their products. After the empty bottles were returned via collection or deposit, these businesses washed and refilled the bottles until they were no longer usable. When that occurred, the business sent the bottles back to the glass company for melting and forming into new bottles.

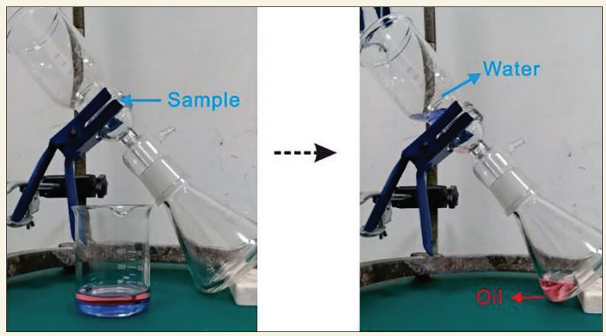
Though many companies and communities no longer make use of this business model due to increased transportation costs, these now single-use glass bottles remain highly recyclable. In the paper "Characterization of soda–lime silicate glass bottles to support recycling efforts," Gerace and Mauro showed that the mixed- colored, discarded bottles found in typical recycle streams can be reformed to create new glasses with consistent color.

Though transporting glass for recycling can be expensive, recycled glass offers the benefits of lower energy usage and carbon dioxide emissions compared to production based on carbonate raw materials. To make the most of these benefits, the reuse of ceramic and glass materials at or near the use location greatly extends the value to the user.

Being able to clean, refresh, and restore functionality via washing, calcination, or similar low-effort, low-cost methods can extend the life and utility acceptably of recycled ceramic and glass materials. Numerous papers in this month's Topical Collection explore removing simulated and real-world contaminants, including methylene blue, phosphates, and organic and pharmaceutical compounds.

Adsorption and filtration are two physical processes for removing contaminants. Adsorption is limited by the number of active physical sites to which contaminants can attach on the adsorbent's surface. Once capacity is reached, the adsorbed material must be removed to restore the adsorbent. In the paper "Pore size regulation of BN fibers and its effect on tetracycline adsorption," Liu et al. fabricated boron nitride fiber adsorbents with multiscale pores. They found the fibers adsorbed tetracycline in a nearly 1:1 removal rate. The capacity was retained at nearly 100% after five cycles of adsorption and removal via calcination.

Interestingly, in the paper "Preparation of oil–water separation network based on the novel strategies of SiO_2 ceramic micro-nano structure and PDMS modification," Liu, Zeng, and Yang developed a ceramic filter that reliably separates hydrocarbons from water. Their technology relies upon superhydrophobicity to prevent water from passing through the filter, and a simultaneous superoleophilic nature that uses surface tension to "push" the organics through the filter. They tested the filter under a wide range of real-world conditions (Figure 1) and were able to repair (recoat) the screen after eroding away the coating with sand. The refreshed screen retained more than 90% efficiency relative to the undamaged filter.



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

Figure 1. Advanced ceramic filter used to separate oil (red) from water (blue).

In recent years, research into catalytic removal of organic contaminants have focused on photodegradation methods. Titanium dioxide (TiO_2) is a classic photocatalyst often used in powder forms, which can be difficult to remove from the cleaned system. In the paper "Granular titanium dioxide and silicon-doped titanium dioxide as reusable photocatalysts for dye removal," Atali et al. developed a method for granulating TiO_2. The granules exhibited activity similar to powders but were substantially easier to separate from the water.

Wang et al. took a different approach to reusability of photocatalysts in the paper "High-performance Cu_2O-based photocatalysts enabled by self-curling nanocelluloses via a freeze-drying route." They developed a copper oxide/carbon fiber aerogel fabricated by freeze-drying nanocellulose. Their material degraded 97% of the tetracycline initially, falling to 89% after 10 cycles with no regeneration required between uses.

For more information on the articles discussed above along with others in the Topical Collection "Recycling and reuse of ceramics and glass," please visit https://ceramics.org/sustainability-collections. ■

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IMERYS ON ITS WAY TO REDUCE CO_2 EMISSIONS THROUGH BIOMASS WASTE CONSUMPTION IN GEORGIA

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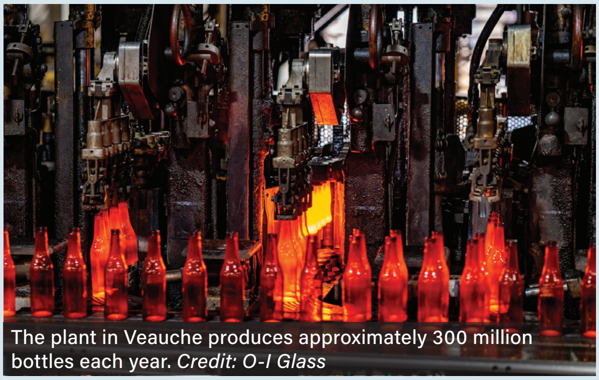
INDUSTRY NEWS

HEIDELBERG MATERIALS ACQUIRES TEXAS MATERIALS PRODUCER

Heidelberg Materials North America acquired all assets of Aaron Materials, a concrete recycler and materials producer in Corpus Christi, Texas. The operations include concrete crushing, stabilized materials, and a volumetric concrete business. Heidelberg says the acquisition aligns with its strategic focus on optimizing its portfolio in core markets, strengthening its existing businesses through bolt-on acquisitions, and advancing its focus on sustainable and circular products.

The acquisition accelerates Heidelberg's focus on recycled concrete and circular solutions. *Credit: Heidelberg Materials*


The plant in Veauche produces approximately 300 million bottles each year. *Credit: O-I Glass*

O-I INVESTS IN ELECTRIFICATION AT FRANCE PLANT

O-I Glass Inc. says it plans to invest $65 million in electrification and decarbonization at its plant in Veauche, France. One of its two furnaces will be renovated and equipped with hybrid-flex technology, giving it the ability to replace up to 70% of conventional, fossil-fuel-based energy with electricity. The furnace will also be equipped with heat recovery and an air preheating system, further reducing energy consumption and emissions. O-I also plans to install a heat recovery system to feed an energy distribution network that will supply up to 94% of the plant's heating needs.

SINTX EXPLORES STRATEGIC OPTIONS

SINTX Technologies announced that its board initiated a process to explore potential strategic options for the company. According to CEO Sonny Bal, "With technologies targeted at the medical, defense, and renewable energy markets, year-over-year growth in revenues, and other commercial opportunities in the pipeline, SINTX will require additional investment and resources. As such, we want to examine all strategic opportunities targeted at maximizing shareholder value." The company has retained Ascendiant Capital Markets as its strategic advisor.


SINTX has manufacturing and R&D facilities in Utah and Maryland. *Credit: SINTX Technologies*


The funds will support the Cowboy State Mine in Halleck Creek, Wyoming. *Credit: American Rare Earths*

MULTIMILLION-DOLLAR GRANT AWARDED TO WYOMING RARE EARTHS PROJECT

American Rare Earths received approval for a $7.1 million grant from the state of Wyoming to advance a rare earth element mine at its Halleck Creek Project. The funding will be used for exploration drilling and bulk sampling on state mineral leases, baseline environmental studies for state permitting, a pilot processing plant, prefeasibility studies, and economic and community impact assessments. The funding will be awarded through a three-year agreement as part of a matching funds arrangement.

The Research Center for Materials Nanoarchitectonics at the Japanese National Institute for Materials Science. *Credit: NIMS*

ORNL SIGNS RESEARCH AGREEMENT WITH JAPANESE INSTITUTE

Oak Ridge National Laboratory and Japan's National Institute of Materials Science (NIMS) signed a memorandum of understanding on advanced materials research to enable energy-efficient, cost-competitive, and environmentally friendly technologies. NIMS is a national research and development institute in Japan focused on materials science and technology. The five-year agreement will promote institutional exchange of staff and scientific and technical information as well as lead to symposia and workshops in both countries.

SIBELCO ACQUIRES MAJOR NORTH AMERICAN GLASS RECYCLER

Sibelco completed its purchase of Strategic Materials Inc. (SMI), one of North America's largest glass recyclers. SMI operates 42 sites across North America, processing around 2 million tons of recycled glass per year. Sibelco operates 24 recycling plants in Belgium, Estonia, France, Italy, Poland, and the United Kingdom. SMI employs 800 full-time workers at sites in the United States, Canada, and Mexico. Its products are used across a range of markets, including container glass, fiberglass insulation, reflective materials, fillers, and abrasives.

The acquisition positions Sibelco as a global player in glass recycling. *Credit: Sibelco*

The new production facility was inaugurated by top officials of Hungary and Schott. *Credit: Schott Pharma*

SCHOTT OPENS NEW SYRINGE PLANT IN HUNGARY

Schott Pharma opened its newest production facility in Lukácsháza, Hungary, following a 76-million-euro investment. The new production capacity adds 120 jobs and will support market growth for prefillable syringes made of specialty glass. Schott says it is planning a further multi-million-euro investment in Hungary in prefillable syringes in the future. Schott Pharma operates a global production network in 14 countries.

RHI MAGNESITA JOINT VENTURE ACQUIRES RECYCLER

MIRECO, a joint venture of RHI Magnesita and Horn & Co. Group, acquired Italian refractory recycling specialist Refrattari Trezzi, a family-owned company with more than 60 years of experience in refractory recycling. RHI Magnesita says the acquisition will enable an increased supply of high-value, secondary raw materials and is a step toward its decarbonization targets.

RHI Magnesita employs 20,000 people in 47 production sites around the world. *Credit: RHI Magnesita*

INVESTING IN THE FUTURE: PRACTICES FOR ENSURING ENVIRONMENTALLY FRIENDLY AND COST-EFFECTIVE MANUFACTURING

By David Holthaus

There has never been a better time to put an environmental focus at the center of the manufacturing process, as addressing concerns around climate change and resource scarcity is increasingly critical for long-term business success.

Local and national governments around the world are implementing stricter regulations in part because their constituents are becoming more attuned to these issues. But there is also a clear economic benefit because environmentally friendly practices can lead to long-term cost savings through reduced energy use. Likewise, many manufacturers are under pressure from their partners and suppliers to meet targets for emissions and waste reduction. And adopting environmentally friendly processes can be a competitive advantage, as a reputation for environmental stewardship can attract environmentally conscious customers, build loyalty, and improve sales.

Every industry and every company has its own environmental challenges. In this article, we gathered the perspectives of three companies that collaborate with ceramics and glass industries to learn how they work to ensure current needs are being met without compromising the ability to meet future demand.

INTOCERAMICS: CONVERTING WASTE INTO USABLE PRODUCTS

Bryan Geary and Carl Sorrell founded On the Plant Floor (Houston, Texas), a manufacturing consultancy, in 2010. About five years ago, "We found the nature of our business changing," Sorrell says. "We had large manufacturing companies coming to us and saying 'I've got this waste stream. Is there something we can do about it?'" That led to the creation of the IntoCeramics division, which aims to convert waste materials into usable products. The work for that part of the business has remained steady ever since then.

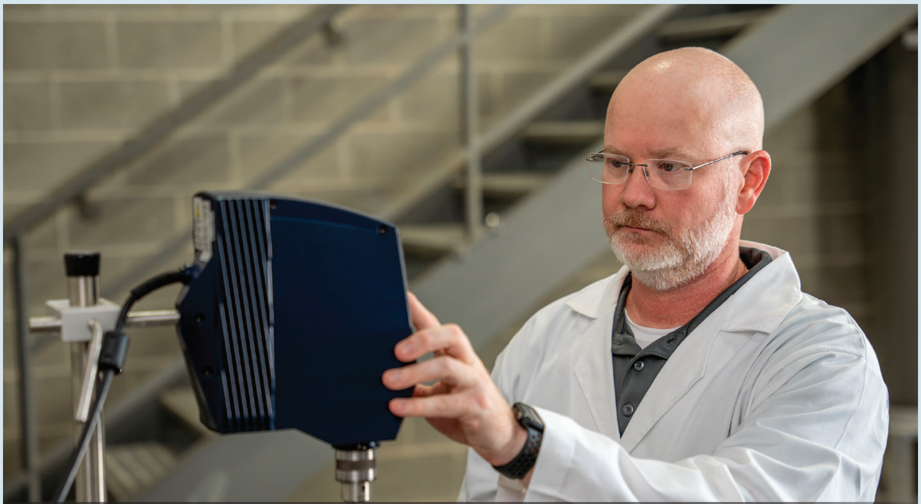

A high intensity mixer-granulator at the IntoCeramics lab. *Credit: IntoCeramics*

Even before IntoCeramics, Sorrell had an interest in converting waste into usable products dating to the 1970s, when he worked for a brick manufacturer. Once a year, a mobile unit would be brought in to crush waste brick to be used as landscaping material.

"Lo and behold, we made more money on the landscaping material per pound than we did on the brick," he says. "It just started something rolling in my mind, and I've been working in that arena ever since."

These days, their work makes much more use of high-tech methods to analyze materials and to target potential uses for the waste stream. One successful project involved an aggregate company that produced 30,000 metric tons a year of waste from a washing operation. It cost $2.2 million a year in tipping fees to dispose of the material, and the company was running out of landfill space to dispose of it. They had even considered shipping the waste out of state for disposal, which would have been very costly. The company was interested in saving that money and finding some productive use for it.

IntoCeramics used X-ray diffraction and X-ray fluorescence technology to examine the material, analyzed its thermal performance and its forming characteristics, and discovered it was unsuitable for use in brick, tile, or other traditional ceramic materials. But the analysis did find that a lightweight aggregate could be made from it, with potential uses in road construction and other areas where lightweight concrete is used. The IntoCeramics team then went through a three-phase process, including a capital expenditure analysis and pilot manufacturing, to determine if the product was suitable for recycling.



IntoCeramics uses high-tech methods to analyze materials and target potential uses for waste. *Credit: IntoCeramics*

The team at IntoCeramics is also working with a company called Vecor Technologies (Houston, Texas) on methods for processing a waste stream material as a substitute for titanium dioxide, a product used in paints, coatings, inks, ceramics, and plastics.

"In this case, you're taking a material that is relatively low cost to begin with and using it to replace material that is extremely expensive," Sorrell says.

Conversely, analysis sometimes reveals that waste streams are not always feasible. A large mining company approached the team at IntoCeramics a few years ago to ask about turning mining waste into ceramic tile. Although it was possible to do, the company generated so much waste that it could not use it all and the capital expenditure involved in setting up such an operation would have been prohibitive.

Kyanite Mining Corp.'s Virginia quarry is the main source of the mineral kyanite in North America. *Credit: Kyanite Mining Corp.*

Sorrell says that worldwide mineral waste generated annually is between 88 billion and 98 billion metric tons, while worldwide production of cement, ceramic tile, glass, sanitaryware, and refractories is only 10 billion metric tons.

"You've got to target the approach and define what your goal is," he says. "If your goal is to recycle as much as possible, then you've got to target areas where lots of the material can be used."

The growth of environmental regulations and awareness has helped drive the company's business.

"Our business has expanded significantly," Sorrell says. "Five years ago, we had one laboratory in Houston. We now have four, and we are looking to expand even further."

KYANITE MINING: GOING BEYOND THE MINIMUM

Kyanite is a mineral used in the manufacture of refractories, and in North America, it is produced by one company from two mines in central Virginia. Kyanite Mining Corp. (Dillwyn, Va.) is a family-owned and operated business that has been producing kyanite and its calcined derivative, mullite, since the 1940s. Its two quarries and four processing plants in Buckingham County, Va., supply most of the world's kyanite.

A long list of federal laws and regulations covers all aspects of mining, and each state also has laws that companies must follow. At Kyanite Mining Corp., those voluminous regulations are just the beginning of its environmental stewardship.

"The bare minimum is not the goal for us," says John Snoddy, Kyanite Mining's environmental and safety director. "Our goal is to achieve more than the minimum threshold between compliance and noncompliance."

That goal stems largely from the fact that many of the company's 130 employees are either natives of central Virginia or of Buckingham County itself, Snoddy explains.

"When you're operating in the county that's home, you treat it like home," he says.

It is also just good business. The company works to use or sell as much of the material that it extracts as possible, including the mining byproducts of sand, pyrite, and magnetite. That minimizes waste and follows sound resource recovery practices. It also works to contain pollution and restore the land to its natural state after mining, ensuring that the company can operate effectively for years to come.

Producing 150,000 tons of highly purified kyanite a year requires drilling, blasting, and moving massive amounts of earth to extract dirt, rock, and the minerals they contain. All that exposes whatever lies beneath the surface to the elements and can lead to runoff. Building sediment ponds, sediment traps, diversion berms, and rock filter berms ensures that the sediment stays on site.

"Our goal is to capture all of that sediment so that despite the fact we have to disturb the earth to operate, the sediment that is exposed to stormwater doesn't migrate off our site," Snoddy says. "That's arguably the most important environmental requirement that mining companies have. Allowing your sediment to migrate offsite is a recipe for having your neighbors upset at you."

Kyanite Mining has won several state and national environmental stewardship awards, the most notable of which is for the work completed at its original mine site at Baker Mountain. The site, in Virginia's Prince Edward County, was operated as a mine from the 1920s into the 1970s, and a processing plant attached to the quarry continued to operate into the early 2000s. In 2006, the company began a large reclamation project, removing the industrial structures and turned the plant's footprint and surrounding acreage into wildlife habitat.

"You'd be hard pressed to believe that there was once a processing plant on the site," Snoddy says. "It's now grassland and forest land with all of the native wildlife you would expect to see here in central Virginia."

LUCIDEON: RESEARCHING AND TESTING ADVANCES IN SUSTAINABLE MANUFACTURING

The British Ceramic Research Association was created in 1948 to serve the ceramic industry with research and then later with testing and certification services. As the association grew and evolved, its name changed to CERAM Research Ltd. Following the acquisition of a testing and analysis company in the United States, the organization eventually rebranded in 2014 under the name Lucideon.

Through its expansions, Lucideon (Stoke-on-Trent, U.K.) has continued servicing the ceramic industry and has branched into aerospace, construction, energy, and health care, as well as other industries. Its team of experts in seven locations in the United Kingdom, the United States, and Japan assist companies with difficult materials challenges.

"If it's made out of stuff, we're probably going to be an expert in it," says Richard Goodhead, Lucideon's chief marketing officer.

Lucideon's kiln for research and development incorporating hydrogen fuel. *Credit: Lucideon*

For the ceramic and glass industries, Lucideon is consulting on a range of projects to reduce energy use and assist with decarbonization efforts. For more than two years, Lucideon researchers have explored the potential of hydrogen as a clean fuel for kilns. Hydrogen produces only water vapor as a byproduct of being combusted, but using the fuel comes with its own challenges, including how the finished products are affected. Lucideon owns two state-of-the-art kilns used for research into the potential of hydrogen fuel.

The pilot scale facility allows clients to explore using various blends of hydrogen and natural gas in their firing at an offsite location.

"If there are R&D challenges that an organization wants to try and undertake, the one thing they can't afford to do is to shut down their production line to carry out those experiments," Goodhead says. "So this is an off-plant, pilot-scale facility where they can do that kind of experimentation."

Lucideon also has the capability to demonstrate and develop flash sintering technology, an advanced method that can reduce processing time and furnace temperatures, with the potential to have a big impact on energy use.

"What flash sintering seeks to do is to sinter at a lower ambient temperature and apply electrical fields to produce a localized and controllable input of energy into the body to cause the sintering process to still occur," Goodhead says.

In a case study, Lucideon experts worked with a fuel cell manufacturer to test flash sintering technology for ceramic electrodes, with results showing a decrease in energy use, increased productivity, and lower cost.

Lucideon is developing and demonstrating flash sintering technology. *Credit: Lucideon*

Lucideon researchers also developed a solution to the global challenge of disposing of nuclear wastes. The traditional method is to capture it in cement, a process that is energy intensive and leaves a carbon footprint. Lucideon and a partner use a geopolymer technology based on a chemical reaction at low temperatures, reducing energy usage and carbon emissions.

"We've also found through experimentation that we can encapsulate more waste per unit volume in a geopolymer formulation than you can in traditional concrete, so you can therefore take up less space," Goodhead says.

The lower-cost, lower-carbon technique has been successful in completely encapsulating problematic waste streams, withstanding radiation, and other stresses.

"We're quite optimistic that this could be a real game changer for nuclear waste," Goodhead says.

Lucideon is also a member of the Foundation Industries Sustainability Consortium, a group of research leaders in the foundation industries of cement, metal, glass, ceramic, paper, polymer and chemicals, all of which require a lot of energy to produce the foundational products that they do. The group plans to work on a process optimization project for the ceramic industry, experimenting with better furnaces and heat management to improve efficiency and reduce energy use.

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IMERYS ON ITS WAY TO REDUCE CO_2 EMISSIONS THROUGH BIOMASS WASTE CONSUMPTION IN GEORGIA

By Nancy Bunt

Five years ago, multinational group Imerys S.A. (Paris, France) embarked on a journey at its Andersonville plant in Georgia to reduce greenhouse gas emissions.

Imerys Andersonville is the home of a superior sintered mullite product called Mulcoa®.[1] This product, which is produced from unique high-purity refractory grade kaolin clay from the southeastern kaolin belt, is renowned in the world of refractory aluminosilicate calcines as the benchmark for refractory production.

The carbon footprint of Mulcoa, which has been in production for 54 years, is impacted by the combustion of fossil fuels during the manufacturing process. This plant consumes the most energy across all Imerys facilities.[2]

To address the plant's environmental impact, Imerys Andersonville personnel initially aimed to reduce the plant's greenhouse gas emissions by 103 Kt CO_2 /year, which is equal to a 4% reduction in the Group's emissions. To achieve this reduction, they planned to implement a solution successfully adopted at five other plants: transition from the use of fossil fuels to biomass waste and natural gas. Fortunately, the Andersonville plant is uniquely positioned to make use of a local biomass waste source: peanut shell hulls.

Andersonville is located in the largest peanut growing area in the United States. Peanuts were designated the state crop of Georgia in 1995, and today 53% of the peanuts grown in the United States are grown in southern Georgia.

To make use of ground peanut shell hulls as biomass waste, the US$20-million project entailed converting the existing kiln burners to accommodate ground peanut hulls (GPH) as well as installing the necessary infrastructure to handle and store a large quantity of GPH. The first phase of this project was completed in 2019, with first results being reported in 2020. As of 2023, 13% of the site's total energy consumption came from GPH, which resulted in a 30-Kt reduction of CO_2 emissions annually.

As of mid-2024, the second phase of the project was completed. The plant now runs on a combustion source of roughly 20% natural gas and 80% ground peanut hulls, and it consumes close to 40 trucks per day of ground peanut shells. When the third and final phase of the project is completed by 2030, an overall reduction target of 140 Kt CO_2 emissions per year will be achieved, compared to the emissions in 2018 when the project was conceived and designed.

The impact this fuel switching project will have on the individual product carbon footprint of Mulcoa products is significant, with up to a 50% reduction. Finalized life cycle assessments evaluating the new energy mix of natural gas and biomass waste will be available in 2025.

On June 11, 2024, Imerys held a ceremony inaugurating the carbon reduction project at its Mulcoa® production site in Andersonville, Ga. *Credit: Imerys*

A loading bay for the ground peanut hulls at the Andersonville, Ga., site. *Credit: Imerys*

This project is just one example of Imery's commitment and investment to align its activities to the 1.5°C trajectory under the Paris Agreement.[3] The Group invests approximately US$16–21 million annually on projects and technologies to decarbonize its operations, all with the goal of reaching two set targets by 2030: reducing the Group's scope 1 and scope 2 emissions by 42% and its scope 3 emissions by 25% from the base year of 2021. Through these activities and collaborations with suppliers across the value chain, Imerys is on the path to create more sustainable value for its customers.

REFERENCES

[1]Mulcoa, https://www.imerys.com/product-ranges/mulcoa

[2]Andersonville, https://www.imerys.com/usa

[3]United Nations Climate Change Conference COP21 Paris Agreement 2015, https://unfccc.int/process-and-meetings/the-paris-agreement

ABOUT THE AUTHOR

Nancy Bunt is global sustainability director at Imerys Refractory Abrasives and Construction. Contact Bunt at nancy.bunt@imerys.com.

ALFRED UNIVERSITY GLASS SCIENTISTS PURSUE METHOD TO REUSE WINE BOTTLES

By Mark Whitehouse

Glass scientists at Alfred University in New York, in partnership with New York state and consulting company Vitricity (Madison, Wis.), are studying ways to wash and reuse wine bottles. The project could remove tens of thousands of wine bottles from the waste stream each year while helping Finger Lakes Region wine producers realize significant savings.

There are more than 130 wineries in the Finger Lakes Region, primarily on Keuka, Seneca, and Cayuga lakes. According to a survey of the region's wine producers, the average winery uses about 10,000 bottles each year in their tasting rooms alone, with some going through as many as 50,000 annually. For the most part, those bottles are not reused and likely end up in landfills.

With the cost of wine bottles increasing, due in large part to supply chain issues, there is an incentive for wineries to reuse their bottles. In addition, "Most wine producers who answered our survey said they were concerned about the environment and want to make the Finger Lakes Region more sustainable. Sustainability is at the core of a lot of their business models," says Rebecca Welch, Ph.D. student in materials science and engineering at The Pennsylvania State University and researcher for Vitricity.

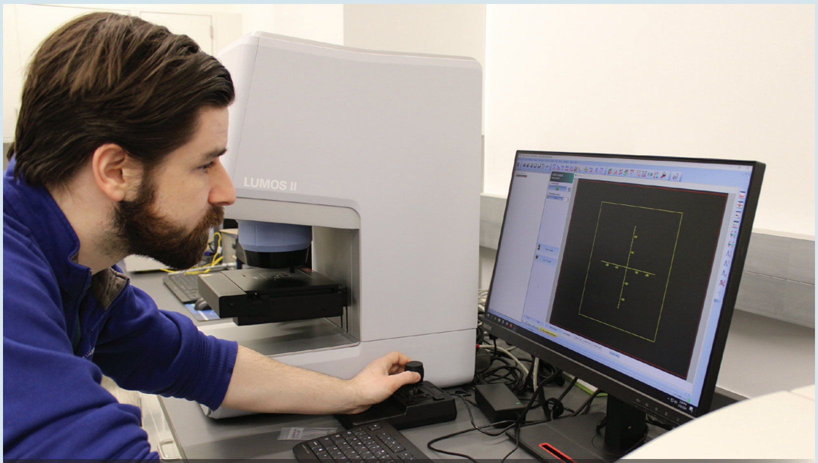
Welch led the survey to gauge the interest of wine producers in the project and to provide education on its benefits. For example, based on the team's research, some countries that have bottle washing can reuse bottles up to 30 times.

"Canada has programs in place, focusing on the beer industry. We'd like to do what they've done and apply it to wineries in the Finger Lakes Region. This would be a huge benefit, not only for the vineyards financially but for our overall sustainability efforts," Welch says.

There are some concerns, however. As Welch explains, "How do we know the bottles are clean enough to be reused? What is the impact of water and the cleaning detergents: does it corrode the glass? How does wine impact the integrity of the glass? As the bottles are washed, how long before the glass breaks?"

The bottle washing research project at the Center for Glass Innovation in Alfred University's Inamori School of Engineering will ideally provide the answers to these questions. The project is supported by grant monies from the New York State Department of Environmental Conservation, which awarded Alfred University $4.2 million from its Environmental Protection Fund to perform research aimed at promoting glass recycling and reuse.

Arron Potter, postdoctoral researcher in the Center for Glass Innovation, is helping lead efforts to find effective ways to clean wine bottles. He says the porous nature of glass is one of the main challenges preventing glass from being effectively cleaned, as liquid can settle into the nanometer-sized pores and leave an odor. To overcome this challenge, he is looking into a washing method that removes a micron-thin layer of the glass surface, taking away any residual moisture and leaving a new, more pristine interior surface of the bottle.



Arron Potter, postdoctoral researcher at the Center for Glass Innovation in Alfred University's Inamori School of Engineering, uses an infrared microscope on a fragment of glass taken from a wine bottle to measure the extent of damage caused to the bottle's interior surface by exposure to liquid. *Credit: Alfred University*

Welch says once a suitable method for washing the bottles is achieved, focus will be placed on developing facilities for collecting and washing the bottles and determining how they will be transported to and from the wineries.

"We need to make washing and reusing bottles cheaper or the same as buying new," Welch explains, noting that the state may consider providing subsidies to wineries as an incentive to reuse bottles. "I feel we can meet the current cost without subsidies. With government support, it would be cheaper [to reuse bottles]."

ABOUT THE AUTHOR

Mark Whitehouse is director of communications at Alfred University. Contact Whitehouse at whitehouse@alfred.edu.

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STRUCTURAL CLAY EXPERTS CONVENE IN OKLAHOMA CITY FOR NETWORKING AND PLANT TOURS

Nearly 120 attendees converged in downtown Oklahoma City, Okla., on June 17–19, 2024, to take part in the combined meeting of the ACerS Structural Clay Products Division (SCPD), ACerS Southwest (SW) Section, and Clemson University's National Brick Research Center (NBRC).

The three-day meeting kicked off with a networking reception on Monday night, followed by a full day of informative talks and then plant tours at several local brick manufacturing sites. The meeting wrapped up with an awards banquet on Wednesday night.

ACerS SCPD and SW Section officers and NBRC staff honored Greg Geiger (center), ACerS technical content manager who is retiring at the end of 2024, with a certificate of appreciation for his 35 years of service to ACerS and 20 years of support of this meeting. *Credit: Neil Klein, Acme Brick*

NATIONAL BRICK RESEARCH CENTER MEETING

During the NBRC's Spring Executive Committee Meeting on Tuesday morning, NBRC director John Sanders along with research associates Nate Huygen and Kathy Hill provided the members with updates about the center. Sanders reminded the committee of the upcoming Clemson Brick Forum, which will take place Sept. 30–Oct. 1, 2024, in Anderson, S.C.

TECHNICAL SESSION

On Tuesday afternoon, attendees heard from 12 industry experts on a wide range of topics, including ways to improve manufacturing efficiency, brick efflorescence, surface decoration, particle size analysis, and more.

PLANT TOURS

On Wednesday, attendees toured two plants: Acme Brick's Oklahoma City plant and Red River Brick Union City plant. Attendees enjoyed a BBQ lunch at Iron Star restaurant between the two visits.

AWARDS

Several awards were given out during the banquet. Alan Autrand of Red River Brick received the 2023 SCPD Best Paper award for his presentation titled "Aerial surveying program at Red River Brick." Nathan Fields of Endicott Clay Products received a plaque for his service as the current SW Section chair, while Holly Rohrer of Halbert Mill Co. received a certificate for her service as the past SCPD chair.

In addition, SW Section treasurer Harland Dixson recognized two award recipients who were not in attendance at the banquet. He announced Luke Odenthal of Acme Brick as this year's recipient of the prestigious SW Section Harry E. Ebright Award, which recognizes outstanding service to the SW Section. Dixson then thanked SW Section secretary Fred McMann for his decades of leadership and dedication to the SW Section and to the SW Section meeting.

View more pictures from the meeting on ACerS Flickr page at https://bit.ly/SCPD-2024. Next year's meeting is scheduled for June 9–11, 2025, in Birmingham, Ala. ■

14TH ADVANCES IN CEMENT-BASED MATERIALS COVERS ALL ASPECTS OF CEMENTS RESEARCH, FROM BASIC TO APPLIED

The American Ceramic Society's Cements Division hosted the 14th Advances in Cement-Based Materials meeting from June 19–21, 2024, at Missouri University of Science and Technology in Rolla, Mo. The meeting welcomed 148 attendees.

Thirty-four people participated in the new ACerS Conference Mentor Program at Cements 2024. *Credit: ACerS*

Wednesday's program opened with a presentation by keynote speaker Shiho Kawashima of Columbia University, titled "Cement, Rheology, and Processing—why give a CRAP."

Then, Division chair Will V. Srubar III presided over the Division's business meeting. Afterward, the first round of breakout sessions began, with topics including durability and service life modeling, cement chemistry, and rheology and additive manufacturing.

Wednesday afternoon, Maria Juenger of The University of Texas at Austin presented the Della Roy Lecture on "The road to sustainable cement." Juenger's lecture was followed by the Della Roy Reception and poster session, sponsored by Elsevier. More than 20 presenters detailed their research.

Thursday began with a special session in honor of Edward Garboczi, who is retiring later this year. The session included presentations by Jeff Bullard, Joe Biernacki, and David Lange on computational cements research, 3D printing, and identifying and overcoming inefficient research methods, respectively.

Friday began with an industry panel discussion, which included Jeffrey Thomas of GCP Applied Technologies, Matthew D'Ambrosia of MJ2 Consulting, and Aida Margarita Ley Hernandez of ICON. The final break-out sessions of the conference followed.

The new ACerS Conference Mentor Program was also held at Cements 2024, and one participant reported that the program was "an enjoyable experience." The meeting concluded with the announcement of the 2025 meeting location, which will be the University of Colorado in Boulder.

View more photos from the event on ACerS Flickr page at https://bit.ly/Cements2024. ■

CERAMIC SCIENTISTS AND ENGINEERS EXPERIENCE THE MAGIC OF MONTRÉAL AT ICC'10

The 2024 International Congress on Ceramics (ICC'10) took place in Montréal, Québec, Canada—sometimes known as "the Paris of North America"—from July 14–18, 2024. The event, which was co-organized by ACerS and the International Ceramic Federation (ICF), hosted 250 attendees, including 45 students, representing 24 countries.

Between the bustling city streets and flurries of French, ICC'10 showcased a variety of events, including robust plenary speakers, an Emerging Leaders Industry panel, and a lively student poster session. The conference featured many technical sessions, covering topics such as green ceramics, educational trends in ceramics and glass, nanostructured ceramics, and more. ICC'10 also welcomed a special performance by magician Drew Murray during the Wednesday evening reception.

Some highlights from ICC'10 are summarized below. Special thanks go to 2024 ICF president Paolo Columbo, 2024 ICC president Edgar Lara-Curzio, and ICC program chairs Lisa Rueschhoff and Miladin Radovic for helping coordinate this robust international gathering.

PLENARY LECTURES NAVIGATE A PLETHORA OF NOVEL MATERIALS AND PROCESSES

Five plenary lectures took place at ICC'10 across Monday, Tuesday, and Wednesday morning. These sessions provided a comprehensive overview of several novel ceramic research areas. Each plenary speaker received a certificate of appreciation after their talk.

Eva Hemmer, associate professor of materials chemistry at the University of Ottawa, talked about the fascinating world of lanthanide-based materials, focusing on their exceptional optical properties that make them suitable for diverse applications in biomedicine, optomagnetics, and energy conversion. She explained the benefits of fabricating lanthanides using microwave-assisted synthesis, which allows precise control of the material's structure and so leads to optimized optical and magnetic properties.

Gaurav Sant, professor and Pritzker Endowed Chair in Sustainability in the Samueli School of Engineering at the University of California, Los Angeles, presented an innovative approach used at his company Equatic to achieve simultaneous carbon dioxide removal and green hydrogen production from seawater.

Chang-Jun Bae, principal investigator for 3D printing materials at Korea Institute of Materials Science and professor of material science and engineering at the University of Science & Technology, discussed the transformative potential of ceramic additive manufacturing in various industries. He then introduced an in-situ sensing system for real-time defect detection during processing.

Diletta Sciti, director of research at the National Research Council of the Institute of Science, Technology, and Sustainability for Ceramics, delved into the challenges that come with deploying ultrahigh-temperature ceramics and their composites in real-world applications. These advanced materials help withstand extreme conditions in space exploration and hypersonic travel.

Hala Zreigat, Biomaterials and Tissue Engineering Unit, University of Sydney, focused on the development of nanostructured, 3D-printed bioceramics for personalized bone healing. She outlined strategies for creating engineered biomaterials that enhance the repair of critical bone defects, particularly in aging populations with impaired regenerative responses.

INCOMING ICF PRESIDENT AND ECERS–ACERS JOINT AWARD WINNER ANNOUNCED

Two important announcements were made before dinner on Wednesday evening. First, current ICF president Paolo Columbo announced that Sylvia Johnson, ACerS past president (2018–2019) and Distinguished Life Member, would be the next ICF president. Then, Columbo was presented with the ECerS–ACerS Joint Award by ACerS president Rajendra Bordia and European Ceramic Society Fellow Jon Binner. This award recognizes individuals who foster international cooperation between ACerS and ECerS in demonstration of both organizations' commitment to work together to better serve the international ceramics community.

Top: Current and future ICF presidents Paolo Columbo, left, and Sylvia Johnson, right, pose together onstage before the Wednesday evening dinner.

Bottom: Participants in the ACerS Conference Mentor Program at ICC'10.

All photos credit: ACerS

NETWORKING AND MENTORING HELP ENGAGE STUDENTS AND YOUNG PROFESSIONALS

ICC'10 also provided networking opportunities for the students who attended, including the welcome reception on Sunday evening, the poster session on Tuesday evening, and the Emerging Leaders Industry panel on Wednesday. These events, along with the new ACerS Conference Mentor Program, which saw seven mentors paired with 14 mentees at ICC'10, allowed students to connect with peers and professionals alike to discuss their research and network. View more photos from ICC'10 on ACerS Flickr page at https://bit.ly/ICC-10. ICC'11 will be held in 2026 in Japan.

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Calendar of events

September 2024

10–12 ★ Sintering of Ceramics – Virtual; https://ceramics.org/castro-sintering-course

16–19 ➨ 85th Glass Problems Conference and Symposium, 14th Advances in Fusion and Processing of Glass – Toledo, Ohio; https://gmic.org/glass-problems-conference

16–Dec. 16 ★ Refractory Fundamentals – Virtual; https://ceramics.org/homeny-refractory-fundamentals

October 2024

6–9 ACerS 126th Annual Meeting with Materials Science and Technology 2024 – David L. Lawrence Convention Center, Pittsburgh, Pa.; https://ceramics.org/mst24

15–Nov. 14 ★ Exploring Nanoworlds: Scanning Probe Microscopy and Machine Learning – Virtual; https://ceramics.org/kalinin-probe-microscopy-machine-learning

January 2025

26–31 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/quinn-mechanical-properties

February 2025

25–28 EMA 2025: Basic Science and Electronics Division Meeting – Hilton City Center, Denver, Colo.; https://ceramics.org/event/ema-2025-basic-science-and-electronic-materials-meeting

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

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

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

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.

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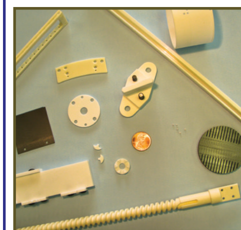

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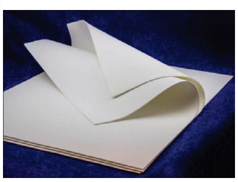

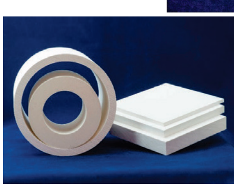

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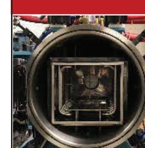

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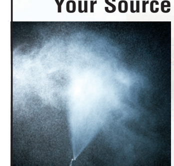

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A regular column offering the perspectives of the next generation of ceramic and glass scientists, organized by the ACerS President's Council of Student Advisors.

By Nabil Ashraf Shuvo

Guest columnist

Magnetic separation using nanoparticles: Prospects in nuclear waste management

Magnetic separation is a technique frequently employed in the minerals processing industry to target and capture contaminants (Figure 1). In recent years, the efficacy of this technique has improved significantly thanks to the development of iron-based magnetic nanoparticles.[1]

Iron is one of the best known ferromagnets, meaning this metal can retain its magnetization even in the absence of an applied magnetic field. However, when iron oxides such as magnetite (Fe_3O_4) and maghemite (γ-Fe_2O_3) are shrunk to very small sizes, the material begins to exhibit superparamagnetic properties. In other words, the nanoparticles become strongly magnetized in the presence of an external magnetic field but become fully demagnetized once the field is removed. This behavior prevents the nanoparticles from agglomerating, which is highly beneficial for their effective use in dynamic and controlled separation processes, as well as cleaning of the particles for reuse.

In wastewater treatment, iron-based magnetic nanoparticles have successfully helped remove various contaminants.[2] In many cases, the surfaces of these nanoparticles are modified to exhibit specific functionalities.[3] But some particles without surface modification perform well due to the inherent surface area available for sorption.[4]

Iron-based magnetic nanoparticles can also separate and extract radioactive contaminants, which makes them useful in nuclear waste management. For example, researchers previously developed magnetic nanoparticles functionalized with phosphate to selectively capture heavy metals and isotopes from liquid waste streams.[5] After being bound, these complexes were separated from the nonradioactive waste using a magnetic field.

Additionally, compared to other magnetic separation approaches, magnetic nanoparticles perform well in nuclear waste management applications because of their high surface area-to-volume ratio, which enhances their binding capacity and efficiency. This attribute is particularly useful in dealing with the complex and diverse nature of nuclear waste, which often contains a mixture of elements in low concentrations.

Despite the potential of magnetic nanoparticles, several challenges hinder their widespread adoption. Researchers must address the nanoparticles' long-term stability and recyclability to ensure this method is affordable and environmentally friendly. Comprehensive safety evaluations are also required to ensure the hazard-free usage of magnetic nanoparticles.

In the Nuclear, Optical, Magnetic, and Electronic (NOME) Materials Laboratory at Washington State University, the vitrification of nuclear waste into various glass waste forms is being studied. Finding alternative methods of pretreatment for other forms of nuclear waste, such as liquid waste streams, and implementing magnetic nanoparticles for magnetic separation are also important research areas. Currently, NOME researchers are investigating the redox chemistry of iron sulfide nanoparticles and their interaction with radionuclides in nuclear waste, such as is present at the U.S. Department of Energy Hanford cleanup site, as part of this alternative approach.

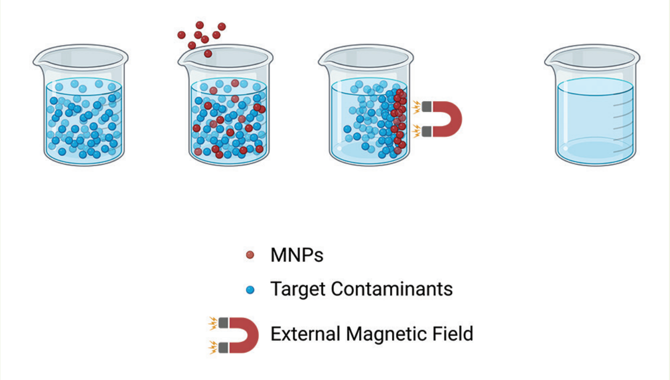

Figure 1. Schematic demonstrating magnetic separation. Contaminating blue particles are sorbed by magnetic red particles and then separated out using an applied magnetic field.

As a graduate student at Washington State University working in NOME, I have high hopes that these novel approaches will be crucial in solving the pressing problem of radioactive waste. Ultimately, magnetic nanoparticles may be our way to achieve effective and selective nuclear waste management.

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Nabil Ashraf Shuvo is a graduate student in chemistry at Washington State University. Since joining the Nuclear, Optical, Magnetic, and Electronic Materials Laboratory at Washington State led by John S. McCloy, his research has focused on magnetic nanoparticles and their interaction with radionuclides. In his free time, Nabil enjoys exploring nature and studying history and language. ■

WELCOMING NEW FACULTY

Dr. Benjamin Moulton —

Alfred University would like to introduce you to our latest faculty member Dr. Benjamin Moulton has been hired as Assistant Professor of Glass Science. Ben earned a Ph. D. in Earth Sciences at the University of Toronto, Canada after which he spent time at the Center for Research, Technology, and Education in Vitreous Materials (CeRTEV) at the Federal University of São Carlos (UFSCar) in Brazil and then in Materials Science at Friedrich-Alexander Universität Erlangen-Nürnberg (FAU) in Germany. Dr. Moulton's research focuses on the role of structure in all properties, with an emphasis on the mechanical properties and crystallization behavior. Ben is interested in building broad-based models of glass structure that allow for predictive intuitions based on the chemistry of the glass. This goal intersects with understanding the links between mechanics (e.g., toughness, strength), optics (e.g., transparency, refractive index), processing (e.g., the glass transition, viscosity) and thermodynamics (e.g., heat capacity) and structure as well as pragmatic considerations such as environmental impact of source materials and energy demand. In the years ahead, he hopes to explore more exotic compositions, including producing non-traditional oxide glass that require hyper-quenching and fiber draw approaches.

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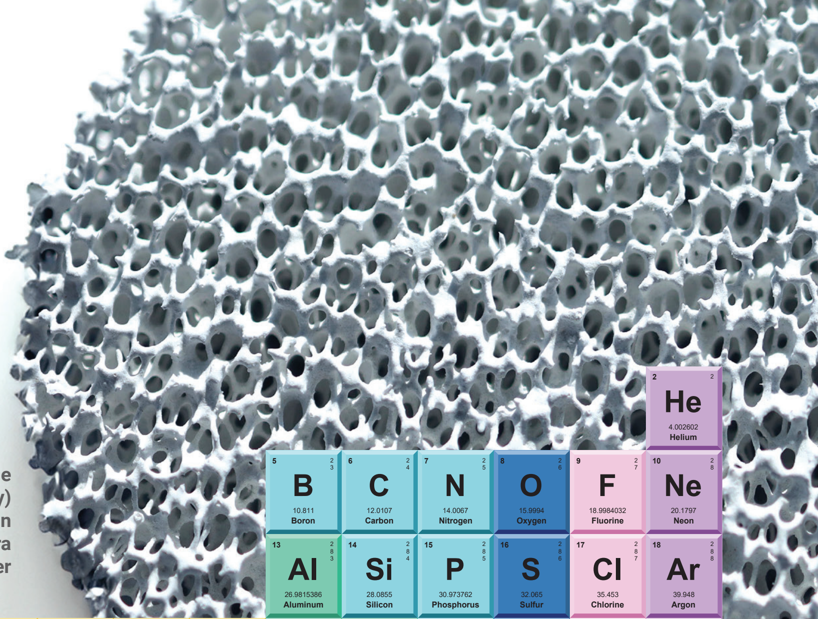

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