AMERICAN CERAMIC SOCIETY
bulletin
emerging ceramics & glass technology
MAY 2022

ACerS celebrates the International Year of Glass

INTERNATIONAL YEAR OF GLASS 2022

AI and ML for glass design | Glass for optical technologies | Kreidl award abstract

contents

May 2022 • Vol. 101 No.4

feature articles

departments

columns

meetings

resources

Cover art:

Group photo is a congregation at the opening ceremony for the United Nations International Year of Glass in February 2022 at the United Nations Palace of Nations, Geneva, Switzerland. Other featured photos from the National Day of Glass Conference in April 2022 in Washington, D.C.

Editor's note:

Attentive readers may notice that this *Bulletin* is more slender than usual. An acute, global shortage of the paper has led us to reduce the number of pages printed. For more information on the shortage, visit our website at www.ceramics.org or contact customer service at customerservice@ceramics.org.

AMERICAN CERAMIC SOCIETY
bulletin

news & trends

Surging natural gas prices affect Europe's ceramics and glass industries

Natural gas and gasoline prices are reaching near record highs, and many people are pointing to the ongoing Russian invasion of Ukraine as the reason for these prices. However, the current crisis is contributing to a trend that has been in place since last fall, driven by a confluence of factors.

"Following a colder-than-average 2020–21 winter, gas storage facilities in Europe have not been able to replenish their stocks to sufficient levels ahead of the start of the new winter season. …. Gazprom, which remains the single largest supplier to the European market, has met contractual delivery obligations but has not been able to deliver additional volume to its customers. Compounding the issue, weak wind output and low hydro storage levels due to drought conditions during the summer means that demand for natural gas for power generation is unusually strong," a CME Group article explains.

In addition, domestic production of natural gas in Europe is in long-term decline, making European markets more vulnerable to issues in other regions than countries like the U.S., which have a large domestic supply.

Europe's ceramics industry is one sector hit hard by the surging prices. In 2021, this $35 billion industry had just started recovering from the pandemic, with sales jumping more than 10% in the first half of the year. However, "surging gas prices have caught out

Credit: Gayafores, YouTube

Ceramic tiles produced by Spanish tile contractor Gayafores. European ceramic companies are employing various measures to handle the surge in natural gas prices.

companies in an energy-intensive business, leaving them to choose between passing on higher costs to customers and scaling back or halting production. And all at a time when many feel energy transition costs are already hurting them," a *Reuters* article explains.

Italy specifically is feeling the effects because the country, along with Spain, dominates Europe's ceramics trade. In the past six years, Italy invested more than 2 billion euros ($2.3 billion) in new materials and technologies to help it compete with cheaper production from China, India, and Turkey. Yet even as demand returns in the ceramic tile business, the rise in orders "cannot keep pace with the impact of energy costs," the *Reuters* article says.

Ceramic companies are employing various measures to handle the price surge, including introducing energy surcharges, temporarily cutting production, and even considering investment in factories outside of Europe.

American Ceramic Society Bulletin covers news and activities of the Society and its members, includes items of interest to the ceramics community, and provides the most current information concerning all aspects of ceramic technology, including R&D, manufacturing, engineering, and marketing. The American Ceramic Society is not responsible for the accuracy of information in the editorial, articles, and advertising sections of this publication. Readers should independently evaluate the accuracy of any statement in the editorial, articles, and advertising sections of this publication. *American Ceramic Society Bulletin* (ISSN No. 0002-7812). ©2022. Printed in the United States of America. *ACerS Bulletin* is published monthly, except for February, July, and November, as a "dual-media" magazine in print and electronic formats (www.ceramics.org). Editorial and Subscription Offices: 550 Polaris Parkway, Suite 510, Westerville, OH 43082-7045. Subscription included with The American Ceramic Society membership. Nonmember print subscription rates, including online access: United States and Canada, 1 year $135; international, 1 year $150.* Rates include shipping charges. International Remail Service is standard outside of the United States and Canada. *International nonmembers also may elect to receive an electronic-only, email delivery subscription for $100. Single issues, January–October/November: member $6 per issue; nonmember $15 per issue. December issue (*ceramicSOURCE*): member $20, nonmember $40. Postage/handling for single issues: United States and Canada, $3 per item; United States and Canada Expedited (UPS 2nd day air), $8 per item; International Standard, $6 per item.

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ACSBA7, Vol. 101, No. 4, pp 1– 32. All feature articles are covered in Current Contents.

While the European Union is investing strongly in renewable energy sources and plans to introduce measures targeting transport and industry—where use of emissions-free energy sources is lagging—those efforts cannot help in the current situation.

Ceramics is not the only industry in Italy threatened by soaring prices—Venice glassblowers are struggling to keep their centuries-old tradition alive.

The origins of glassmaking in Venice go back to the Roman Empire, when molded glass was used for illumination in bathhouses. By the late 1200s, production of glass objects was the city's major industry. The industry experienced a series of ups and downs in the following centuries, but initiatives in the 19th century helped revive the art, and today the Italian island of Murano is again viewed as the "glassblowing capital of the world."

In January 2022, *The Washington Post* reported on the challenges that Murano glassblowers face due to the surge in natural gas prices. Unlike other industries that can simply turn off unused machines, glassblowers must maintain their furnaces at the required holding temperature 24 hours a day because shutting down and starting up again is a hugely expensive process.

"The cooling process cracks the crucibles—the clay vats in which glass is cooked. Both those and the fire-resistant bricks have to be replaced. It then

Credit: Business Insider, YouTube

Murano glassblowers Mariana Oliboni, left, and Chiara Taiariol create glass pieces in their workshop. They are two of the many Murano glassblowers struggling to keep their workshop alive.

can take two weeks to get back up to the right temperature," *The Washington Post* explains.

Though the Italian government set aside several billion euros to help curb energy bills, the current crisis in Ukraine has exacerbated the situation. "If the situation keeps going like this, we cannot continue for sure," Murano glassblower Chiara Taiariol states in a *Business Insider* interview. ■

National Science Foundation adds new directorate for the first time in more than 30 years

On March 16, 2022, the National Science Foundation announced the establishment of a new Directorate for Technology, Innovation, and Partnerships.

NSF is an independent agency of the United States government that was created by Congress in 1950 "to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences." NSF has undergone several major reorganizations as lawmakers sought to emphasize different areas of research. However, since the Directorate for Social, Behavioral, and Economic Sciences was established in 1991, NSF has maintained seven directorates, each subdivided into various divisions and offices that focus on a given area of science and engineering research and education.

Over the last 30 years, lawmakers and experts floated the possibility of creating more directorates in NSF, such as for materials science research. These proposals rarely advance beyond the idea stage, though, due in part to worries about diluting or unnecessarily complicating NSF's structure and purpose.

The genesis for the new directorate traces back to 2019, when Senate Majority Leader Chuck Schumer (D-NY) first spoke publicly about a proposal to have the federal government increase support for applied research.

Credit: National Science Foundation

The Directorate for Technology, Innovation, and Partnerships is the first new National Science Foundation directorate in more than 30 years.

This proposal came largely in response to concerns that the science and technology gap between the United States and the rest of the world—especially China—is closing fast.

In May 2020, Schumer and three bipartisan colleagues introduced the Endless Frontier Act, which proposed to establish a new Directorate for Technology within NSF. This act eventually became part of the Senate's U.S. Innovation and Competition Act (USICA), which was passed in June 2021.

While the Senate-proposed directorate focuses heavily on strategic technologies, the U.S. House of Representatives propose an alternate vision for the directorate in the COMPETES Act, their response to USICA. Passed in February 2022, the COMPETES Act urges that the new directorate should also address a range of societal challenges, such as climate change and economic inequality. It also emphasizes that the directorate should not lead NSF to lose focus on basic science, which has been the agency's focus since its founding.

In the final fiscal year 2022 funding package that Congress sent to Biden in March 2022, the Senate and House agreed to endorse the new Directorate for Technology, Innovation, and Partnerships (TIP), which NSF subsequently announced following passage of the funding package. However, the mission and scope of the directorate is still unclear as senators and representatives continue debating the different visions proposed in USICA and COMPETES. Nonetheless, there are a few activities of the new directorate that are settled matters. An FYI article outlines these knowns, which include

- The TIP directorate will assume responsibility for several existing programs, including the SBIR/STTR small business R&D programs, the Innovation Corps (I-Corps) entrepreneurial education program, and the "Convergence Accelerator" established as part of NSF's 10 Big Ideas for advancing multidisciplinary research.
- The TIP directorate will launch some completely new activities, including the recently announced Pathways to Enable Open-Source Ecosystems (POSE) program, which aims to expand the community of researchers who develop and use open-source tools and platforms, and a Regional Innovation Accelerators program, which will seed R&D hubs across the U.S. as part of the agency's efforts to expand its "geography of innovation."

As the Senate and House prepare for a conference committee to reconcile USICA and the COMPETES Act, a webpage for the TIP directorate is available at https://beta.nsf.gov/tip for readers to learn more and track the directorate's progress. ■

Fiber optic instrumentation market

By BCC Publishing Staff

The global market for fiber optic instrumentation was valued at $8.1 billion in 2020 and is estimated to grow at a compound annual growth rate (CAGR) of 8.8% to reach $13.7 billion in 2026.

Fiber optics is an emerging technology that uses strands of fiber made of glass or plastic to transmit information as pulses of light (Figure 1). The fiber optic instrumentation market is segregated based on instrument (Table 1), with fiber optic connectors dominating the market, accounting for nearly half (48.9%) in 2020. Different types of connectors include

- **Subscriber connector**, the most common type of connector. These connectors employ a ceramic ferrule to ensure precise alignment of the single-mode fiber.
- **Straight tip connector**, which are widely used in networking applications. These connectors have round ceramic ferrules and bayonet locking features.
- **Lucent connector**, a miniaturized version of the subscriber connector. This connector was designed for use in telecom environments by the now-defunct company Lucent Technologies, and it is frequently used when space is limited. There are two types of Lucent connectors on the market: behind-the-wall connectors and jumper connectors.

There is a high degree of competition in the fiber optic instrumentation market due to the presence of many companies that are producing this equipment. However, there is no significant differentiation in products between the companies, and they are being used for common applications (e.g., testing, inspection, transmission).

Asia-Pacific dominated the fiber optic instrumentation market in 2020, holding nearly 35% of the market share, followed by North America, with approximately 30% of the market share. In January 2021, China took measures to launch a cross-border fiber optic cable that stretches between China and Pakistan and will support an international telecommunication sector.

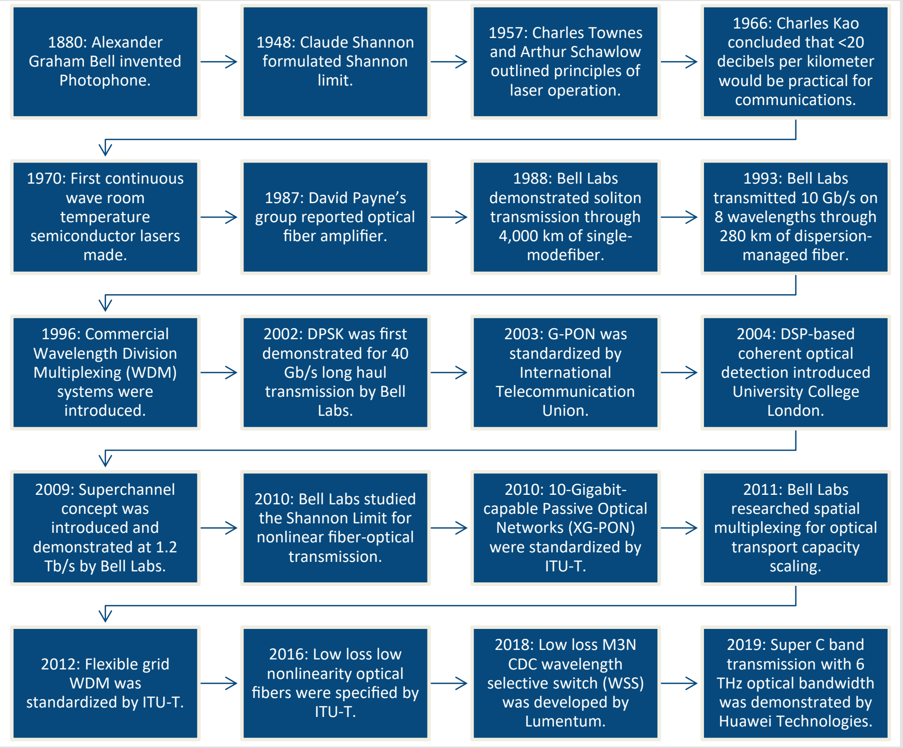


Figure 1. Fiber optics evolution.

Table 1. Global market for fiber optic instrumentation, by instrument, through 2026 ($ millions)

Application	2020	2021	2022	2024	2026	CAGR % (2021–2026)
Connectors	3,973.2	4,431.3	4,899.8	5,846.4	6,623.8	8.4
Sensors	2,921.2	3,286.8	3,676.9	4,528.3	5,431.5	10.6
Spectrum analyzers	347.8	366.8	383.1	434.4	461.2	4.7
Visual cable tracers and fault locators	211.8	224.5	242.2	271.3	292.0	5.4
Optical loss test sets	185.9	198.2	215.3	244.6	266.9	6.1
Optical time domain reflectometer	170.0	180.6	195.4	220.0	238.0	5.7
Power meters and light sources	143.5	152.3	164.6	185.0	199.7	5.6
Others	165.4	173.3	184.2	200.2	209.0	3.8
Total	8,118.8	9,013.8	9,971.5	11,930.2	13,722.1	8.8

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, "Fiber optic instrumentation market" BCC Research Report PHO040A, March 2022. www.bccresearch.com. ■

international year of glass

Each month, we will be highlighting articles from different areas of glass science in the online blog *Ceramic Tech Today*.

Glass for optical technologies

By John Ballato

It cannot be overstated how glass permeates virtually all aspects of modern life in ways other materials or material families do not. This ubiquity is a result of the richness of glass compositions and forming methods that have enabled an equally diverse range of glasses and forms.

From the earliest medieval windows to the first telescopes and microscopes to today's optical fibers that can carry light with intensities that exceed those on the surface of the sun, it is hard to separate the history of glass from the history of light-based technologies (see timeline: *A brief history of glass and light*). In honor of the International Year of Glass, this column celebrates this intertwined history by briefly discussing selected areas of the future impact of optical glasses.

Glass as a propagator

When it comes to optical technologies, amongst the greatest success stories are the billions of kilometers of (silica) optical fiber that circle the globe and connect nearly all her citizens. Indeed, glass as a carrier of light has enabled the Information Age, whose conveniences we now enjoy nearly all day, every day. But glass is not just in the fiber; glass is central to a great many forms of lasers and optical amplifiers, as well as in the planar waveguide devices that route the light around the optoelectronic chip. And these glasses are not just silica. Phosphate laser glasses, fluoride glass infrared lasers, and chalcogenide planar waveguides are all equally important for their specific purposes. One will see continued explorations and adoption of these glasses into future photonic and laser systems associated with laser fusion, on-chip optoelectronics, quantum computing and secured communications, as well as distributed optical sensors.

Glass as a protector

In addition to creating and propagating light, the transparency of glass is equally useful for windows, covers, bottles, and displays, applications where the glass

A brief history of glass and light

* Denotes recipients of various ACerS awards.

Stone Age (~4000–2000 BCE)
First glass known to early humans (obsidian, volcanic glass).

3500 BCE
Earliest known human-made glass (Egypt and Eastern Mesopotamia).

400 BCE
Plato's "emission theory" of vision: we see because our eyes emit vision beams.

399–300 BCE
Founding of Alexandria (331) accelerates development of glass production.

300 BCE
Euclid writes *Optica*. In it, he proposes that light travels in straight lines and provides mathematical formulae for reflection and refraction.

1610
Galileo improves telescope design and applies it to astronomy.
Kepler described a more practical telescope using a convex objective lens and a convex eyepiece.

1615
Willebrord Snellius describes what today is known as Snell's Law (though first described in 984 CE by Ibn Sahl).

1665–1676
Robert Hooke publishes *Micrographia* (1665). Antonie van Leeuwenhoek achieves 300 times magnification with a single lens microscope. Van Leeuwenhoek reports the existence of microorganisms (1676).

1668
Isaac Newton credited with building the first reflector.

1672
Newton uses a (glass) prism to demonstrate how white light is comprised of colors.

1673
Lead oxide added to potash glass, resulting in clear, heavy glasses that are ideal for cutting and shaping.

1801
Thomas Young experimentally supports Huygens's wave theory of light.

1842
Colladon and Babinet invent the "lighted laminar water fountain," which is based on total internal reflection.

1846
Carl Zeiss founds his microscope company.

1854
James Clerk Maxwell proposed the "Dynamical Theory of the Electromagnetic Field" and conjectures that light is a transverse electromagnetic wave.
John Tyndall formulates the ray picture of optical waveguiding.

1866
Ernst Abbe is hired by Zeiss and creates new microscope designs that lead to new types of (engineered) glasses.

1964
Nobel Prize in Physics for the maser/laser principle.
Snitzer* demonstrates the first fiber laser/amplifier.

1966
Kao* and Hockham propose that glass fibers could exhibit transmission lower than 20 dB/km.

1970
Corning breaks the "20 dB/km" loss mark.

1975
Discovery of fluoride glasses.*

1977
First live telephone traffic using optical fiber.

1986
Erbium-doped fiber amplifier (EDFA) reported.

1995
First photonic bandgap optical fiber.

2005
Experiments revived on what becomes Gorilla glass, which Corning had first begun developing chemically strengthened glasses in the 1960s.

2009
Kao* awarded Nobel Prize in Physics for glass optical fiber for communications.

transmits light or images and protects that which is inside from the outside. In the future, such uses of glass will become more prevalent based on continuing innovations, for example, chemical strengthening. Efforts to make thinner glass progressively stronger has broad applicability and will support a myriad of products, from covers for phones and tablets to automotive windshields to the glass vials employed for EpiPens and COVID-19 vaccines. Another area where glass acts as a form of protector is in numerous aspects of human health, such as in the growing area of optogenetics, which use glass fibers to optically control the behavior of cells.

Glass as a projector

Among the first glass-enabled optical technologies were telescopes and microscopes, where lenses permitted us to see objects both far away and small in size. Today, lenses and related glass-based optics remain critical to nearly all optical systems. Some of the most exciting aspects in modern physics rely critically on glass. For example, in the study of gravitational waves, glass beam splitters yield requisite interferometric beams used to detect gravitational waves—ironically, using light to see the dark. Another example of glass as projector are the glass fibers used in high energy/power laser systems. Whether for precision laser machining and manufacturing or directed energy defense applications, light–matter (glass) interactions at extreme intensities and the bounty of nonlinearities that result will be an area of important study and solution for many years to come.

Lastly, but only for reasons of space, is that benefits afforded by the natural diversity of glass compositions and properties beget a paradox of choice: of all these permutations of composition and processing, what glass does one use for an application? To answer this question, the power of artificial intelligence and machine learning will inevitably help crystallize selection. Applying data science to glasses and photonics drives us toward a symbiotic future in much the same way as the 2022 International Year of Glass reflects on the 2015 International Year of Light.

About the author

John Ballato is professor of materials science and engineering and director of the Center for Optical Materials Science and Engineering Technologies at Clemson University. Contact Ballato at jballat@clemson.edu. ■

100 BCE
Discovery of glass-blowing.

160 CE
Ptolemy writes about refraction and further expands the emission theory of vision.

982 CE
First recorded reference to Venetian glassmaking.

984 CE
Ibn Sahl writes *On burning mirrors and lenses*, which describes how curved mirrors and lenses work. He also discovers a law of refraction equivalent to Snell's law.

Ibn al-Haytham, (965–1040 CE) writes the *Book of Optics*, a seven-volume treatise on optics. Also develops the Intromissionist theory (1021 CE), which posits that vision occurs because light rays enter the eyes. He also proposes that magnification results from refraction and link magnification to glass curvature in lenses.

1200–1299
Sodium oxide added instead of potash (variety of potassium compounds), which now makes glass easier to form.

Venetian glassmaking moved to Murano (1291), due to risk of fire in Venice.

Earliest known use of (simple) microscopes resulting from more widespread use of glass lenses for eyeglasses.

1268
Earliest recorded comment on use of lenses for optical purposes. Roger Bacon uses glass spheres for magnification. Discovers light reflecting from objects and not being emitted by them.

1450
Cristallo glass invented, a very clear soda glass.

1590–1620
Earliest known examples of compound microscopes, combining an objective lens and an eyepiece. First telescope patent application (Hans Lippershey, 1608). Patent not awarded.

1604
Johannes Kepler describes how light is focused by the eye.

1888
Roth and Reuss use bent glass rods to illuminate inside the body.

1893
Adolph Winkelmann published on the "law of mixtures" for glass composition and properties, creating the foundation of modern glass science.

Otto Schott works with Zeiss and Abbe and collaborates with Winkelmann to extend the understanding of glass composition and optical properties.

1899
Max Planck's model for black body radiation and the postulation of quanta.

1900s
Soda-lime glass invented.

1905
Albert Einstein describes the photoelectric effect and establishes that light consists of quanta, later called photons.

1930
Heinrich Lamm first demonstrates imaging using glass bundles.

1932
Publication of Zachariasen's paper "The atomic arrangement of glass" and the first understanding of the amorphous structure of glass.

1933
First television signals optically transmitted using glass rods.

1952
Alastair Pilkington invents the float glass process for large scale production of flat glass.

1953
First maser built by Townes, Gordon, and Zeiger.

1960
Theodore Maiman demonstrates the first laser.

1961
Elias Snitzer* reports on the waveguide modes of cylindrical glass waveguides, fabricates a single mode fiber, and demonstrates the first bulk glass laser.

SOCIETY DIVISION SECTION CHAPTER NEWS

Welcome new ACerS Corporate Partners

ACerS is pleased to welcome its newest Corporate Partners

Sapphire Corporate Partner

Blasch Precision Ceramics

Corporate Partners

Jilin Changyou Advanced Materials Co., Ltd.

Lingl Installation & Service Co., Inc.

To learn about the benefits of ACerS Corporate Partnership, contact Kevin Thompson, industry relations director, at (614) 794-5894 or kthompson@ceramics.org. ■

Volunteer spotlight

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

Poerschkei

David Poerschke is assistant professor in the Department of Chemical Engineering and Materials Science at the University of Minnesota. He received his Ph.D. in materials from the University of California, Santa Barbara, and B.S. and M.S. degrees in materials science and engineering from Case Western Reserve University.

Poerschke is a member of the Engineering Ceramics Division and Basic Science Division. He is active in ACerS as chair of the Publications Committee, as a member of the Committee on Strategic Planning for Emerging Opportunities, and as a member of the Young Professionals Network steering committee. He regularly serves on symposium organizing committees for ACerS meetings and in organizing and facilitating ACerS networking and professional development events. He is presently the faculty advisor for the UMN Material Advantage student chapter.

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

Dayton/Cincinnati/Northern Kentucky Section: Dayton Dragons game

When: Sunday, April 24, 1 p.m.
Where: Dayton Dragons Stadium
220 North Patterson Blvd
Dayton, OH 45402

Tickets: Members: Free
Nonmembers: $10

RSVP at https://bit.ly/3tUZl8i by **April 6, 2022**. This is a joint event with the Dayton Section of the American Chemical Society. ■

Central Ohio and Dayton/Cincinnati/Northern Kentucky Sections co-host webinar: Funding opportunities with Department of Defense research grants

When: Thursday, May 5, 12:30–1:30 p.m.

The Department of Defense and 10 other federal agencies provide grants to support innovative research and technology development at small companies. The primary funding mechanism is the Small Business Innovation Research program.

This webinar will introduce the SBIR program, with a special emphasis on current research grant opportunities with the DoD. It will also introduce other tax-supported efforts to help Ohio manufacturers grow their defense-related business.

Register for this free webinar at https://ceramics.zoom.us/webinar/register/WN_AWfpc6oOS3enOefvP7s73A. ■

Carolinas Section: Tour, networking, and student poster session at University of North Carolina at Charlotte

When: Tuesday, May 10, 3–7 p.m.
Where: University of North Carolina at Charlotte
Duke Centennial Hall, Room 324
9330 Robert D. Snyder Rd
Charlotte, NC 28223

Agenda: 3 p.m. Welcome and tours of UNCC facilities
4 p.m. Carolinas Section business meeting
4:30 p.m. Student posters in Duke Hall lobby
5 p.m. Networking event in Duke Hall lobby

RSVP at https://forms.gle/yh7FL1K4fJpZwKc67 by **April 10, 2022**. The first 20 graduate or Ph.D. students to RSVP will receive a complimentary membership in ACerS Global Graduate Researcher Network. ■

ACerS president Beth Dickey to visit NoCal and SoCal Sections

ACerS president Beth Dickey will visit California this May. Dickey will first stop in Southern California on **May 2** to network and present "Point defect migration in metal oxides" at the California Institute of Technology.

The Northern California Section welcomes Dickey on **May 4**. She will again present and network with undergraduate and graduate students. The Section will offer tours of the laboratories of University of California, Davis professors Scott McCormack and Ricardo Castro.

Visit the Northern and Southern California Section webpages at https://ceramics.org/members/member-communities/sections for more details, including a complete agenda and registration details. ■

St. Louis Section seeks input on future activities and leadership

Section leadership is an opportunity to build your local network, sharpen your leadership skills, and grow within ACerS. The St. Louis Section encourages its members to share ideas regarding the future of the Section by completing a survey at https://www.surveymonkey.com/r/5F235VK. Your input is welcomed! ■

Spain Chapter sponsors Additive Manufacturing Symposium at the SECV Conference

The SECV Conference is scheduled for **May 3–6, 2022**. Visit the Spain Chapter webpage at https://ceramics.org/spain-chapter for more details. ■

Italy Chapter workshop: "The thousand lives of glass"

The Italy Chapter is planning "The thousand lives of glass" workshop, which will take place in Venice, Italy, on **May 20, 2022**.

This workshop (in Italian) is free and available to researchers, industries, and students interested in glass science and technology. The aim is to move innovative ideas on the use of glass out of the laboratories and toward commercialization. Visit the Italy Chapter webpage at https://ceramics.org/members/member-communities/international-chapters/italy-chapter-2 for more details. ■

more SOCIETY DIVISION SECTION CHAPTER NEWS

Names in the news

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


Goski

Dana Goski, FACerS, vice president of research & development at Allied Mineral Products, received the UNITECR Distinguished Life Member at UNITECR 2022 in Chicago, Ill. She is the first woman to receive UNITECR's highest honor.


Wu

Yiquan Wu, professor of ceramic engineering in the Inamori School of Engineering at Alfred University, was named an Inamori Professor. He is the fourth faculty member to receive this designation.

AWARDS AND DEADLINES

Division	Award	Nomination Deadline	Contacts
GOMD	**Alfred R. Cooper Scholars**	May 15	Steve Martin swmartin@iastate.edu
EDiv	**Edward C Henry**	May 30	Elizabeth Paisley eapaisl@sandia.gov
EDiv	**Lewis C. Hoffman Scholarship**	May 30	Elizabeth Paisley eapaisl@sandia.gov
ECD	**Jubilee Global Diversity**	July 1	Michael Halbig michael.c.halbig@nasa.gov
ECD	**Global Young Investigator**	July 1	Young-Wook Kim ywkim@uos.ac.kr
ECD	**James I. Mueller**	July 1	Hisayuki Suematsu suematsu@nagaokaut.ac.jp
ECD	**Bridge Building**	July 1	Palani Balaya mpepb@nus.edu.sg
EMSD	**Outstanding Student Researcher**	July 31	Yang Bai yang.bai@oulu.fi
BSD	**Graduate Excellence in Materials Science**	August 12	John Blendell Blendell@Purdue.edu

FOR MORE INFORMATION:

ceramics.org/members/awards

Ceramic Tech Chat: The Glass of Wine

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 second Wednesday of each month.

In the March episode of Ceramic Tech Chat, Jim and Penelope Shackelford, authors of the ACerS-Wiley book "The Glass of Wine," share how they developed a lifelong appreciation of wine, discuss the many intersections between winemaking and wine enjoyment that involve glass, and touch on how ceramics play a role in winemaking as well.

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

Description
Recognizes undergraduate students who have demonstrated excellence in research, engineering, and/or study in glass science or technology.
Recognizes an outstanding paper reporting original work in the *Journal of the American Ceramic Society* or the *Bulletin* during the previous calendar year on a subject related to electronic ceramics.
Recognizes academic interest and excellence among undergraduate students in the area of ceramics/materials science and engineering.
Recognizes exceptional early- to mid-career professionals who are women and/or underrepresented minorities (i.e., based on race, ethnicity, nationality, and/or geographic location) in the area of ceramic science and engineering.
Recognizes the outstanding young ceramic engineer and scientist whose achievements have been significant to the profession and to the general welfare of the community around the globe. Nominations are open to candidates from industry, academia, or government-funded laboratories around the world.
Recognizes individuals who, like James I. Mueller, have made contributions to the ECD and the field of engineering ceramics.
Recognizes individuals outside of the United States who have made outstanding contributions to engineering ceramics.
Recognizes exemplary student research related to the mission of the Energy Materials and Systems Division.
Recognizes the outstanding achievements of graduate students in materials science and engineering. It is open to all graduate students who are making an oral presentation in any symposium or session at MS&T.

more AWARDS AND DEADLINES

GOMD 2022 awardees

Stookey Lecture of Discovery
Herbert Gleiter, Karlsruhe Institute of Technology

George W. Morey Award
John Ballato, Clemson University

Norbert J. Kreidl Award for Young Scholars
Nagia S. Tagiara, National Hellenic Research Foundation

Darshana and Arun Varshneya Frontiers of Glass Science Lecture
Kathleen Richardson, University of Central Florida

Darshana and Arun Varshneya Frontiers of Glass Technology Lecture
Qiang Fu, Corning Incorporated

L. David Pye Lifetime Achievement Award
William LaCourse, Alfred University ■

MEMBERSHIP SPOTLIGHT

Haiku from a pandemic

Be Like Glass
Liquid or solid?
Frozen excess entropy
I still flow inside.

Silica for Ever
Formed after Big Bang
First silica tickling feet
Go infinity!

Fiat Lux
Swift arrow of time…
Photons slow down to stop cold.
Say – Let Newton be?

–Dr. Shanmugavelayutham Kamakshi Sundaram—aka "S.K." or "Shan"or "Sundaram"—is an Inamori Professor of Materials Science and Engineering at Alfred University and a literary writer whose thoughts turned to haiku during the pandemic. ■

STUDENTS AND OUTREACH

Students: Are you eligible for the GEMS award?

The Basic Science Division organizes the annual Graduate Excellence in Materials Science (GEMS) award to recognize the outstanding achievements of graduate students in materials science and engineering. The award is open to all graduate students making an oral presentation in any symposium or session at ACerS Annual Meeting at the Materials Science & Technology conference.

In addition to abstract submission, students must also submit a nomination packet to the chair of the GEMS Award Selection Committee, John Blendell, by **Aug. 12, 2022.** For further details, visit www.ceramics.org/GEMS. ■

An abundance of student opportunities available at MS&T22

There are many opportunities available at this year's ACerS Annual Meeting at MS&T. Make sure to sign up for the these student contests:

- Undergraduate student poster contest
- Undergraduate student speaking contest
- Graduate student poster contest
- Ceramic mug drop contest
- Ceramic disc golf contest
- Humanitarian pitch competition
- ...and MORE!

For more information on any of the contests or student activities at MS&T, visit www.matscitech.org/MST22, or contact Yolanda Natividad at ynatividad@ceramics.org. ■

CERAMICANDGLASSINDUSTRY FOUNDATION

The Ceramic and Glass Industry Foundation sponsors two special awards at the Future City National Competition

Future City is a project-based engineering education program that challenges middle-school students in the United States to imagine, design, and build cities of the future. Participants learn about the wonders of engineering, use the engineering design process to address civic and social issues, and become change-makers in their own communities.

This year's theme was "A Waste-Free Future." The Ceramic and Glass Industry Foundation sponsored two special awards for national-level competitors for innovative uses of ceramic and glass materials.

CGIF board members Jim Marra, Tim Powers, Bryn Snow, and Todd Steyer served as technical judges to award the student designs that best demonstrated how ceramic and glass materials are being used to create novel technological solutions that help solve sustainability issues, such as combating pollution, improving clean energy, reducing material waste, and applying environmental engineering principles.

We extend our congratulations to the team from Fulton Science Academy Private School in Alpharetta, Ga., for winning the Special Award for the Best Use of Ceramics in Technology and for Sustainability. Our judges thought the team did an excellent job of incorporating broad and innovative uses of ceramics throughout their city design and kept sustainability top of mind.

Additionally, we send congratulations to the team from The Ellis School in Pittsburgh, Pa., for winning the Special Award for the Best Use of Glass in Technology and for Sustainability. The team used glass and tidal sails for energy creation. Our judges were particularly impressed that they addressed the current societal problem of how to collect glass for recycling with their autonomous transportation pods.

Fulton Science Academy Private School in Alpharetta, Ga.

The Ellis School in Pittsburgh, Pa.

The CGIF continues to sponsor innovative programs such as the Future City Competition to help introduce more students to ceramic and glass science. If you would like to support the CGIF and their outreach efforts, visit ceramics.org/donate. ■

Toward the design of tunable ceramics: A review on vacancy ordering in substoichiometric zirconium carbide

In a recent open-access paper, ACerS member Theresa (Tessa) Davey, assistant professor at Tohoku University in Japan, and fellow Tohoku professor Ying Chen review the effects of vacancy arrangement on the properties of zirconium carbide.

Zirconium carbide is an ultrahigh-temperature ceramic that forms in a wide range of stable compositions with varying properties. The composition variation in zirconium carbide is facilitated by varying numbers of carbon vacancies in the material's structure.

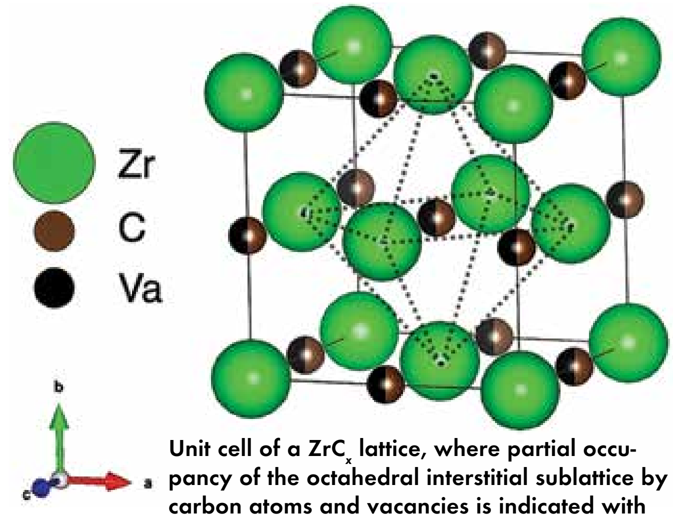
Much research has established that the number of carbon vacancies significantly affects the thermodynamic and thermophysical properties of zirconium carbide. However, while one may naturally expect that the arrangement of vacancies affects the properties as well, less is known about these effects due to the challenging nature of relevant experimental studies. Fortunately, recent theoretical considerations have helped advance understanding of these effects.

Mechanism of vacancy ordering

In early studies on zirconium carbide, much attention was given to the structure of unit cells within the material. These cells consist of a fully occupied face-centered cubic lattice containing zirconium atoms and a sublattice formed by octahedral interstitial sites containing a mixture of carbon atoms and vacancies.

The focus on short-range ordering led early studies to report zirconium carbide as a solid solution, or a material family that has a range of compositions and a single crystal structure. However, in 1967, Goretzki performed neutron powder diffraction on titanium–carbon and zirconium–carbon alloys of several compositions, and he observed the existence of a separate ordered zirconium carbide structural phase at low carbon concentrations.

Davey and Chen write that long-range ordering can explain this observation. "To form an ordered phase, the carbon atoms and the vacant sites of the octahedral interstitial lattice are arranged with long-range ordering, generating a superstructure where the repeating units may be larger than the parent rock salt unit cell or may have significantly different symmetry," they write.



Unit cell of a ZrC_x lattice, where partial occupancy of the octahedral interstitial sublattice by carbon atoms and vacancies is indicated with mixed-color atoms.

Following Goretzki's study, several groups tried to clarify zirconium carbide's structure and revealed further ordered phases in the process. In 1977, de Novion and Maurice reviewed the information related to short- and long-range ordering of vacancies in transition metal carbides. They determined that long-range ordering of vacancies was driven by short-range ordering, which in this case tended to avoid second nearest-neighbor vacancy pairs. Future theoretical works validated this early view.

Following Novion and Maurice's review in 1977, only a few more experimental studies on the structure of zirconium carbide were published in that decade before interest dropped off. No new experimental studies appeared in the literature until the 2010s, when interest in this material revived due to increased global initiatives toward developing nuclear fuel coatings for use in high-temperature gas-cooled reactors and hypersonic aviation. Theoretical studies began appearing in the literature as well, thanks to increasingly available, efficient, and accurate supercomputing resources.

The challenge with experimental studies

While theoretical studies have predicted several stable ordered phases, experimental observation of these phases remains limited. Davey and Chen state there are several possible explanations for this scarcity.

Hypothesis one: Synthesis temperatures are too high

Davey and Chen explain that during synthesis, zirconium carbide may be heated to about 2,000°C. However, at about 1,473–1,673°C, zirconium carbide experiences an order–disorder phase transition. Synthesizing the material above this transition temperature could lead to a disordered solid solution phase being frozen-in during quenching or cooling, rather than the ordered phases.

Synthesizing zirconium carbide at lower temperatures could address this issue. In 2019, Zhou et al. successfully synthesized zirconium carbide at 1,300°C.

Research News

Toward high-powered telecommunication systems

Researchers from Harvard University and Freedom Photonics and HyperLight Corporation developed the first fully integrated high-power laser on a lithium niobate chip. The lasers sit in small wells or trenches etched into the lithium niobate and deliver up to 60 milliwatts of optical power in the waveguides fabricated in the same platform. This chip is a building block that can be integrated into larger optical systems for a range of applications. For more information, visit https://www.seas.harvard.edu/news.

Hypothesis two: Significant amounts of impurities

Significant amounts of impurities, such as nitrogen and oxygen, commonly occur in experimentally synthesized zirconium carbide and may affect vacancy ordering. "However, precise characterization of impurity concentration in zirconium carbide is notoriously challenging, which can mean that impurity concentrations are not accurately reported," Davey and Chen write.

Further modeling studies could help identify processing parameters that mitigate the chance of impurities.

Hypothesis three: Composition too close to stoichiometric zirconium carbide

Carbon (or vacancy) diffusion in zirconium carbide is influenced by the vacancy composition—carbon diffusivity increases with higher vacancy concentration, and vice versa. "This offers a further possible explanation for the limited observances of other ordered phases closer to stoichiometric zirconium carbide [where vacancy concentration is lower]," Davey and Chen write.

Hypothesis four: Ordered phases affect each other

Currently, knowledge of all possible ordered phases is extremely limited, but it is theoretically feasible that a nonstoichiometric ordered phase may destabilize other predicted phases and prevent them from forming. "This, once again, offers a potential explanation for why Zr_2C is the only consistently observed superstructural phase," Davey and Chen write.

Next steps

Davey and Chen conclude the review by noting that experimental and theoretical studies to date confirm that vacancy arrangement as well as vacancy concentration significantly affect the thermophysical properties of zirconium carbide. However, the elastic and mechanical properties show conflicting results among different studies and thus require further work for clarification.

They suggest a few directions future research could take, including

- **Experimentally confirm predicted stable structures**: Recent theoretical work provides threshold values for temperature and impurity content that could assist in this area.
- **Clarify the cause of variations in thermophysical properties**: Some researchers have suggested these variations may be understood by considering the arrangements of vacancies and their pair cluster, although further work is needed to validate this hypothesis across all properties.
- **Further explore short-range ordering behavior at high temperatures**: The strong energetic preference for certain pair configurations in short-range ordering could explain why particular stoichiometries have such high melting points if the preference persists at high temperatures.

The open-access paper, published in *International Journal of Ceramic Engineering & Science*, is "Vacancy ordering in substoichiometric zirconium carbide: A review" (DOI: 10.1002/ces2.10126). ■

Electrodynamic fragmentation could provide high-quality recycled materials for the refractory industry

Researchers at the Fraunhofer Institute for Building Physics in Germany explored the potential of electrodynamic fragmentation to recover high-quality recycled materials for the refractory industry.

Electrodynamic fragmentation, which was first investigated and described by Russian scientists in the late 1940s, uses pulsed high-voltage discharges to separate bulky multiphase material selectively along grain boundaries. Compared to mechanical separation processes, electrodynamic fragmentation does not generate abrasion and thus no dust or other contamination.

Since 2012, Volker Thome, head of the Department of Inorganic Materials and Recycling at Fraunhofer IBP, has led experiments using electrodynamic fragmentation to recycle waste concrete, carbon fiber-reinforced polymers, and municipal waste incineration ash. In the recent open-access paper, two of Thome's frequent collaborators—Severin Seifert and Sebastian Dittrich of Fraunhofer IBP—worked with independent researcher Jürgen Bach to explore the applicability of electrodynamic fragmentation to refractory waste.

They chose refractory waste samples from three different fields of application for the experiment—highly sintered brick for sintering or rotary kilns (RefMat-1); corundum stone for melting tanks (RefMat-2); and functional refractory ceramic from the steel industry (RefMat-3).

These samples were selected to determine the effectiveness of electrodynamic fragmentation at separating materials exposed to different temperatures, as "higher temperatures lead to a stronger sintering of the individual components, which makes it considerably more difficult to process or cleanly separate," they explain.

They began by crushing the samples into small pieces, about 4–5 cm each, and processed them to determine the optimal fragmentation parameters for each material. They then used these optimal parameters to fragment 20–32-kg batches of each of the three samples.

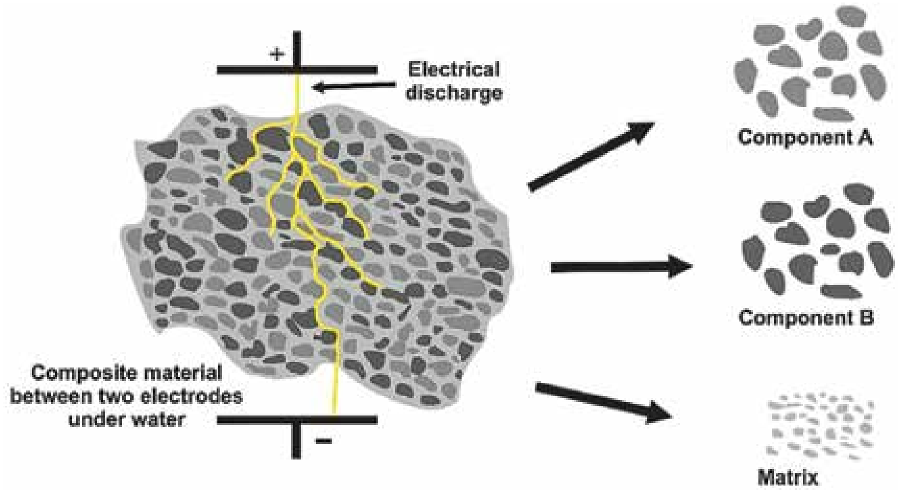


Illustration showing electrodynamic fragmentation of a composite material. This process takes place underwater to enable pulsed high-voltage discharges to penetrate the composite, which then separates selectively along grain boundaries.

The researchers found they could use optical sorting to categorize the various materials separated out during the fragmentation process. Only the white corundum from sample material RefMat-3 could not be sorted out because the color differences compared to the matrix material were too small.

Analysis of the separated and sorted materials revealed a very clean surface that was almost completely free of binder residues and other adhesions. Additionally, comparison of the chemical composition with original raw materials showed almost no observable differences.

After confirming the chemical similarity, the researchers fabricated new refractory ceramics using the recovered materials. The processing properties and mechanical tests of the recycled refractories did not show any adverse effects.

"However, no testing of the newly developed refractory material under working conditions (e.g., lining in an aluminum melting furnace) has been taken place so far. Thus, the material must be checked for further aspects such as corrosion resistance, thermal shock resistance and abrasion resistance," they write.

Sample material RefMat-3 before (center) and after fragmentation and subsequent classification by grain size.

The researchers conclude that electrodynamic fragmentation may be a promising alternative to existing recycling technologies. "However, further research and development work is needed to make a recycling process for refractory materials economically realizable on an industrial scale," they write.

Based on this study, the researchers applied for a patent titled "Method for recycling ceramics, regenerated materials obtained thereby, and use of the regenerated materials for manufacturing ceramics."

The open-access paper, published in *Processes*, is "Recovery of raw materials from ceramic waste materials for the refractory industry" (DOI: 10.3390/pr9020228). ■

ceramics in energy

DOE funds projects to reduce waste from and sustain future deployment of advanced nuclear reactors

On March 10, 2022, the U.S. Department of Energy announced $36 million for 11 projects seeking to increase deployment and use of nuclear power and limit the amount of waste produced from advanced nuclear reactors.

"Developing novel approaches to safely manage nuclear waste will enable us to power even more homes and businesses in America with carbon-free nuclear energy," U.S. Secretary of Energy Jennifer M. Granholm says in the press release.

The Advanced Research Projects Agency–Energy (ARPA–E) is funding the projects through the Optimizing Nuclear Waste and Advanced Reactor Disposal Systems (ONWARDS) program. This program, which was unveiled last year, is ARPA–E's first focused program to identify and facilitate technologies for advanced research on used nuclear fuel recycling, waste forms, disposal pathways, and associated advanced safeguard technologies.

Among the 11 projects, two stand out for their focus on ceramic-based solutions.

Rutgers University (New Brunswick, NJ): Pioneering a cermet waste form for disposal of waste streams from advanced reactors

The Rutgers-led project, which includes ACerS Fellow and Alfred University professor S.K. Sundaram, will deliver a simple, scalable route for turning used nuclear fuel into a high-density, durable cermet waste form (a heat-resistant ceramic and metallic composite).

Award amount: $4,000,007

Citrine Informatics (Redwood City, CA): Novel phosphate waste forms to enable efficient dehalogenation and immobilization of salt waste

Materials informatics platform Citrine Informatics will use artificial intelligence and physics-based simulation methods to develop novel phosphate waste forms (including glasses, ceramics, and their composites) to enable dehalogenation (removal of halides) and more secure immobilization of salt waste from molten salt reactors.

Award amount: $3,103,770

Further details on the 11 projects are available at https://bit.ly/3KB8JDW. ■

Sequoyah Nuclear Power Plant in Tennessee.

Credit: Photorush, Wikimedia (CC BY-SA 3.0)

Harnessing artificial intelligence and machine learning to design new glasses

Credit: Michael Dziedzic, Unsplash

By Eileen De Guire

An interview with Mathieu Bauchy and John C. Mauro on the current progress in harnessing artificial intelligence and machine learning to design new glasses and how these techniques may develop in the future.

Mathieu Bauchy

John C. Mauro

In the past 30 years, significant and sustained development has advanced artificial intelligence to a point that it is beginning to demonstrate its potential in research and industry.

Artificial intelligence is the ability of a computer to mimic human cognitive functions, such as problem solving or decision making. Machine learning, a subset of AI, is the application of artificial intelligence to address a specific problem without direct instructions from the programmer.

AI and ML offer a completely different paradigm for designing new processes and materials compared to traditional programming. Before, a researcher needed to explicitly develop a series of fixed instructions to achieve a given task. Now, researchers "train" the computer program with a set of data, and it will evolve the algorithm to perform the task.

Glass researchers are particularly interested in harnessing AI and ML for materials development. With nearly the entire periodic table to select from, vast possibilities exist for potential glass compositions. AI and ML can identify the most promising compositions much more quickly than traditional lab-based trial-and-error experiments.

John C. Mauro and Mathieu Bauchy are two researchers exploring the use of AI and ML in glass research. Mauro is professor of materials science & engineering and associate head for graduate education at The Pennsylvania State University. Bauchy is associate professor of civil and environmental engineering at the University of California, Los Angeles. In an interview with ACerS *Bulletin* editor Eileen De Guire, they discuss the current progress in harnessing AI and ML to design new glasses and how these techniques may develop in the future.

Q. *What methods are currently used for modeling new glasses, and what benefits do AI and ML offer over these traditional techniques?*

[JCM]: Physics-based models are the preferred option whenever possible, because they are more likely to give accurate extrapolations to new composition spaces and can also provide helpful new physical insights. However, for many properties or glass compositional families, physical models may be too difficult to derive. Hence, there is a need for data-driven modeling approaches. Many glasses exhibit nonlinear composition–property relationships, which can be difficult to capture with simple regression models. Machine learning gives the opportunity to capture these complicated nonlinear relationships to aid in the design of new glass compositions.

[MB]: These are all good points. I would add that traditional models are often limited by our own experience, knowledge, and intuition. Because computers are not limited by any biases, the hope is that, by unveiling some previously hidden patterns in datasets, machine learning models could lead to discovery of new types of glasses that were previously thought to be impossible, for example, "unbreakable" glasses.

Q. *What types of AI and ML techniques are most useful for predicting glass compositions?*

[JCM]: It depends on the problem under study. So far, I would say that neural networks are the most commonly used approach for developing machine learning-based models for glass composition–property relationships.

[MB]: Agreed; artificial neural networks tend to be the method of choice because they are flexible enough to offer a one-size-fits-all solution to many types of problems. However, neural networks can often be outperformed by gradient-boosted decision tree models—but these models are challenging to tune. One should also keep in mind that many problems do not require complex neural networks and can actually more effectively be solved with simple linear or polynomial regression methods.

Q. *Are there barriers or limitations to using these techniques?*

[JCM]: The biggest barrier is the availability of a sufficient quantity of high-quality data for use in training the machine learning models. Glass melting and characterization is a time-consuming and expensive process, which limits the amount of data that can be obtained to build the models. This limitation becomes even greater for many-component systems because each new component added to the glass increases the dimensionality of the problem by one. Hence, we almost always must deal with the problem of sparse data, especially for many-component glass systems.

[MB]: I would also add that, in practice, developing a machine learning algorithm to accelerate the discovery of new glasses requires a combined expertise in glass and computer science. This requirement is a challenge because traditional siloed education programs rarely expose materials science students to artificial intelligence, or computer science students to materials research. There is a need to develop new programs that train multidimensional engineers who are well versed in materials and computer science.

Q. *Are these AI and ML techniques limited to designing new compositions, or can they be used, for example, to develop new manufacturing processes? Which area offers the greater gains from an industrial perspective?*

[JCM]: Machine learning can also be used for process optimization, market forecasting, and even human resource management. Anytime there is a large amount of data available, machine learning can be used to find correlations between a set of input conditions and output results. The main limitation for machine learning is that it cannot be used to discover something totally new, i.e., something completely outside the domain of data used to construct the model. Within the realm of process engineering, machine learning can be used to help optimize current processes, but it cannot be used to develop a completely new process. The human mind is still vastly superior to artificial intelligence for anything that involves creative "outside-the-box" thinking. Machine learning is, by its very nature, a form of "inside-the-box" thinking.

[MB]: Agreed. Machine learning is not limited to the discovery of new glasses. In fact, there is much promise in the emerging concept of "digital twin" in manufacturing (or digital replica). The idea is that, with sufficient data, one can develop a surrogate model that virtually replicates real-world components in a manufacturing process. This model makes it possible to test the effect of certain process adjustments within the digital twin, which allows researchers to predict how the real-life manufacturing process would be affected by such changes, without the need to actually deploy these adjustments. This approach has the potential to dramatically accelerate the optimization of manufacturing processes, which typically relies on time-consuming trial-and-error experiments.

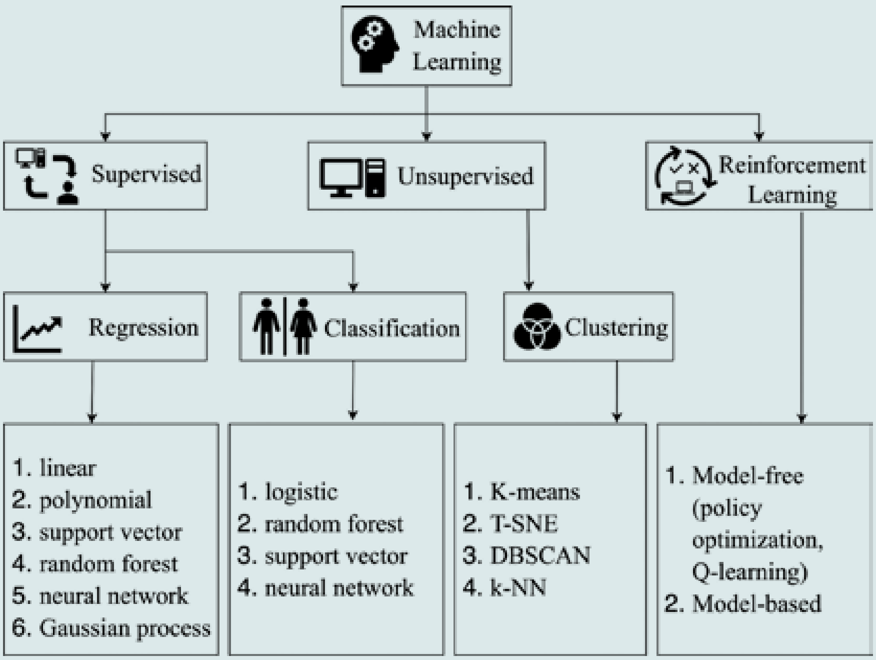
Q. *Have glass scientists mainly adapted AI and ML techniques in other fields for their own purposes, or are there novel techniques developed specifically for glass science?*

[JCM]: Thus far, glass scientists have mainly applied already existing machine learning methods to our specific problems, rather than developing entirely new AI-based approaches.

[MB]: Agreed, but I think that, going forward, new techniques that are tailored to materials will need to be

Harnessing artificial intelligence and machine learning to design new glasses

Basic machine learning paradigm



Machine learning approaches are broadly classified into three types: supervised, unsupervised, and reinforcement learning. Supervised learning involves an algorithm that "learns" a function that maps input information to an output using "training" data. Unsupervised learning seeks to uncover hidden, unlabeled patterns in data. Because the algorithm does not map onto an output, the approach is "unsupervised." Reinforced learning is more useful in systems applications, such as robotics or high-throughput laboratory techniques, and is not used much for glass or materials science applications.[1]

The four boxes across the bottom list the algorithms that execute the machine learning functions.

Credit: Venugopal et al., IJAGS

developed. Most of the state-of-the-art deep learning methods are designed to handle very large datasets comprising millions of datapoints and do not necessarily perform well on sparse materials datasets comprising only a few hundreds of datapoints. Present machine learning approaches are often not tailored to materials, for example, in terms of structure representation, limited number of datapoints, importance of uncertainty quantification, focus on inverse design. There are also many opportunities to develop physics- or chemistry-informed machine learning models that simultaneously leverage data and knowledge.

Q. *Are there any commercial products that were developed using AI and ML techniques?*

[JCM]: Yes, absolutely. But machine learning is never used on its own. Machine learning is one tool in a larger toolbox that can help us with the design of new glass compositions. Machine learning can be used most effectively when it is combined with experimental insights and physics-based models. This combined approach provides a highly effective and efficient means for designing new glass compositions, including commercial products. Ultimately, the model-predicted glass compositions still need to be reduced to practice in experiments.

[MB]: Although glass manufacturing companies rarely advertise the details of their internal research and development processes when launching new products, there are definitely some success stories where machine learning enabled the design of new commercial materials. For instance, the Concrete-AI platform (http://www.concrete-ai.com) led to the development of new ready-mix concrete commercial formulations featuring a decrease in cost and carbon footprint of 10% and 50%, respectively, as compared to previously used formulations, while achieving similar performance.

Q. *What is the most pressing need to advance the use of AI and ML techniques to the next level for the R&D of commercially important glasses?*

[JCM]: We need greater community organization around data management, especially having a common database where everyone can contribute data and freely access the full archive of data for modeling purposes.

[MB]: Agreed; the lack of curated datasets that are accessible, complete, self-consistent, and well populated is clearly the main bottleneck at this point.

Q. *Are there resources, such as databases, designed for glass that AI and ML researchers can use or contribute to?*

[JCM]: GlassPy is an open source Python database created by Daniel Cassar. GlassPy is available at https://github.com/drcassar/glasspy. PyGGi is a commercial Python code by Anoop Krishnan for performing machine learning modeling of glass composition–property relationships. PyGGi is available at https://pyggi.iitd.ac.in/about.

Q. *As more materials scientists use AI and ML techniques to advance their respective fields, does that translate into the courses taught to materials science students? For example, are more computer science courses being required or are universities developing courses that specifically focus on computational methods for materials science?*

[JCM]: Computational materials science courses are now being taught as electives at the undergraduate and graduate levels. These courses cover a wide range of computational approaches but do not focus exclusively on machine learning. Students can also take elective courses specific to machine learning, e.g., from computer science or data science departments. There is also a trend of incorporating more computation into core materials science courses so that students can develop some elementary programming and modeling skills as a core part of the curriculum.

[MB]: Such transversal courses are very needed and typically appreciated by students. For anybody who would be interested in learning more, I developed a course on artificial intelligence and machine learning for engineers at UCLA. All lecture videos are freely available online at https://bit.ly/3Lq4pre. I also offer a short course through ACerS (https://ceramics.org/ML-for-glass-science), which is a great introduction to the topic, especially for graduate students at the beginning of their programs.

Q. *What other fields or disciplines would be able to collaborate with glass researchers to advance the art of computational glass science?*

[JCM]: When it comes to computational glass science, we have a lot of common interests with several other disciplines, including physics, chemistry, chemical engineering, and nuclear engineering. There is also a lot of value in collaborating with computer scientists, who can offer advances to the computational techniques themselves.

[MB]: Yes, I think there is a lot of value in collaborating with computer scientists, who may not be familiar with the unique challenges associated with the application of machine learning to material-related problems.

Q. *What excites you about the future of AI and ML applied to glass?*

[JCM]: As someone with a dual background in glass science and computer science, it excites me to see how effectively these two fields have come together to offer powerful solutions for problems of technological interest. An exciting next step will be the application of these approaches to the design of glass-ceramics, including use of convolutional neural networks to analyze microstructural image data and link that data to mechanical and optical properties.

[MB]: What excites me the most is the opportunity offered by the integration of theory, numerical simulations, and machine learning, wherein all the approaches learn, inform, and advance each other. There are also a lot of exciting developments in robotics and "self-driving" laboratories where new materials could be discovered in a high-throughput fashion without any human intervention.

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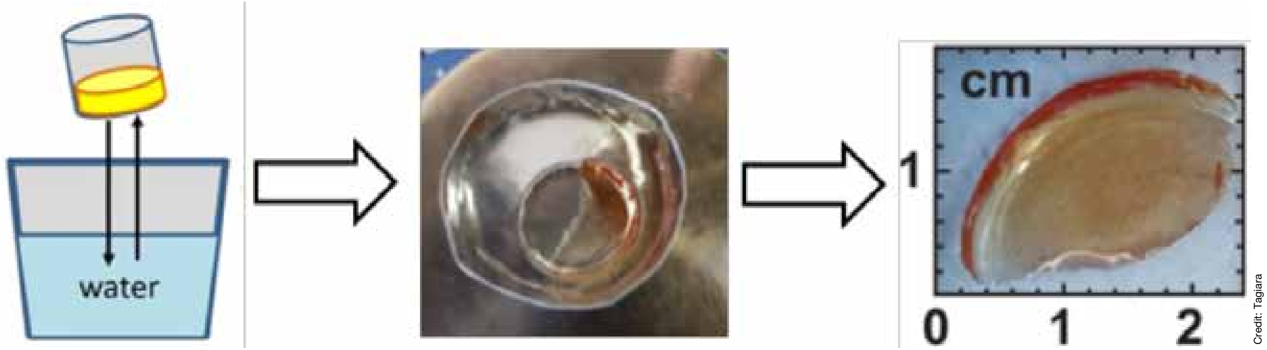

Figure 1. Schematic presentation of the intermittent quenching technique for synthesis of pure TeO_2 glass.

Synthesis, structure, and properties of pure TeO_2 glass and tellurite glasses

By Nagia S. Tagiara and Efstratios I. Kamitsos

Tellurium dioxide-based glasses attract special interest due to their exceptional properties like low melting temperatures, good infrared transmittance, high refractive index, and high third-order optical nonlinearity.

Despite its high tendency for crystallization,[1,2] TeO_2 glass can be formed by quenching melts from alumina crucibles[3–6] and by rapid quenching from platinum crucibles using the twin-roller technique.[7] The first method easily produces glasses in large sizes, while the second method produces glass flakes used in neutron diffraction studies. Physical properties of tellurite glasses melted in alumina crucibles[3–6] differ drastically from those melted in platinum crucibles.[7,8]

In this research, we report on the synthesis of pure TeO_2 glass in gram quantities using a newly developed technique. The goal is to synthesize pure tellurite glasses, to probe the evolution of structure and physical properties with composition, and to understand structure–property correlations.

A new technique for synthesizing pure TeO_2 glass

The new synthesis method is based on an intermittent quenching (IQ) technique.[9] It involves melting polycrystalline TeO_2 in a platinum crucible and then dipping the bottom of the crucible containing the viscous melt into room temperature water several times (Fig. 1). This procedure results in monolithic pieces of pure TeO_2 glass with approximate dimensions of 2.5 cm × 1.5 cm × 2 mm, based on the size of the platinum crucible used (~20 cm³).

TeO_2 glass synthesized by the IQ-technique has glass transition temperature (T_g=303°C) and density (ρ=5.62 g/cm³) values[9,10] that are well outside the ranges for glasses melted in alumina crucibles (T_g=320–385°C, ρ=4.8–5.10 g/cm³).[3–6] These differences are due to the leaching of Al_2O_3 from the alumina crucible, as found by Raman spectroscopy.[9,10]

The structure of TeO_2 glass was studied further by infrared and Raman spectroscopy, and density functional theory calculations on $(TeO_2)_6$ and $(TeO_2)_{12}$ clusters. Among many studied stable conformers, closed and nonsymmetric structures were optimized without Te=O double bonds.[11] The $(TeO_2)_{12}$ cluster in Fig. 2 (left) gives calculated IR and Raman spectra in very good agreement with the experimental spectra (Fig. 2, right). Also, the calculated total pair distribution function is in agreement with results of neutron[7] and high-energy X-ray[12] diffraction studies. The $(TeO_2)_{12}$ cluster consists of TeO_4 trigonal bipyramid units connected by asymmetric and nearly symmetric Te–O–Te bridges, as in γ-TeO_2, and involves edge-sharing of TeO_4 units by double-oxygen Te–O_2–Te bridges, as in the β-TeO_2 polymorph. The optimized $(TeO_2)_{12}$ cluster is slightly unstable compared to the calculated global minimum structure, suggesting a kinetically stable product similar to its corresponding lab-made TeO_2 glass. Clusters with Te=O bonds were studied as well and found to give Raman and IR activity above 850 cm⁻¹ due to the stretching of Te=O bonds; the absence of such vibrational activity from the measured spectra shows that no Te=O bonds are present in pure TeO_2 glass.

Binary and ternary tellurite glasses

The work was extended to binary and ternary tellurite glasses xZnO–(1–x)TeO_2 ($0 \le x \le 0.50$), $y$$Al_{2/3}O$–(1–$y$)$TeO_2$ ($0 \le y \le 0.43$), and $z$$R_{2/3}O$–(0.30–$z$)ZnO–0.70$TeO_2$ (R=Al, B and $0 \le z \le 0.30$).[10] Glasses were prepared by melting in platinum crucibles and investigated for correlations between structure and thermal as well as mechanical properties. The properties measured are glass transition temperature (T_g), density (ρ), ultrasonic velocities, atomic packing density, elastic moduli, and Poisson's ratio (σ).

Representative Raman spectra are shown in Fig. 3 (left) for glasses xZnO–(1–x)TeO_2 ($0 \le x \le 0.50$).[9] The observed spectral changes upon doping with ZnO are attributed to the progressive conversion of TeO_4 trigonal bipyramid units to TeO_{3+1} polyhedra with two terminal oxygens, and finally to TeO_3 trigonal pyramids with three terminal oxygens (x=0.50). This progressive depolymerization of the tellurite network is reflected in the composition dependence of properties like Poisson's ratio, which increases in the range $0.25 \le \sigma \le 0.27$ for $0 \le x \le 0.35$ (Fig. 3, top right).

A Raman study of glasses $y\mathrm{Al}_{2/3}\mathrm{O}$–$(1-y)\mathrm{TeO}_2$ showed that part of the added Al_2O_3 does not modify TeO_2; instead, it builds AlO_n polyhedral, which crosslink the TeO_4 and TeO_3 units through Te–O–Al bridges.[10] This structural crosslinking decreases Poisson's ratio from σ=0.25 (y=0) to σ=0.23 (y=0.3) (Fig. 3, top right), and leads to the fast increase of T_g with Al_2O_3 (Fig. 3, bottom right). Compared to Al_2O_3, ZnO increases T_g at a smaller rate (Fig. 3, bottom right) because of the weaker crosslinking ability of ZnO_4 units.

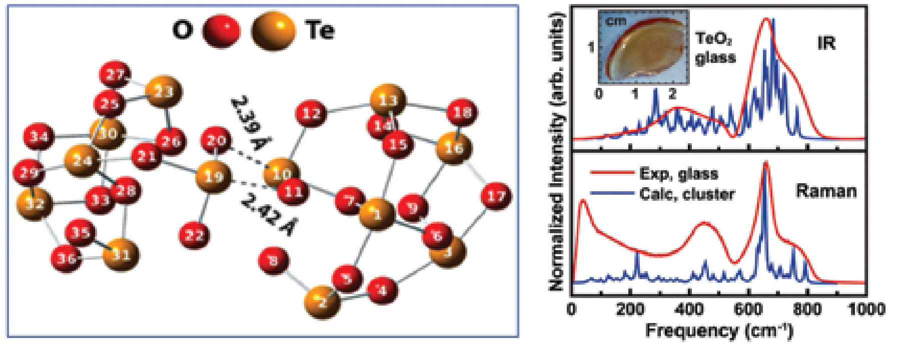

Figure 2. (left) A $(TeO_2)_{12}$ cluster structure without Te=O double bonds. (right) Calculated infrared (in blue, top) and Raman (in blue, bottom) spectra of the $(TeO_2)_{12}$ cluster, in comparison with the experimental infrared and Raman spectra (in red) of pure TeO_2 glass developed by the IQ-technique. Reprinted with permission from Reference 11. Copyright 2020 American Chemical Society.

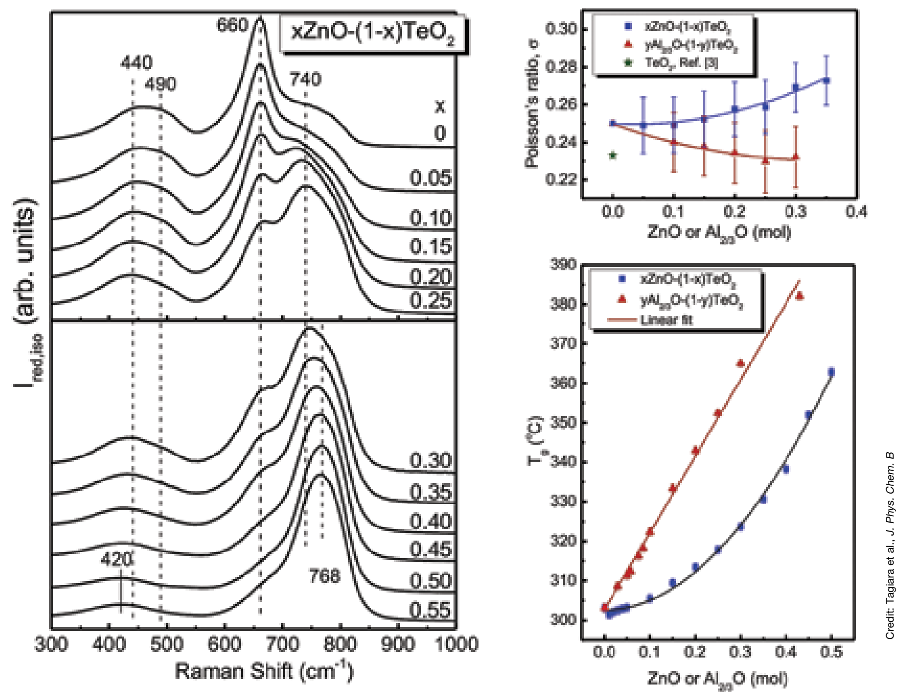

Figure 3. (left) Reduced isotropic Raman spectra of glasses $x\mathrm{ZnO}$–$(1-x)\mathrm{TeO}_2$ for x=0–0.55. Poisson's ratio (right, top) and glass transition temperature (right, bottom) for glasses $x\mathrm{ZnO}$–$(1-x)\mathrm{TeO}_2$ and $y\mathrm{Al}_{2/3}\mathrm{O}$–$(1-y)\mathrm{TeO}_2$. The point indicated with the green star in the top right figure gives the literature value of Poisson's ratio for TeO_2 glass melted in alumina crucible,[3] and reflects the doping of TeO_2 with Al_2O_3 leached from the crucible. Reprinted with permission from Reference 10. Copyright 2019 American Chemical Society.

Conclusion

In summary, the structure and properties of the studied tellurite glasses are controlled by the effect of ZnO, Al_2O_3, and B_2O_3 on (a) the crosslinking of the tellurite structural units (Al_2O_3 > ZnO > B_2O_3), (b) the bonding strength of the glass network (B_2O_3 > Al_2O_3 > ZnO), and (c) the atomic packing density of glass (B_2O_3 > Al_2O_3 ≈ ZnO). Factor (a) directly affects T_g, and factors (b) and (c) affect mainly the elastic properties of glass (e.g., Young's modulus). For example, glasses $z\mathrm{B}_{2/3}\mathrm{O}$–$(0.30-z)$ZnO–0.70$\mathrm{TeO}_2$ have the largest atomic packing density and exhibit the steepest increase of Young's modulus with T_g among the studied tellurite glass systems.

Acknowledgements

The authors gratefully acknowledge Anastasios G. Papadopoulos for his help with DFT calculations.

About the authors

Nagia S. Tagiara conducted her Ph.D. studies at the National Hellenic Research Foundation in Athens, Greece, under the supervision of Efstratios I. Kamitsos. Contact Tagiara at ntayara@eie.gr.

Editor's note

Tagiara will present the 2022 Kreidl Award Lecture at the Glass & Optical Materials Division Annual Meeting on May 24, 2022. Learn more about the conference at https://ceramics.org/gomd2022.

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National Day of Glass Conference celeb

April 5–7, 2022 | Washington, DC

The National Day of Glass Conference (NDGC) kicked off North American-based celebrations of the United Nations International Year of Glass.

Planning for NDGC began almost immediately after the U.N. announced the 2022 International Year of Glass last May. The U.N. has declared International Years since 1959 to highlight industries, concepts, or ideals that promote its objectives, and IYOG marks the first time the U.N. has recognized a material with the International Year designation. Glass has been identified as having a role in addressing 11 of the UN's 17 sustainability goals.

"It was an incredible few days of celebrating all things glass. By welcoming a range of leaders from all sectors of our glass community, we were able to share diverse perspectives on the rich history and promising future that glass has in our world," says Kathleen Richardson, lead organizer.

The program was designed to showcase the impact of glass—past, present, and future—and was envisioned as a celebration of glass science, technology, engineering, education, and art.

Kathleen Richardson opens the National Day of Glass Conference, April 5–7, 2022, in Washington, D.C.

Corning International CEO Wendell Weeks set the tone for the conference by focusing on four key attributes of glass: stability, strength, interaction with light, and impermeability. Weeks artfully wove human history and scientific advances to show the impact of glass on the arc of human progress. One striking example was the development of transparent, colorless glasses with improved stability, which led to the development of eyeglasses and more reading after the printing press was invented. Glass enabled the growth of an educated population and the spread of ideas.

In another example, the British were at war in the early 17th century and conscripted all wood for shipbuilding. Glassmakers turned to coal as a fuel source and found that the hotter furnace temperatures allowed them to make bottles with higher silica content. These stronger bottles turned out to be perfect containers for the new bubbly wines developed by French winemakers in the Champagne region. "Talk about glass being essential to human progress!" says Weeks.

Other examples familiar to this audience included Gorilla Glass, optical fibers, and pharmaceutical packaging—all of which point to the impact of glass on the

Corning International CEO Wendell Weeks set the tone with his talk, "Glass—Vital to our future."

everyday as well as the extraordinary moments of life.

Thought leaders from government—NSF, DOE, DARPA—talked about the innovation enterprise, which integrates government investment, open science policies, and workforce development. Kelvin Droegemeier, Regents' Professor of Meteorology and Teigen Presidential Professor at Oklahoma University, with nearly two decades of experience working in government (former director of the White House Office of Science and Technology Policy and former acting director of the National

Corning's Chris Heckle leads a panel discussion of leaders from academia, art, and industry. Panelists from left: Himanshu Jain, Lehigh University; Judith Schaechter, Tyler School of Art, Temple University; Anuradha Agarwal, Massachusetts Institute of Technology; Scott Cooper, Owens-Illinois; Jacquelyn Fetrow and Adele Schade, Albright College.

Science Foundation), introduced the notion of finding the "missing millions" of talent hidden in areas of the United States often outside the mainstream flow of opportunity, but whom it would behoove the nation to engage with resources and opportunity.

Top executives from Owens-Illinois, Schott Glass, AGC, Nippon Electric Glass Fiber America, and entrepreneurs raised the importance of sustainability in their supply chains and manufacturing processes. It was frequently noted that glass is infinitely recyclable but often poorly recycled, especially in the U.S.

Three panel discussions were at least as stimulating as the talks. The panels comprised leaders from academia, industry, government, and art with widely diverse perspectives, which led to vigorous conversation on the panel and also with the audience.

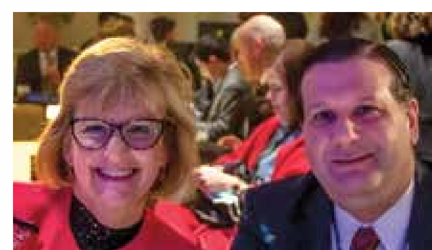
The glass art community bridges the aesthetic and scientific attributes of glass, and glass art provides a beautiful point of entry to glass appreciation to a wide audience. Artists, scientists, business leaders, and funding agency leaders connected over their mutual interest in glass, often finding that their interests overlap; it is the exploration of those interests that diverges.

Richardson says, "The richness of our global glass community was on display, including a further expansion of our relationship with the glass art community. Together we shared thoughts, concerns, and opportunities where we can make key inroads as a sector, toward some of our globe's most challenging sustainability issues."

A gala banquet Wednesday night featured a recorded presented by Dale and Leslie Chihuly and a live presentation by Narcissus Quagliata. Quagliata describes himself as a painter and an artist interested in light. He eventually discovered glass as a fascinating medium for exploring the interaction of light in art. His glass paintings are fascinating visual essays, and Quagliata has won several commissions to install his work in prominent locations throughout the world.

Pictures from the event are located on ACerS Flickr page at https://bit.ly/NDGC2022. All talks were recorded and will be available on the ACerS website by the end of April. Learn more about global activities planned for the International Year of Glass at https://iyog2022.org/home/upcoming_events. ■

David Pye, Alfred University dean emeritus, suggested a United Nations International Year of Glass. Alicia Durán, who was president of the International Commission on Glass at the time, organized the proposal to the United Nations, which included 2,200 endorsement letters from 90 countries.



Kathleen Richardson and Mario Affatigato organized the two-day event. Richardson is Pegasus Professor of Optics and Materials Science and Engineering at CREOL/College of Optics and Photonics at the University of Central Florida, and Affatigato is Fran Allison and Francis Halpin Professor of Physics at Coe College.

Celebrating women working with glass during the opening reception for the National Day of Glass Conference. The reception was held at the National Academy of Sciences in Washington, D.C.

17TH BIENNIAL WORLDWIDE CONGRESS ON REFRACTORIES

UNITECR 2022

ACerS meeting highlights

Refractory professionals gather in Chicago to celebrate the return of UNITECR

After pivoting to a virtual format for EMA and ICACC in January, the excitement for a live meeting was palpable during the in-person Unified International Technical Conference on Refractories (UNITECR) that took place March 15–18, 2022, in Chicago, Ill.

Originally scheduled to take place in 2021, UNITECR was moved to 2022 due to pandemic restrictions. As the first hybrid meeting organized by ACerS, UNITECR turned out to be a great success—470 people registered for the meeting, with more than 420 attending in person. Thanks to countries around the world lifting COVID-19 restrictions, people from 28 countries were able to attend the conference.

"I was so happy to see my colleagues face to face for the first time in years and thought the conference went better than ever could have been expected. Everyone seemed upbeat, the exchanges in the hallways and coffee breaks were invaluable, and the technical presentations were excellent," says James Hemrick, UNITECR 2022 technical program chair and North American UNITECR Committee member.

Each morning of UNITECR 2022 started with talks by preeminent speakers from the refractory and raw materials industries, including

• **Carol Jackson**, HarbisonWalker International chairman and CEO: Jackson shared her experience leading the World Refractories Association at the start of the COVID-19 pandemic. She says the pandemic helped raise global awareness of the criticality of refractories, and the industry now needs to build on this momentum to inspire the next generation of students to pursue careers in this field.

Credit: ACerS

Allied Mineral Products vice president of research & development Dana Goski, right, accepts her certificate from UNITECR 2022 president Tom Vert announcing her as the first woman UNITECR Distinguished Life Member.

• **Mike O'Driscoll**, IMFORMED director: O'Driscoll gave an overview of the global refractory raw material market and outlook in coming years. He showed how a recent succession of "perfect storms" have affected the refractory mineral market in China, and how these factors are leading refractory companies to explore ways to strengthen and diversify the supply chain.

• **Dana Goski**, Allied Mineral Products vice president of research & development: Goski discussed various frontiers in refractories, including new forming and sintering technologies that could reduce the industry's carbon footprint to data driven discovery of new refractory materials.

This year's Theodore J. Planje–St. Louis Refractories Award winner was Chris Parr, science & technology vice president for refractories at Imerys. He is also chairman of the Federation for International Refractory Research and Education (FIRE), and he highlighted some of the benefits that FIRE offers to students during his award talk.

Credit: ACerS

Imerys sustainability coordinator and past Planje Award winner Nancy Bunt, left, presents Chris Parr with the 2022 Planje Award.

Several special events held throughout the week offered ample networking opportunities. On Tuesday, shuttle buses took attendees to a welcome reception sponsored by RHI Magnesita at the Museum of Science and Industry, Chicago. On Wednesday, a poster session during the day and a young professional reception sponsored by Imerys at night offered further networking opportunities. On Thursday, a Women in Refractories reception sponsored by Allied Mineral Products and Imerys was followed by a conference dinner sponsored by TRI Corporation. At the dinner, Allied Mineral Products vice president of research & development Dana Goski was announced as the first woman UNITECR Distinguished Life Member.

UNITECR will be held again next year in Germany to bring the conference back in alignment with pre-pandemic scheduling. Visit the ACerS Flickr page at https://bit.ly/UNITECR2022 for more photos from the conference. ■

UPCOMING DATES

MAY 22–26, 2022

Register Now!

2022 GLASS AND OPTICAL MATERIALS DIVISION ANNUAL MEETING (GOMD 2022)

https://ceramics.org/gomd2022

HYATT REGENCY BALTIMORE, BALTIMORE, MD.

The 2022 GOMD meeting is unique because the United Nations declared 2022 as the **International Year of Glass**. We will have a number of special events to commemorate this occasion as we meet together in person for the first time since 2019.

The 2022 technical program will feature four symposia: Fundamentals of the Glassy State; Glass and Interaction with its Environment—Fundamentals and Applications; Optical and Electronic Materials and Devices—Fundamentals and Applications; Glass Technology and Cross-cutting Topics.

JULY 11–13, 2022

Register Now!

12TH ADVANCES IN CEMENT-BASED MATERIALS

https://ceramics.org/cements2022

UNIVERSITY OF CALIFORNIA, IRVINE, CALIF.

Cement is the key ingredient in concrete—the most-used building material in the world—so every advance in understanding how it behaves presents an opportunity to reduce greenhouse gases, advance construction engineering, and improve quality of life around the globe.

JULY 24–28, 2022

Register Now!

2022 PAN AMERICAN CERAMICS CONGRESS and FERROELECTRICS MEETING OF AMERICAS (PACC-FMAs)

Panama -fmas 2022

PAN AMERICAN CERAMICS CONGRESS AND FERROELECTRICS MEETING OF AMERICAS (PACC-FMAs 2022)

ceramics.org/PACCFMAs

HILTON PANAMA, PANAMA CITY, PANAMA

The Pan American Ceramics Congress brings together a wide variety of experts from academia, industries, research institutes, and laboratories to discuss current state-of-the-art and various technical challenges in research, development, engineering, manufacturing, and application of ceramic and glass materials. The Congress will provide a collegial forum for information exchange on current status and emerging trends in various technologies in the American continent (South and Central America, Canada, and the United States).

OCT. 9–13, 2022

ACerS 124TH ANNUAL MEETING with MS&T22

MATERIALS SCIENCE & TECHNOLOGY

Organizers:

The American Ceramic Society www.ceramics.org

AIST Association for Iron & Steel Technology

TMS The Minerals, Metals & Materials Society

https://www.matscitech.org/MST22

DAVID L. LAWRENCE CONVENTION CENTER, PITTSBURGH, PA.

NEW this year—The Materials Science and Technology Partnership has engaged the commercial exhibition firm Event Partners to sell and manage the full exhibition at MS&T22. In addition, Event Partners will co-locate two commercial exhibitions run by the company within MS&T22: The Advanced Materials Show and the first-ever Nanotechnology Show.

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

Calendar of events

May 2022

9–12 ACerS 2022 Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Omni Charlotte Hotel, Charlotte, N.C.; https://ceramics.org/scpd2022

19–21 The 11th International Academy of Ceramic Implantology World Congress – Hotel Washington, Washington D.C.; https://www.iaoci.com/iaoci-2022/general-information

22–26 Glass & Optical Materials Division Annual Meeting (GOMD 2022) – Hyatt Regency Baltimore, Baltimore, Md.; https://ceramics.org/gomd2022

June 2022

13–15 12th Advances in Cement-Based Materials (Cements 2022) – University of California, Irvine; https://ceramics.org/cements2022

21–22 ceramitec 2022 – Munich, Germany; https://www.ceramitec.com/en/trade-fair/information/exhibition-sectors

28–30 2022 FIRE-ECerS Summer School: Eco-Design of Refractories – RWTH Aachen University, Germany; https://ecers.org/fire-ecers-summer-school

28–Jul 2 ICG Workshop for new researchers in glass science and applications – Berlin, Germany; https://icglass.org

July 2022

3–8 ➨ ICG Annual Meeting 2022 – Berlin, Germany; https://ceramics.org/event/icg-annual-meeting-2022

10–14 International Congress on Ceramics (ICC9) – Krakow, Poland; https://ceramics.org/event/international-congress-on-ceramics-icc9

24–28 Pan American Ceramics Congress and Ferroelectrics Meeting of Americas (PACC-FMAs 2022) – Hilton Panama, Panama City, Panama; https://ceramics.org/PACCFMAs

August 2022

28–Sept 1 ➨ 11th International Conference on High Temperature Ceramic Matrix Composites – Ramada Plaza Jeju Hotel, Jeju, Korea; https://www.ht-cmc11.org

29–31 ➨ 7th Ceramics Expo co-located with Thermal Technologies Expo – Huntington Convention Center, Cleveland, Ohio; https://ceramics.org/event/ceramics-expo

September 2022

7–9 5th Energy Harvesting Society Meeting – Falls Church Marriott Fairview Park, Falls Church, Va.; https://ceramics.org/event/5th-energy-harvesting-society-meeting

October 2022

9–13 ACerS 124th Annual Meeting with Materials Science & Technology 2022 – David L. Lawrence Convention Center, Pittsburgh, Pa.; https://ceramics.org/MS&T22

12–13 AM Ceramics 2022 – Fraunhofer IKTS, Winterbergstraße, Dresden, Germany; http://www.am-ceramics.dkg.de

November 2022

30–Dec 2 ASEAN Ceramics – IMPACT Forum Hall 4, Bangkok, Thailand; https://aseanceramics.com/thailand/#thai-about

January 2023

17–20 Electronic Materials and Applications 2023 (EMA 2023) – DoubleTree by Hilton Orlando at Sea World Conference Hotel, Orlando, Fla; https://ceramics.org/EMA23

22–27 47th International Conference and Expo on Advanced Ceramics and Composites (ICACC 2023) – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla; https://ceramics.org/ICACC23

27–31 The International Conference on Sintering 2023 (Sintering 2023) – Nagaragawa Convention Center, Gifu, Japan; https://www.sintering2021.org

September 2023

26–29 ➨ Unified International Technical Conference on Refractories (UNITECR) with 18th Biennial World-wide Congress on Refractories – Kap Europa, Frankfurt am Main, Germany; https://unitecr2023.org

July 2024

14–19 International Congress on Ceramics – Hotel Bonaventure, Montreal, Canada; www.ceramics.org

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

Entries in **BLUE** denote ACerS events.

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

denotes International Year of Glass event

denotes virtual meeting

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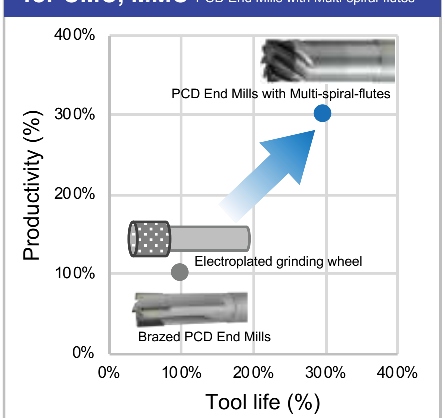

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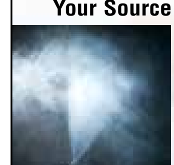

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Guest columnist

Expanding materials for optical applications: Pure and nickel-doped transparent $MgGa_2O_4$ ceramics

Magnesium gallate ($MgGa_2O_4$) has attracted much attention recently in both optical and electrical applications due to its unique and versatile properties.

Compared to many other transparent oxide semiconductors, which suffer from low stability at high temperatures, $MgGa_2O_4$ has a melting point of about 1,930°C, which makes it easier to process.[1] $MgGa_2O_4$ also exhibits a large degree of inversion in its crystal structure, unlike other materials in the spinel family, which makes it a perfect host for transition metal cation dopant spectroscopy.

One attribute of $MgGa_2O_4$ that remains largely unexplored is its potential to form as a transparent ceramic. Like $MgAl_2O_4$ (spinel), $MgGa_2O_4$ is cubic and resistant to decomposition, which in principle makes it possible to fabricate transparently. So, we attempted to fabricate transparent $MgGa_2O_4$ and Ni^{2+}-doped $MgGa_2O_4$ ceramics by pulsed electric current sintering.

To ensure the stoichiometry of cations and simultaneously obtain small enough ceramic particles, we synthesized $MgGa_2O_4$ ceramic powder via a nitrate pyrolysis method. The resulting powder was further deagglomerate by 24-hour ball milling in anhydrous alcohol. To reduce carbon diffusion and contamination from the graphite tool, a metallic molybdenum foil isolated the $MgGa_2O_4$ ceramic powder during this process. Boron nitride powder was also added as a special buffer layer before sintering, so it could absorb mechanical and thermal shock during the pressure releasing stage at the end of sintering.

After sintering, nearly full densification was achieved for both $MgGa_2O_4$ and Ni^{2+}-doped $MgGa_2O_4$ ceramics with submicron average grain size. A partially inverse spinel structure was confirmed by the doublets seen in the recorded Raman spectra (Fig. 1).[2]

Testing revealed the highest in-line transmittance of pure and nickel-doped transparent $MgGa_2O_4$ ceramics, after air annealing, was 73.3% (at ~1.2 μm) and 72.6% (at ~0.85 μm), respectively. With 1 at. % nickel dopant, transparent $MgGa_2O_4$ ceramics exhibited a wide range of near infrared emission centered at 1264 nm under 980 nm laser excitation, which matches the emission spectra of both Ni:$MgGa_2O_4$ single crystals and the energy diagram estimated from absorption spectra using Tanabe-Sugano diagram. These properties suggest that the nickel-doped transparent $MgGa_2O_4$ ceramic has potential as a lasing ceramic operating at temperatures above 100 K.[3]

As the first report of transparent $MgGa_2O_4$ ceramics, the optical quality is sufficient for spectral study. However, further improvement must be made for more demanding applications. The nitrate pyrolysis method used in this work does not only suit the stoichiometry and particle consideration, but it also greatly decreases the influence on the ceramic particles and transparency due to differences in the raw materials. Thus, we hope to see more attempts of its application in new transparent ceramics development.

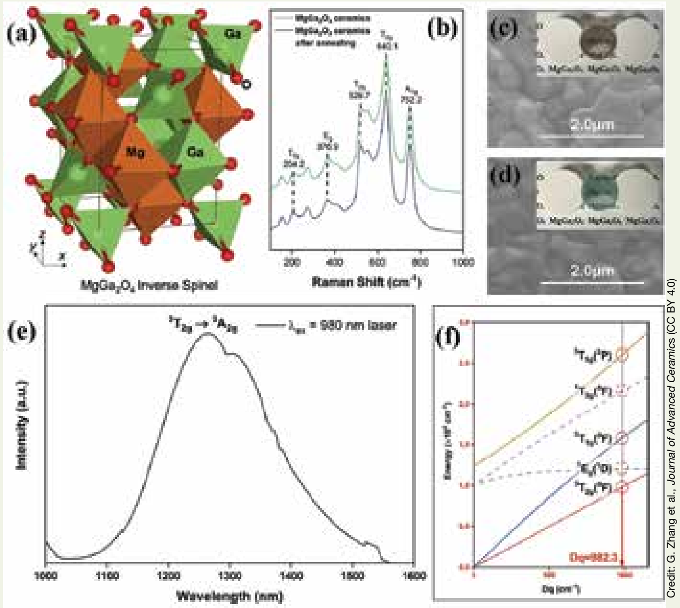

Figure 1. (a) Inverse spinel structure $MgGa_2O_4$; (b) doublets seen from the Raman spectra; transparent (c) $MgGa_2O_4$ and (d) Ni^{2+}-doped $MgGa_2O_4$ ceramics; (e) near infrared emission spectra of Ni^{2+}-doped $MgGa_2O_4$; (f) energy diagram of octahedral Ni^{2+}-doped $MgGa_2O_4$ transparent ceramics.

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