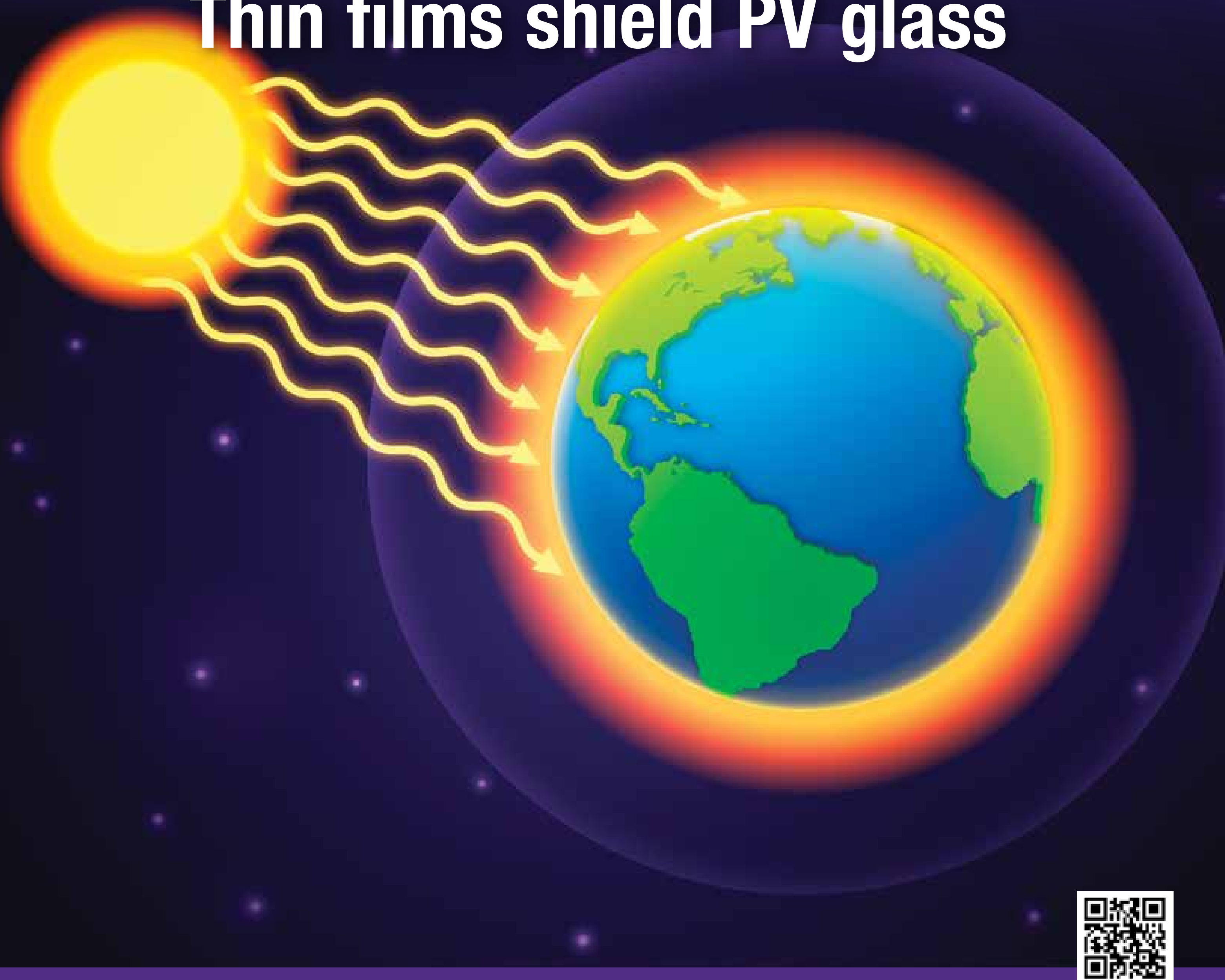
AMERICAN CERAMIC SOCIETY
bulletin
emerging ceramics & glass technology
MAY 2020

Protecting the future of energy: Thin films shield PV glass



Coalescence of glass art and glass science | Reconfigurable optics | Meetings: New dates and cancellations

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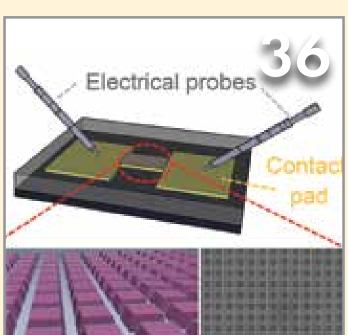

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Correction

In the April 2020 *Bulletin*, Figure 4 in the article "Smog begone!" shows an accumulated soot layer, not ash layer, as incorrectly stated in the caption.

AMERICAN CERAMIC SOCIETY
bulletin

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As seen on *Ceramic Tech Today*...

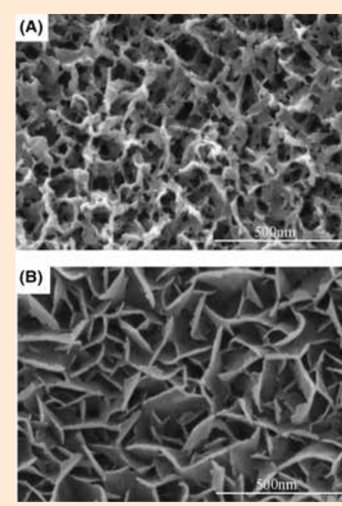
Credit: Ilya Kuzniatsou, Flickr (CC BY 2.0)

Bricks used to characterize past presence of radioactive materials

For successful nuclear nonproliferation initiatives, authorities must be able to detect and characterize radioactive sources—but how can they do so if the radioactive material was removed before they arrived? Researchers at North Carolina State University developed a technique that allows retrospective characterization of radioactive sources.

Read more at www.ceramics.org/pastradiation

Also see our ACerS journals...



Processing technologies for sealing glasses and glass-ceramics
By A. de Pablos-Martín, S. Rodríguez-López, and M. J. Pascual
International Journal of Applied Glass Science

Electrodeposition of fluorohydroxyapatite gradient coating on titanium alloy
By Q. X. Zhu, W. W. Han, S. Z. Wen, et al.
International Journal of Applied Ceramic Technology

Bi@$Bi_4Ti_3O_{12}$/TiO_2 films on glass with photocatalytic and self-cleaning performance
By X. Lv, Z. Zhang, Z. Cao, et al.
Journal of the American Ceramic Society

Microstructural effects on hardness and optical transparency of birefringent aluminosilicate nanoceramics
By N. A. Gaida, N. Nishiyama, O. Beermann, et al.
International Journal of Ceramic Engineering & Science

Read more at www.ceramics.org/journals

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). ©2020. 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. 99, No. 4, pp 1– 48. All feature articles are covered in Current Contents.

letter from the president

To our members, friends, and colleagues,

We find ourselves in an extraordinary time experiencing a common battle against the coronavirus. A true pandemic, the coronavirus recognizes no borders between nations, beliefs, education levels, job descriptions, or class. We are all affected in some way, and it is our fervent hope that you and your personal and professional communities are safe as we come through this situation.

The times offer a heroic moment for science to address the virus and for the engineering spirit to solve immediate problems. Our members are finding new ways to teach, research, employ their staffs, keep businesses open, and otherwise respond to a new reality. We appreciate and applaud the many adjustments and sacrifices that you have made.

Many ceramic and glass manufacturers remain open as essential businesses or because of their role as suppliers to other essential manufacturers. These businesses and their employees face challenges structuring a safe work environment while keeping elements of the economy functioning. Next month, the Ceramic & Glass Manufacturing magazine will report on how ceramic manufacturers are handling operations during this time. Look for C&GM within the pages of the June/July Bulletin.

Here at ACerS headquarters, we remain open for business while we comply with government guidelines for social distancing. The ACerS staff is working from their homes at least through May 1, 2020, and we appreciate your patience as we continue to serve you. As we write you in mid-April, all ACerS events through July have been rescheduled. Please check www.ceramics.org/meetings-events for the latest information and new changes.

Please know our thoughts are with you as we go through this experience together. As always, the Society is here to serve. Please direct any questions or concerns to customerservice@ceramics.org.

With best wisheøs for your health and safety,

Tatsuki Ohji, President

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news & trends

Minerals world faces challenging future

Excerpted with permission from *"Minerals world faces challenging future"*

By Mike O'Driscoll
IMFORMED director

Right now it is hard to find anything but gloom and uncertainty for the near and possibly medium future for the industrial minerals industry.

The impact of the COVID-19 pandemic has and will continue to affect mineral operations and consuming market sectors for the next few months, if not the remainder of the year, and a global economic recession is more than likely.

What we can do is see how certain markets may or may not be impacted, which specific minerals are affected, and highlight some potential positive outcomes after the crisis has passed.

Cement—expecting closures

Cement (limestone, gypsum, silica sand, clays) manufacturers in India, the world's second largest producer, and in Italy have been closing their plants.

As the construction industry worldwide adjusts to the situation, more plants will most likely close.

As with other sectors that heavily use calciners (e.g., magnesia, lime, bauxite, dolime, kaolin, diatomite), keeping up with maintenance schedules will be a huge challenge with travel across borders severely restricted.

Glass—container glass continues in US

Likewise, the auto and construction markets in turn use huge volumes of glass (limestone, soda ash, silica sand) and coatings (titanium dioxide, calcium carbonate, talc, mica, kaolin, mineral pigments).

Glass tableware manufacturers in France and the United States have closed plants.

There is one ray of light from the U.S.—container glass manufacturing for food, beverages, and pharmaceu-

ticals has been deemed an "essential" industry, meaning that plants can continue to operate even if the country goes into lockdown.

Whether such recognition will be made for Europe's container glass industry remains to be seen. The sector has 160 glass manufacturing plants in the EU with 125,000 jobs operating in a circular economy business model with over 70% of all products sold in the EU destined for recycling to new food grade packaging.

Refractories—striving for 'criticality'

Serving the above market sectors are the refractories manufacturers, who will be keenly following their customers' decision making and performance during the crisis because it will have a direct impact on them.

Clearly with the steel, nonferrous metal, cement, and glass plant shutdowns already underway and perhaps more on the horizon, the refractories sector will be feeling the pinch.

That said, it might be that some of these plants can possibly use the shutdowns to bring forward scheduled refractory maintenance programs. However, whether the refractory products and engineers can travel to and access the plants is another matter.

During the first quarter of 2020, the world's primary source of refractory minerals, China, experienced severe disruption of supply owing to its COVID-19 lockdown and is now starting to get back on stream.

However, just as some 90% of staff are returning to work, fears are emerging of a "second wave" of the virus hitting China, which is apparently already impacting recently re-started plants and supply chains.

Now it is the turn of the rest of the world, with India, Europe, South Africa, and parts of the U.S. in lockdown. Unsurprisingly, orders from these regions for Chinese supplies are drying up as plants close.

This lockdown may somewhat alleviate the outcome of the second virus wave on supply chains, but Chinese mineral suppliers will see little consolation in that.

Certain refractory suppliers are able to maintain some operations.

On Monday, March 30, the Spanish

Table 1. Industrial minerals consumed in refractories

Refractory classification	Industrial mineral (incl. synthetic)	Main chemical component	Primary source country
Basic	Dead burned magnesia	85–99.8% MgO	China
	Fused magnesia	97–99.8% MgO	China
	Dead burned dolomite	56–62% MgO, 36–40% CaO	USA
	Chromite	>46% Cr_2O_3	South Africa
	Sintered/fused spinel	66–88% Al_2O_3, 21–33% MgO	China
	Olivine	40–50% MgO, 35–45% SiO_2	Norway
Acidic	Calcined alumina	>99.5% Al_2O_3	China
High alumina	Fused alumina	94–99.5% Al_2O_3	China
	Calcined bauxite	40–75% Al_2O_3	China
	Sintered/fused mullite	85–88% Al_2O_3	USA
Low alumina	Andalusite, sillimanite, kyanite	60–65% Al_2O_3	South Africa
	Refractory clays	20–45% Al_2O_3	China
	Pyrophyllite	20–30% Al_2O_3	South Korea
Silica	Quartzite, silica sand	>97% SiO_2	Regional
	Fused silica	>99.8% SiO_2	USA
Specialized	Zircon	66% ZrO_2+HfO_2	Australia
	Zirconia	>99% ZrO_2	China
	Silicon carbide	>93% SiC	China
	Graphite	75–99% C	China
Insulating	Diatomite	>75% SiO_2	USA
	Perlite	65–80% SiO_2	China
	Vermiculite	45% SiO_2	South Africa

government decided to further limit the number of businesses allowed to keep their activity going.

The country's leading magnesia and refractories producer, Magnesitas Navarras (MAGNA), has been awarded the status of "essential activity," which will enable continued operations during the current State of Emergency.

On March 26, leading U.S. refractory manufacturer HarbisonWalker International (HWI) announced that it had received written confirmation from Tom Wolf, governor of the Commonwealth of Pennsylvania, that its application to continue business operations at physical locations had been accepted and approved.

On March 19, the Pennsylvania government had ordered "non-life sustaining businesses" to close. HWI has been working to successfully ensure no interruptions in the critical supply chain of refractory products and services provided to customers.

What prompted HWI's application to state authorities was that companies listed in the business category of "Clay Product and Refractory Manufacturing" had been ordered on March 19 to close physical operations.

However, steel, aluminum, pulp and paper, cement, plastics, rubber, and chemicals manufacturers are permitted to remain open in the U.S. Thus, HWI was able to demonstrate, and successfully, that refractory products and services supplying those industries are absolutely essential to their manufacturing processes.

Leading specialty aluminas producer Almatis has also just received the requisite government approvals as a critical business in order to continue its operations in the Americas, Europe, China, and Japan. Almatis supplies numerous markets, including refractories, ceramics, abrasives, glass, flame retardants, and building chemistry.

India's refractories industry is hoping its government will follow decision making in the U.S. and Spain. In a March 30 statement, the Indian Refractory Makers Association (IRMA) wanted to "gently remind" that refractory and refractory raw materials supply chain should be brought under the Essential Services Maintenance Act, 1981 and "allowed to function uninterruptedly" because they are essential inputs for iron and steel, thermal power, petrochemical, cement, nonferrous metal, and glass plants. The latter sectors have been kept operational by the government during its three-week lockdown from March 26, 2020.

"We must continuously produce and service refractories because they are critical components in almost all products' supply chains," said Parmod Sagar, chairman of IRMA.

How other mineral product suppliers to certain industry sectors in different countries fair remains to be seen.

Follow the unfolding story at http://imformed.com/get-imformed/newsfile. ■

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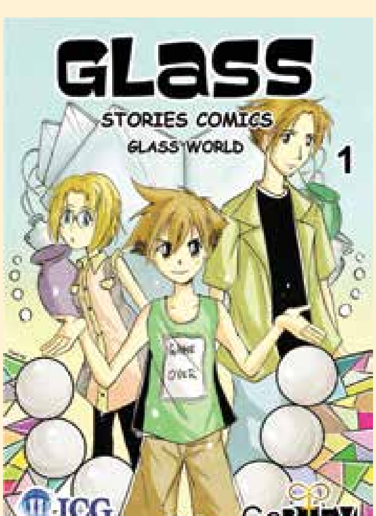
Explore the world of glass

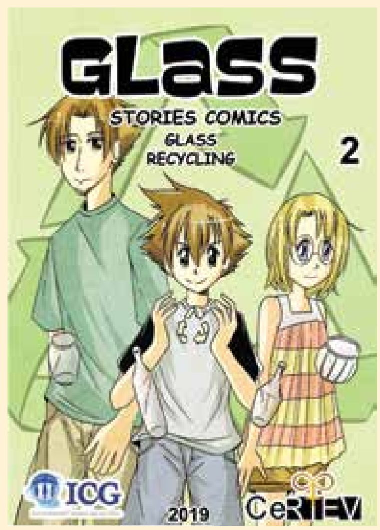
"Glass Comics" series | Center for Research, Technology and Education in Vitreous Materials

The "Glass Comics" series by researchers at the Center for Research, Technology and Education in Vitreous Materials (CeRTEV) in Brazil teaches about various aspects of glass, including what it is, everyday applications, and how to recycle.

Ana C.M. Rodrigues, CeRTEV senior researcher and coordinator of Education and Dissemination and chair of the International Commission of Glass (ICG) TC23–Technical Committee 23 "Glass Education," explains how this free comic series came to be.

"The idea of the 'Glass Comics' came up after CeRTEV, an 11-year project funded by the São Paulo Research Foundation (FAPESP), Brazil, was approved in June 2013. As a counterpart for generous research funding, FAPESP invited us to dedicate a substantial part of the effort to science dissemination. We decided to collaborate with Prof. Karina Omuro Lupetti, who had been working with the science dissemination and chemistry education for over 10 years.





At that time, Adriana Iwata, an M.S. student supervised by Prof. Lupetti, had already drawn and written some comics in Japanese style 'manga' with basic chemistry topics. Thus, Prof. Lupetti proposed that Adriana could write some manga comics on glass-related topics with supervision by her and the CeRTEV glass experts. The first original comics in 2015 were written in Portuguese.

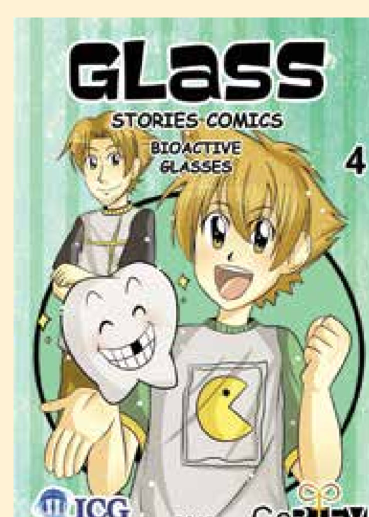
Then, I (Rodrigues) proposed a project aiming to translate this comic series into English to reach a wider audience. The ICG directors readily embraced the idea and funded the translation service by professionals. And… that's it!"

There are currently four comics available in English. A fifth comic, "The Glass Era," is available in Portuguese and will soon be available in English as well.

The comics are available on the ICG Education webpage (http://www.icglass.org/home/education) and on the ACerS "Communicating Science" webpage (https://ceramics.org/communicating-science).

For questions or more information, contact Rodrigues at acmr@ufscar.br.

Learn more about communicating science to nonspecialist audiences on ACerS' new "Communicating Science" webpage! ■



Aerographene and graphene aerogel

By Abhigyan Sengupta

The global aerographene/graphene aerogel market is expected to grow from $51.0 million in 2018 to $621.0 million in 2024 at a compound annual growth rate (CAGR) of 50.29%.

The aerographene/graphene aerogel market is the fastest-growing segment in the overall aerogel market. Aerogel is a kind of solid structure produced when the liquid in a gel-containing element is replaced with gas, which results in the formation of an extremely light solid material that has a very low density and high thermal conductivity.

Initially, graphene aerogel was used as insulation and absorbent in many industries. The rapid development of multiple application industries and increasing research and development in the fields of graphene aerogel have created a diverse range of applications for aerographene materials. It is most used in industries such as the automotive, electronics, and paints and coatings sectors, among others.

There are several types of aerographene/graphene aerogel products, including

- **Granules**, the smallest particles of graphene-based aerogel material. The granules segment held the largest market share (40.2%) and is expected to remain the market leader.
- **Powder**, one of the stronger superconductors of heat and electricity. It is used in electronic devices and industrial applications requiring high electrical conduction.
- **Blocks**, rectangular brick-size structures with superior flexibility, superconductivity, and desalination capabilities. It is expected to experience high demand in multiple applications across different verticals throughout the world.
- **Tiles**, square-sized structures with flat edges. It is used in applications requiring optical transparency, super thermal insulation, and low density.
- **Others**, primarily includes aerographene sheets. The sheets are mostly used for thermal insulation in multiple applications.

Growth opportunities for the aerographene/graphene aerogel market are mainly driven by energy storage sectors. In particular, the nanocatalyst segment is the fastest-growing application segment in the aerographene market, and it is estimated to grow at a CAGR of 60.9% from $5.2 million in 2018 up to $106.9 million in 2024.

Table 1. Global market for aerographene/graphene aerogel, by end-user industry, through 2024 ($ millions)

End-user industry	2018	2019	2024	CAGR% 2019–2024
Oil and gas	11.2	18.6	118.0	44.7
Paints and coatings	11.7	17.0	111.8	45.8
Electronics	4.6	9.7	99.4	59.3
Automotive	2.6	5.0	82.0	75.0
Industrial	3.1	6.5	62.1	57.0
Defense	6.2	9.2	59.0	45.0
Aerospace	5.3	9.2	57.9	44.5
Others	6.3	5.8	30.8	39.6
Total	51.0	81.0	621.0	50.3

The desalination systems segment was the largest revenue-generating segment in 2018, with a market share of 40.2%. It is expected to show steady growth and reach $157.2 million by 2024.

In terms of end users, the paintings and coatings segment held the largest market share as of 2018 and is expected to show steady growth at a CAGR of 45.8% to reach $111.8 million by 2024. The fastest-growing market, however, is the automotive segment, which will grow at a CAGR of 75.0% to reach $82.0 million by 2024.

The Asia-Pacific held the largest market for aerographene/graphene aerogel by region at 52.2% in 2018, and it is expected to grow at a CAGR of 46.3% to reach $261.6 million by 2024. Governments in this region are pushing for energy-efficient solutions in order to achieve energy self-sufficiency.

The market in North America is in a very nascent stage and characterized by the swift adoption of advancement in graphene nanotechnology. In Europe, the energy storage and conversion market is one of the most innovative and advanced markets. In particular, the United Kingdom and Germany are the major markets for energy storage and conversion technology.

Countries in Latin America, the Middle East, and Africa are expected to show the highest growth rate among all the geographic regions studied. Latin American countries, such as Brazil, are going through rapid industrialization, which is expected to create a high demand for graphene aerogel in the region. In the Middle East, the United Arab Emirates is a pioneer in the adoption of graphene-based advanced nanotechnology.

About the author

Abhigyan Sengupta is a research analyst for BCC Research. Contact Sengupta analysts@bccresearch.com.

Resource

A. Sengupta, “Aerographene/graphene aerogel market” BCC Research Report NAN066A, March 2020. www.bccresearch.com. ■

SOCIETY, DIVISION, SECTION, AND CHAPTER NEWS

Corporate Partner news

ACerS extends a warm welcome to all our new members! Please feel free to contact us with any questions you may have regarding your membership.

Our newest Corporate Partner is:

– **Ceramiseal**

ACerS thanks its Corporate Partners for supporting the industry and encourages members to support them. Visit the ACerS Corporate Membership webpage for a complete listing of corporate partners. ■

Meet ceramic scientists and engineers in ACerS upcoming podcast

Ceramics is in some ways a hidden industry—many people do not realize ceramics are essential to numerous advanced technologies. And part of the reason for this obscurity is because people have never talked to a ceramic scientist or engineer.

Ceramic scientists and engineers are all around us, though—and now is your chance to meet them.

Ceramic Tech Chat is a new monthly podcast by The American Ceramic Society that gives you a chance to meet ceramic scientists and engineers whose work makes a big impact in today's world.

Our chats with ACerS members give us a look into their unique and personal stories of how they found their way to careers in ceramics and learn what they discovered personally, professionally, and scientifically along the way.

Ceramic Tech Chat premieres on May 13, 2020, and will publish on the second Wednesday of every month.

Learn more at www.ceramics.org/ceramic-tech-chat. ■

Spain Chapter kicks off with additive manufacturing program

More than 50 professionals attended the first session of the Spain Chapter of The American Ceramic Society held at the Universitat Jaume I Institute for Ceramic Technology on Feb. 20, 2020.

The session was led by Jesús Lancis, vice-rector for Research and Knowledge Transfer at Universitat Jaume I; Gustavo Mallol, director of the Ceramic Industry Research Association; Enrique Sánchez, director of the University Institute for Ceramic Technology "Agustín Escardino"; and Arnaldo Moreno, president of the ACerS Spain Chapter and member of the Institute for Ceramic Technology. ■

Credit: Damián Llorens, Universitat Jaume I

Volunteer Spotlight

Randall

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

Clive Randall is professor of materials science and engineering and director of the Materials Research Institute at The Pennsylvania State University. He has a B.Sc. (Honors) in physics from the University of East Anglia, U.K. (1983), and a Ph.D. in experimental physics from the University of Essex, U.K. (1987).

He was director of Penn State's Center for Dielectric Studies from 1997–2013 and co-director of the Center for Dielectrics and Piezoelectrics from 2013–2015 (now technical advisor). He has served as co-chair of the ACerS Humanitarian Network and helped create a video that introduces low-cost ceramic water filters and how they remove harmful bacteria and parasites from drinking water. Randall successfully submitted nominations for three of this years' Society Awards that will be presented at the Awards Banquet in October.

Randall's interests include discovery, processing, material physics, and compositional design of functional materials. Among his awards are ACerS Fellow, Academician of World Academy of Ceramics, IEEE Distinguished Lecturer, and honorary Fellow of the European Ceramic Society. Randall has a Google h-factor of 76 and over 20,000 citations.

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

2020 ACerS Webinar Series: Facts are not enough

Communicating your research to nonspecialist audiences is challenging, even more so when your audience holds preconceived beliefs on the topic. Studies show facts alone cannot combat misinformation—so how do you correct these inaccuracies?

Save the date for the upcoming webinar, ***Facts are not enough: Combating misinformation in research communication*** to be held on **Tuesday, May 12, at 11 a.m. Eastern time**.

This webinar will provide an overview of misinformation in today's society and how to combat it when communicating research results. Well done and poorly implemented communication examples will be discussed.

Visit www.ceramics.org/webinars for more information and to register today! ■

Names in the news


Navrotsky

Alexandra Navrotsky, professor at Arizona State University, will be honored with the European Materials Research Society 2020 Jan Czochralski Award.


Green

David J. Green was named the McMaster University 2020 Alumni Gallery Recipient. The alumni gallery is a photographic and biographical display of alumni who make outstanding contributions to society. Green was editor of the *Journal of the American Ceramic Society* for nearly 20 years and served as ACerS president.


Sandhage

Ken Sandhage, Reilly Professor of Materials Engineering at Purdue University, was inducted into the Purdue Innovator Hall of Fame. ■

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.

Communicate science to nonspecialist audiences

Communicating science to nonspecialist audiences is something scientists do almost every day, be that from writing grant applications and teaching students to participating in public outreach events or speaking to their company's upper management.

But knowing how to communicate science effectively to these different groups is a skill not always taught in school.

ACerS' new "Communicating Science" webpage, developed with help from ACerS President's Council of Student Advisors, provides useful resources on communicating science effectively to nonspecialist audiences.

Check out the webpage at www.ceramics.org/communicating-science. ■

In memoriam

Richard (Dick) Petticrew	*Richard Robinson*
Norman Severin	*Robert Vernetti*

Some detailed obituaries can also be found at www.ceramics.org/in-memoriam.

AWARDS AND DEADLINES

Upcoming award nomination deadlines

May 15, 2020

Glass & Optical Materials Division: The Alfred R. Cooper Scholars Award recognizes undergraduate students who have demonstrated excellence in research, engineering, and/or study in glass science or technology.

Electronics Division: The Edward C. Henry Award 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.

Electronics Division: The Lewis C. Hoffman Scholarship recognizes academic interest and excellence among undergraduate students in the area of ceramics/materials science and engineering.

Awards and deadlines (cont)

May 23, 2020

Samuel Geijsbeek PACRIM International Award

The Geijsbeek PACRIM International Award recognizes individuals who are members of the Pacific Rim Conference (PACRIM) societies for their contributions in the field of ceramics and glass technology that have resulted in significant industrial and/or academic impact, international advocacy, and visibility of the field. Industrial candidates will be evaluated based on the technology development and commercialization, and the development's current usefulness and importance, its uniqueness, and its economic significance. The award will be presented in 2021 at PACRIM14 in Vancouver, Canada. Visit bit.ly/geijsbeek for more information.

July 1, 2020

Nominations open for ECD Jubilee, Mueller, Bridge Building, and Global Young Investigator awards

The Engineering Ceramics Division invites nominations for the 2021 Jubilee Global Diversity, James I. Mueller, Bridge Building, and Global Young Investigator awards.

The Jubilee Global Diversity Award 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. Nominees must be 45 years old or younger on January 1 of the award year and a member of ACerS Engineering Ceramics Division. Three awards are given per year and consist of a certificate, complimentary registration, and a $500 honorarium to be presented during the plenary session of ICACC. Awardees will make invited presentations at ICACC. For more information, contact Michael Halbig at michael.c.halbig@nasa.gov.

The Mueller Award recognizes the enormous contributions of James I. Mueller to the Engineering Ceramics Division and to the field of engineering ceramics. The award recognizes the accomplishments of individuals who have made similar contributions. The main criteria are long-term service to ECD and/or work in the area of engineering ceramics that has resulted in significant industrial, national, or academic impact. The award consists of a memorial plaque, certificate, and an honorarium of $1,000. If you have questions, contact Surojit Gupta at gsurojit1@gmail.com.

The Bridge Building Award recognizes individuals outside of the United States who have made outstanding contributions to engineering ceramics. The main criteria are contributions to the field of engineering ceramics, including expansion of the knowledge base and/or commercial use thereof, and contributions to the visibility of the field and international advocacy. The award consists of a glass piece, certificate, and an honorarium of $1,000. If you have questions, contact Valerie Wiesner at valerie.l.wiesner@nasa.gov.

The Global Young Investigator Award recognizes an outstanding scientist who is conducting research in academia, industry, or at a government-funded laboratory. Candidates must be ACerS members and 35 years of age or younger. Selection will be based on the nomination and accompanying evidence of scientific contributions and visibility of the field, and advocacy of the global young investigator and professional scientific forum. The award consists of $1,000, a glass piece, and certificate. If you have questions, contact Hisayuki Suematsu at suematsu@etigo.nagaokaut.ac.jp.

August 15, 2020

ECD secretary nominations

The ECD Nominating Committee invites nominations for the incoming 2020–2021 Division secretary candidate. Nominees will be presented for approval at the ECD Annual Business meeting at MS&T20 and included on the ACerS spring 2021 Division officer ballot. Nominations and a short description of the candidate's qualifications should be submitted to Manabu Fukushima at manabu-fukushima@aist.go.jp, Soshu Kirihara at kirihara@jwri.osaka-u.ac.jp, or Carli Marsico at carli.moorehead17@gmail.com. For more information, visit www.ceramics.org/divisions.

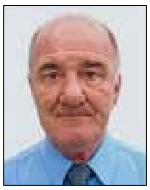
August 20, 2020

2021 Class of Fellows Nominations

The 2021 Class of Society Fellows recognizes members who have made outstanding contributions to the ceramic arts or sciences through productive scholarship or conspicuous achievement in the industry or by outstanding service to the Society. Nominees shall be persons of good reputation who have reached their 35th birthday and who have been members of the Society at least five years continuously. Visit http://bit.ly/SocietyFellows to download the nomination form. ■

GOMD 2020 Awards

Stookey Lecture of Discovery



Tomsia

Antoni Tomsia, Lawrence Berkeley National Laboratory, California

To be announced

George W. Morey Award

Kob

Walter Kob, University of Montpellier, France

Glass: We love it but it breaks

Norbert J. Kreidl Award for Young Scholars

Zhang

Yifei Zhang, Massachusetts Institute of Technology

Reconfigurable materials and optics: A phase change for the better

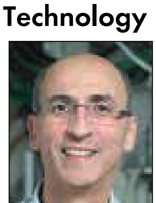
Darshana and Arun Varshneya Frontiers of Glass Science Lecture

Deubener

Joachim Deubener, Institut für Nichtmetallische Werkstoffe Glas und Glastechnologie, Technical University, Clausthal, Germany

Mechanical properties and thermal behavior of hydrous glasses

Darshana and Arun Varshneya Frontiers of Glass Technology Lecture



Messaddeq

Younes Messaddeq, Centre d'optique, photonique et laser, University of Laval, Québec, Canada

Idea to innovation of optical fibers

www.ceramics.org/ceramictechtoday

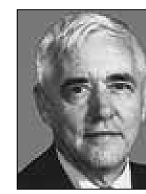
L. David Pye Lifetime Achievement

Chihuly

Dale Chihuly, Chihuly Studio

Conradt

Reinhard Conradt, RWTH Aachen University, Germany



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STUDENTS AND OUTREACH

Grad students—Are you a GEM?

If you submitted an abstract to MS&T20, you may be eligible for the Graduate Excellence in Materials Science (GEMS) award. ACerS Basic Science Division organizes the annual GEMS awards to recognize outstanding achievements of graduate students in materials science and engineering. The award is open to all graduate students who are making an oral presentation in any symposium or session at ACerS Annual Meeting at MS&T.

In addition to their abstract submission, students must also submit a nomination packet to the chair of the GEMS award selection committee, John Blendell, by **Monday, July 20, 2020**. For further details regarding the GEMS award and what to include in your nomination packet, go to www.ceramics.org/GEMS. ■

An abundance of student opportunities available at ACerS Annual Meeting and MS&T20!

There are many opportunities available at this year's ACerS Annual Meeting and MS&T. Make sure to sign up for the following 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, visit www.matscitech.org/students, or contact Yolanda Natividad at ynatividad@ceramics.org. ■

ACerS GGRN for young ceramic and glass researchers

Put yourself on the path toward post-graduate success with ACerS Global Graduate Researcher Network. GGRN is a network of ACerS that addresses the professional and career development needs of graduate-level research students who have a primary interest in ceramics and glass.

GGRN aims to help graduate students

- Engage with The American Ceramic Society,
- Build a network of peers and contacts within the ceramic and glass community, and
- Have access to professional development tools.

Visit www.ceramics.org/ggrn to learn what GGRN can do for you, or contact Yolanda Natividad at ynatividad@ceramics.org. ■

ACerS Associate Membership and Young Professionals Network

The American Ceramic Society offers a one-year Associate Membership at no charge for recent graduates who have completed their terminal degree. Join today to receive the benefits of membership in the world's premier membership organization for ceramics and glass professionals. Start your free year-long membership by visiting www.ceramics.org/associate or contact, Yolanda Natividad, ACerS member engagement manager, at ynatividad@ceramics.org.

Also, consider joining ACerS Young Professionals Network (YPN) once you have become an ACerS member. YPN is designed for members who have completed their degree and are 25 to 40 years of age. YPN gives young ceramic and glass scientists access to invaluable connections and opportunities. For more information, visit www.ceramics.org/ypn. You may join this growing community by logging in to your ACerS Personal Snapshot and marking "Young Professionals Network (YPN)" under the Interest Groups and Communities tab. ■

CERAMICANDGLASSINDUSTRY FOUNDATION

CGIF continues student and educator outreach during pandemic

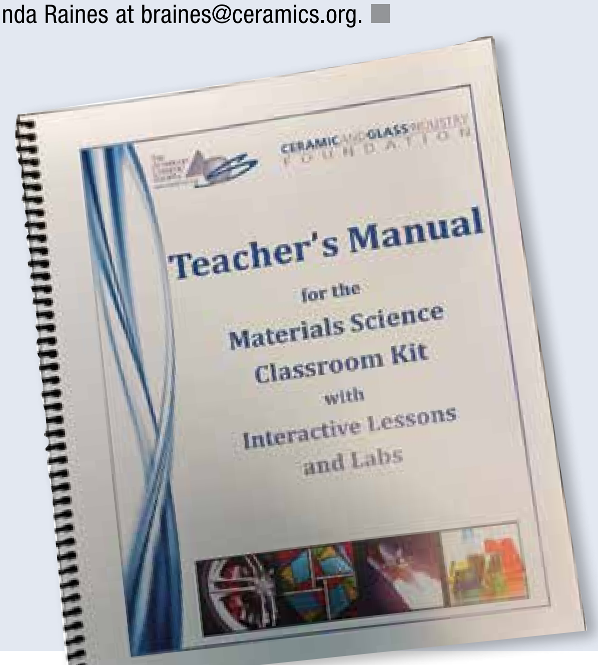
The Ceramic and Glass Industry Foundation continues its mission of outreach to inspire the next generation of glass and ceramic professionals through digital means. The staff of the CGIF remains committed to providing educators, which now includes stay-at-home parents, with resources they can use to teach materials science and STEM topics.

The "Ceramics are Cool" resource page on the ACerS website at www.ceramics.org/ceramics-are-cool offers a number of interesting articles on how ceramic and glass materials are used every day. Those articles accompany the 7^{th}–12^{th} grade resources, which include the nine lessons from the Materials Science Classroom Kit and can be downloaded for free.

Another resource on the "Ceramics are Cool" page links educators and other professionals to a new ACerS webpage developed with help from the ACerS President's Council of Student Advisors: "Communicating Science." This page provides many useful resources for effectively communicating about science to those who do not have a technical background.

The CGIF also provides ongoing informational posts and links to resources for educators on our special LinkedIn community page, "Ceramic and Glass Industry Foundation–Teachers Forum."

We invite ACerS members to share any resources you have that we can make available to students and educators. Please contact Belinda Raines at braines@ceramics.org. ■



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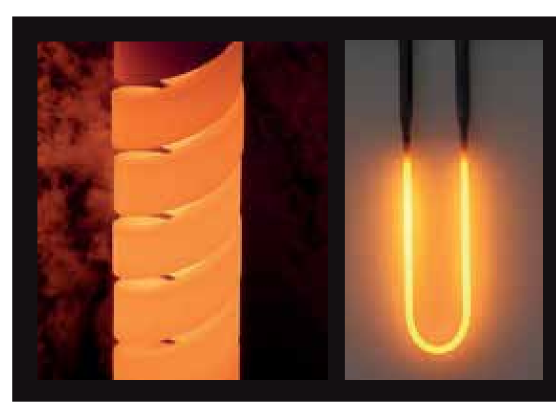

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research briefs

Modified ferroelectric transistor structure improves memory retention

In a recent study, Purdue University researchers say they found a way to lengthen data retention times in ferroelectric field-effect transistors (Fe-FETs), a type of nonvolatile memory technology.

Unlike ferroelectric random access memory (FeRAM), which stores and processes data using a capacitor-transistor combo, Fe-FETs store and process data using only transistors—which makes the read process nondestructive.

Despite this advantage, Fe-FET technology still is not commercialized because of its short data retention times, an issue generally attributed to two major factors: gate leakage current and the depolarization field.

To lengthen retention times, the Purdue researchers replaced the Fe-FETs' semiconductor "channel" region instead of the insulating layer with a ferroelectric material (2D alpha indium selenide, α-In_2Se_3).

In the paper, the researchers explain why using a ferroelectric material in the semiconductor channel rather than insulating layer allows them to overcome the gate leakage current and depolarization field.

Credit: Vincent Walter, Purdue University

By modifying the structure of conventional ferroelectric field-effect transistors, Purdue University researchers found they could improve data retention times.

"[The] mobile charges in the semiconductor can screen the depolarization field across the semiconductor," they write. "Thus, the charge trapping and leakage current through the ferroelectric insulator found in conventional Fe-FETs can potentially be eliminated."

In the conclusion, they report that the α-In_2Se_3 FeS-FETs exhibited high performance with a large memory window, a high on/off ratio of over 108, a maximum on current of 862 μA/μm, and a low supply voltage.

"Our FeS-FETs have the potential to surpass the capabilities of existing Fe-FETs for non-volatile memory applications," they write.

The paper, published in *Nature Electronics*, is "A ferroelectric semiconductor field-effect transistor" (DOI: 10.1038/s41928-019-0338-7). ■

Sol-gel coatings strengthen display glass

A recent study appearing in the April issue of *International Journal of Applied Glass Science* explores using sol-gel glass coatings to strengthen chemically tempered mobile phone cover glass.

Sol-gel is a relatively inexpensive and easily controlled coating method, and sol-gel glass coatings are directly compatible with commercial cover glass.

The initial results from the research team led by Chenyu Li of Xiamen University showed more material translated to greater strength—a 5 μm coating cured at 80°C increased the bending strength more than a 3 μm coating cured at the same temperature (12% versus 6%). However, an article in the literature showed strengthening by a substantially thinner coating was on par with the result from the 5 μm coating—how can that be?

Li et al. inferred the coating in the other study had a substantially higher modulus of elasticity and higher residual stress than the 5 μm coating because it was cured at a much higher temperature (300°C). Residual stress in the coating places

Research News

Long-distance fiber link poised to create powerful networks of optical clocks

An academic-industrial team in Japan connected three laboratories in a 100-kilometer region with an optical telecommunications fiber network stable enough to remotely interrogate optical atomic clocks. Because of optical clocks' extremely high precision, noise is a critical issue when linking optical clocks over a long fiber link. To cope with that noise, the researchers used a cascaded link that divides a long fiber into shorter spans connected by ultralow-noise laser repeater stations that incorporate planar lightwave circuits. They are now preparing optical lattice clocks to demonstrate a clock network using this fiber link. For more information, visit https://www.osa.org/en-us/about_osa/newsroom. ■

Using fiber optics to advance safe and renewable energy

The California Energy Commission awarded Lawrence Berkeley National Laboratory two new grants to develop fiber optics for two novel uses: monitoring offshore wind operations ($2 million) and underground natural gas storage ($1.5 million). In regard to offshore wind, fiber optic cables wrapped around the entire gearbox could provide a 3D map of changes with resolution at the millimeter scale, which could help identify problems with the gearbox at an early stage. Fiber optic cables could similarly be used to monitor the boreholes of underground natural gas storage reservoirs as well. For more information, visit https://newscenter.lbl.gov. ■

a compressive stress on the substrate glass, which prevents surface cracks from widening and thus increases the overall strength of the glass.

To test this hypothesis, Li et al. tested another set of samples with 3 µm coating cured at 180°C, a higher curing temperature than what was used for their original coatings but lower than the curing temperature used in the other study.

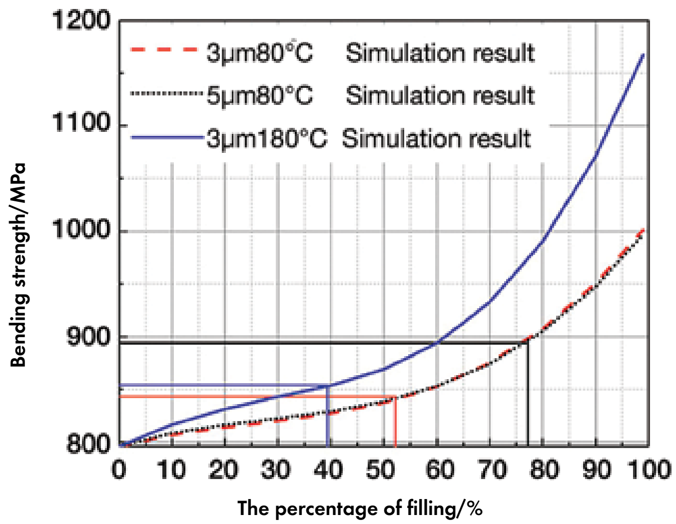
They found the elastic modulus and residual stress of the coating cured at the higher temperature were both approximately double the measurements for the coatings cured at 80°C. Yet the strength of the higher-temperature coated glass was closer to the 3 µm (80°C) coated glass than the 5 µm. This result seemed to contradict the results of the other study.

To determine other factors affecting glass strength, the researchers turned to finite element modeling. Their models showed that the coating's modulus and compressive stress values on the surface were small compared to the native values of the substrate, so small that they could not make a significant impact on strength. So the researchers then considered another factor—crack filling.

The model showed that while the modulus of the higher-temperature cured coating increases, so does its shrinkage upon curing, which means a lower percentage of crack filling. These two factors oppose each other, resulting in a lower-than-expected strength enhancement. On the other hand, the modeling indicates the 5 µm coating has greater crack filling, which leads to substantially higher strengths even with a lower modulus.

In sum, the previous study's coatings were only 0.6–0.8 µm thick and were cured at 300°C, so the major factor influencing strength in that case was the elastic modulus. But because the coatings were a lot thicker in this study and the modulus and compressive stress values compared to the substrate were negligible, crack filling had a bigger influence.

The paper, published in *International Journal of Applied Glass Science*, is "Strengthening mechanism of cover glass by sol-gel SiO_2 coating" (DOI: 10.1111/ijag.14774). ■



By matching the simulated and experimental data of glass bending strength, the actual filling ratios were obtained (the perpendicular lines). This ratio is one of three key factors affecting the ability of sol-gel coatings to strengthen glass.

Shedding light on optimal materials for harvesting sunlight underwater

New York University researchers developed guidelines for optimal band gap values at a range of watery depths. Most previous attempts to develop underwater solar cells were constructed from silicon or amorphous silicon, which each have narrow band gaps. However, the researchers' calculations revealed solar cell absorbers function best with an optimum band gap of about 1.8 electronvolts at a depth of two meters and about 2.4 electronvolts at a depth of 50 meters, suggesting solar cells made from organic materials or alloys made with elements from groups three and five on the periodic table could be ideal in deep waters. For more information, visit https://www.sciencedaily.com. ■

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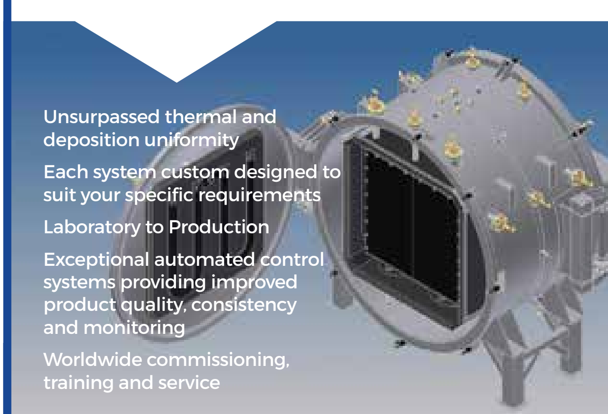

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Ceramic-plastic material might block high-pitched sounds

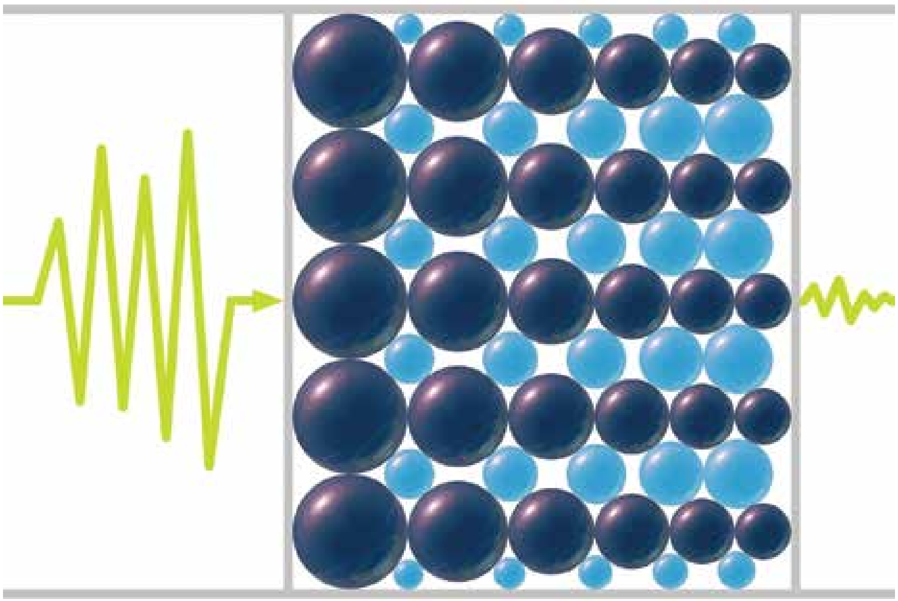
In a new study, two theoretical physicists report that materials made from tapered chains of spherical beads could help dampen sounds that lie at the upper range of human hearing or just beyond.

Luís Paulo Silveira Machado, professor of physics at the Federal University of Pará in Brazil, and Surajit Sen, professor of physics at the State University of New York at Buffalo, used computational modeling to explore how well vari-ous materials dampen incoming sounds in the low-frequency ultrasonic range, 1–100 kHz.

(While this range is "low-frequency" in terms of ultrasonic sounds, the range represents sounds on the "high-pitched" end of human hearing, which generally detects sound only up to 20 kHz.)

In their models, Machado and Sen imagined each material as spherical beads because "granular crystals have demonstrated the ability to control nonlinear pulses and affect the transmission of sinusoidal signals," they write in the paper.

They found the best setup consisted of alternating tapered chains of Delrin beads (a thermoplastic) with smaller tapered chains of tungsten carbide beads. "In computer simulations, this system effectively helped to filter high-frequency noises of varying loudness, greatly reducing these sounds," a University at Buffalo press release explains.



An illustration of the simulated noise-blocking device. Tapered chains of Delrin plastic beads (darker beads) alternating with tapered chains of tungsten carbide beads (lighter beads), surrounded by plastic walls.

Though the researchers have not yet tested the material in the laboratory, they say if it does work, the material's structure is advantageous for transferring the material to application, for example, in headphones.

"An advantage of the proposed device is its simple configuration: spherical beads properly confined and positioned," Machado says in the press release. "This proposal allows a prototype of easy construction, with low cost and little maintenance."

The paper, published in *Granular Matter*, is "Decorated granular crystal as filter of low-frequency ultrasonic signals" (DOI: 10.1007/s10035-019-0977-4). ■

Research News

Laser treatment technique turns metal surfaces into instant bacteria killers

Purdue University engineers created a one-step laser treatment method that could potentially turn any metal surface into a rapid bacteria killer just by giving the metal's surface a different texture. The laser-texturing has a dual effect—it both improves direct contact but also makes a surface more hydrophilic. They demonstrated the technique allows the surface of copper to immediately kill off superbugs such as MRSA. The technique is not yet tailored to killing viruses such as the one responsible for the COVID-19 pandemic, which are much smaller than bacteria, but they have begun testing this technology on the surfaces of other metals and polymers. For more information, visit https://www.purdue.edu/newsroom/index.html. ■

A unique heat storage technology gathers steam

An innovative system currently being developed at the U.S. Department of Energy's Argonne National Laboratory can quickly store heat and release it for use when needed. Argonne's thermal energy storage system, or TESS, is a form of latent heat storage, where the energy is contained within a phase-change material. However, while such materials are good at retaining heat, they are typically poor conductors, so it takes too long for them to absorb and release energy. To get around this limitation, Argonne researchers devised a way to embed phase-change materials within porous, highly thermally conductive foam. For more information, visit https://www.anl.gov/news. ■

Lithium-ion cathode chemistry: A review

In 2019, three scientists won the Nobel Prize in Chemistry for their work developing lithium-ion batteries. A recent review article by ACerS Fellow Arumugam Manthiram, professor and Cockrell Family Regents Chair in Engineering at University of Texas at Austin, traces the work done by John Goodenough's group on oxide cathodes.

Discovery of oxide cathodes

M. Stanley Whittingham of Binghamton University, one of the three Nobel Prize winners, laid the groundwork for rechargeable Li-ion batteries in the 1970s by discovering titanium disulfide that has a molecular structure which can house (intercalate) lithium ions. However, TiS_2-based batteries faced two major issues.

"First, the cell voltage was limited to <2.5 V, limiting the energy density. Second, dendrite growth on lithium-metal anodes during cell cycling caused internal shorting and presented a fire hazard," Manthiram explains in the paper.

In the 1980s, Goodenough's group at the University of Oxford explored cathodes made of oxides to see if such materials would increase cell voltage.

Cell voltage is determined by the energy difference between redox energies of the anode and cathode. So to achieve higher voltage, the cathode energy should be as low as possible, while the anode energy should be as high as possible.

Based on fundamental knowledge of transition-metal oxides, Goodenough knew the top of the sulfur energy band lies at a higher energy than the top of the oxygen energy band. So using oxides for the cathode would lower the cathode energy, thus increasing cell voltage.

This basic idea led Goodenough's group to discover three classes of oxide cathodes—layered oxides, spinel oxides, and polyanion oxides.

Three classes of oxide cathodes

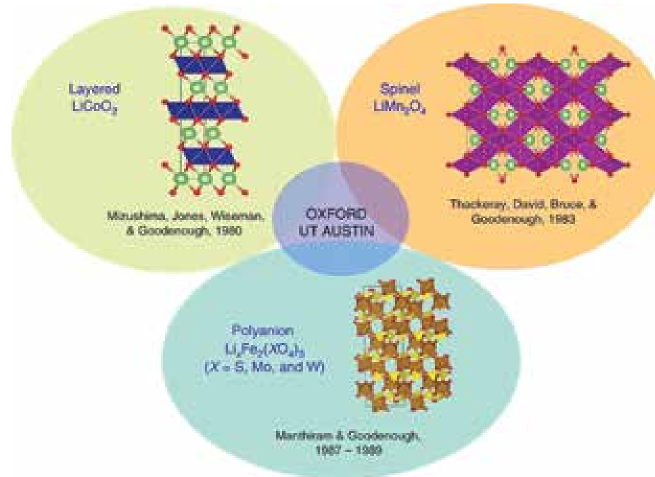
The discovery of three oxide cathode classes involved three visiting scientists from three different parts of the world—Koichi Mizushima from Japan, Michael Thackeray from South Africa, and Manthiram (from India).

Layered oxides

Mizushima worked on layered $LiCoO_2$, the first oxide cathode investigated. This cathode solved two major challenges associated with the sulfide cathodes pursued in the 1970s.

"It enabled not only a substantial increase in the operating voltage from <2.5 V to ~4 V but also the assembly of a cell without the need to employ a metallic lithium anode," Manthiram writes.

Unfortunately, the cobalt energy band overlaps with the oxygen energy band, which leads to a release of oxygen from the crystal lattice on charging more than 50%. "Therefore, despite good electrochemical performance, the practical capacity of $LiCoO_2$ is limited to ~140 mA h g^{-1}," Manthiram writes.



Credit: Manthiram, *Nature Communications* (CC BY 4.0)

The three main classes of oxide cathodes, discovered by John Goodenough's group in the 1980s.

Since then, several layered $LiMO_2$ oxides (M = 3*d* transition metals) have been investigated, including $LiMnO_2$ and $LiFeO_2$. However, they face numerous disadvantages, including structural changes during charge–discharge and charging difficulties. Instead, research in the past couple of decades has

focused on substitution of cobalt with manganese and nickel to create layered cathodes with three transition-metal ions (NMC, nickel-manganese-cobalt).

Spinel oxides

Thackeray worked on the spinel $LiMn_2O_4$, the second class of cathode discovered. Compared to layered $LiCoO_2$, $LiMn_2O_4$'s good 3D structural stability along with high electrical and lithium-ion conductivity offered even faster charge–discharge characteristics and a high operating voltage of 4 V with a practical capacity of just under 130 mA h g^{-1}.

However, one critical issue with $LiMn_2O_4$ is dissolution of manganese in the presence of H^+ ions (acidity) in the electrolyte. "Mn dissolution and its migration to the anode severely poison the graphite anode and limit the cycle life of lithium-ion cells," Manthiram writes. Fortunately, substituting a small amount of lithium for manganese "perturbs the long-range Mn–Mn interaction/contact, frustrates the Mn^{3+} disproportionation reaction, reduces Mn dissolution, and thereby improves the cyclability," he adds.

Spinel oxides are limited to the compositions LiM_2O_4 (M = titanium, vanadium, or manganese) because of difficulty in stabilizing the high oxidation states by conventional high-temperature synthesis. Of these, only the manganese-based spinel makes a suitable cathode. There have been efforts to prepare both $LiCo_2O_4$ and $LiNi_2O_4$ spinel oxides, but such attempts result in either incomplete transformation to spinel-like phases or loss of oxygen.

Polyanion oxides

Manthiram worked on polyanion oxides, the final class of oxide cathodes. He had previously worked with polyanion oxides during his Ph.D. in India and used that work to prepare the polyanion oxides $Fe_2(MoO_4)_3$ and $Fe_2(WO_4)_3$.

When compared to simple oxides, Manthiram found these polyanion oxides exhibited increased operating voltage. However, the rise of high-temperature copper oxide superconductors in the 1980s led Manthiram and Goodenough away from studying polyanion oxides for a while. It was not until the commercialization of lithium-ion batteries with $LiCoO_2$ cathode in 1991 that they refocused on polyanion oxides, specifically ones with phosphate groups (a topic they initially had Ph.D. student Geeta Ahuja explore).

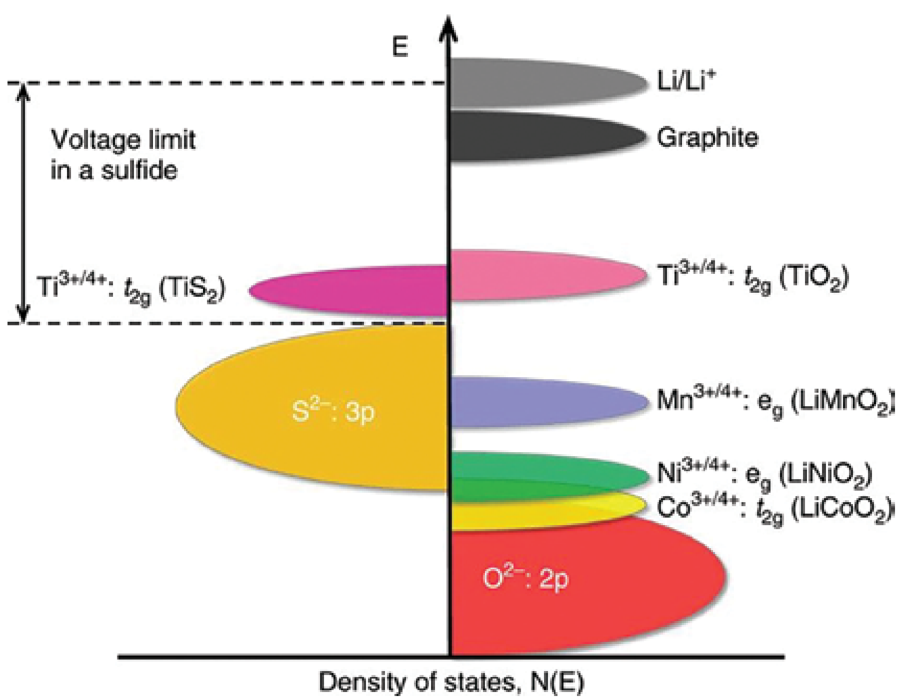
Today, polyanion oxides, especially ones with phosphate groups, have become appealing cathodes for Li-ion or sodium-ion batteries because of the ability to increase voltage drastically (up to about 5 V). Compared to layered and spinal oxide cathodes, "the polyanion oxide class with sulfates, phosphates, and silicates has become diverse ... in terms of versatility and number of materials," Manthiram writes.

The future of oxide cathodes

Among the three classes of oxide cathodes, layered oxides are the favorite candidates—at least in the near term—for their high gravimetric and volumetric energy densities. However, as industry continues with large-scale deployment of Li-ion batteries for electric vehicles and energy storage, "cost and sustainability are becoming critical," Manthiram writes.

In the conclusion, Manthiram previews some of the research taking place currently to advance Li-based battery technology, particularly lithium-sulfur batteries. Ultimately, he concludes that "innovative synthesis and processing approaches along with advanced characterization methodologies and computational analysis could aid the discovery of new materials as we continue our journey to realize a cleaner, more sustainable planet."

The open-access paper, published in *Nature Communications*, is "A reflection on lithium-ion battery cathode chemistry" (DOI: 10.1038/s41467-020-15355-0). ■



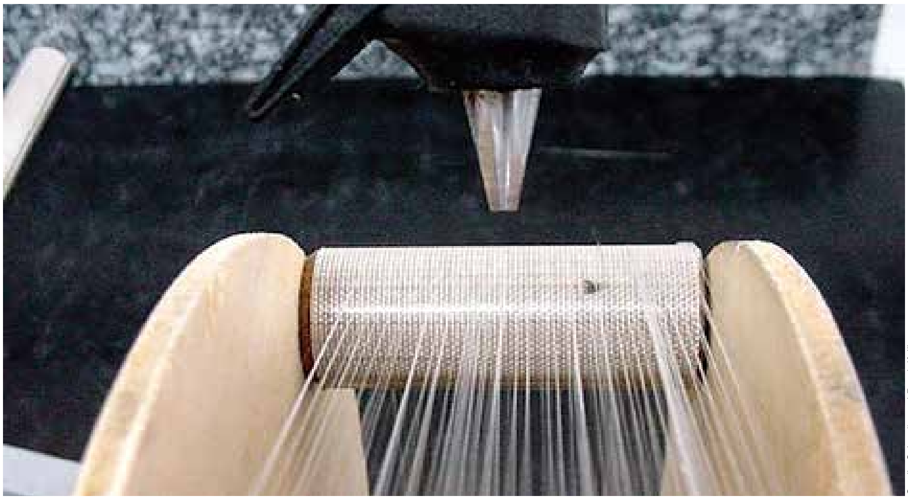
Credit: Manthiram, *Nature Communications* (CC BY 4.0)

Positions of redox energies relative to the top of the anode (*p* bands). The top of the sulfur 3*p* band limits cell voltage to less than 2.5 V. In contrast, the lower-lying oxygen 2*p* band increases cell voltage substantially to about 4 V.

Fibers from recycled beverage straws may make refractories processing safer and cheaper

Brazilian researchers Rafael Salomão (lecturer and researcher, University of São Paulo) and Victor Pandolfelli (professor, Federal University of São Carlos) looked at turning straws into anti-spalling fibers for refractory castables.

Like high-quality concrete, refractory castables are susceptible to spalling, a physical process in which surface layers of materials crumble into small pebble-like pieces in response to high temperatures and/or mechanical pressures. The pressure typically comes from water vapor trapped in the highly packed and low porosity structure of the material. When the material is heated, the water vapor cannot escape, so mechanical pressure builds and ultimately causes the material to spall.



Rafael Salomão and Victor Pandolfelli used a hot-melt glue-gun and rotating barrel to create thin continuous fibers from dense polymeric rods, which they then added to refractory castables to prevent spalling.

To reduce the likelihood of explosive spalling, a common practice in industry is adding fibers to refractory castables. This method works because the fibers dissolve or melt during initial heating of the cast part, increasing the castable's permeability and thus making it easier for water vapor to escape.

The most common fibers used in this technique are thermoplastic polymer-based fibers. Ideally, polymeric fibers that are easily degradable with low melting points suit this purpose best because the sooner the fibers melt, the sooner water vapor pressure is released.

In an email, Salomão says he has studied polymeric fibers for refractory materials with Pandolfelli since the early 2000s, when he was a Ph.D. student in Pandolfelli's lab. But the idea to use polymeric fibers from recycled straws came in 2017 when he watched a video that showed a team of researchers helping a marine turtle who was choking on a plastic straw.

"It was really disturbing for me and gave me the idea of using such plastic waste to produce fibers for refractory castables," he says.

For the recent study, Salomão and Pandolfelli collected two types of drinking straws from their university's cafeterias—thinner ones made of high-density polyethylene (HDPE) and larger ones made of isotactic polypropylene (PP)—and created several dense plastic rods by stuffing four folded straws into a single straw. They then put the rods into a hot-melt glue-gun and collected the melted plastic on a rotating barrel to create thin continuous fibers, which were chopped into 3–4-mm-long sections.

Salomão and Pandolfelli mixed the straw fibers with a high-alumina refractory castable; they also mixed a sample with unprocessed PP fibers for comparison.

Compared to unprocessed PP fibers, the straw fibers "presented a small but significant reduction in melting and decomposition temperature ranges." In particular, while the unprocessed PP fibers melted around 168°C, the straw-PP melted around 161°C and the straw-HDPE at about 141°C.

Not only did this lower melting temperature mean the castables experienced earlier permeability and shorter drying times, but "the most signicant technological impacts of such benefits are the reduction of energy and time consumption during the installation of refractory castables and the possibility of finding a better way of disposing of plastic waste," Salomão and Pandolfelli write.

However, they point out that refractory castables alone cannot deal with the entire straw production each year. "…Even if the estimated entire world annual production of pre-shaped and monolithic refractories were considered (approximately 8–10 × 10^6 tons), it would require almost 20 years of refractory consumption to use the straws produced in a single year," they write.

Fortunately, they note that the results suggest these fibers can be used in civil construction concretes to prevent explosive spalling as well. And based on annual yearly production of civil concrete over the past decade, "it would require 5–30 × 5.10^6 tons of recycled fibers, which is roughly 30–160 times greater than the annual production of straws," they conclude.

Salomão says they plan to test the fibers in construction concrete under firing conditions. They also intend to optimize the melt-spinning process to produce thinner fibers in a more reliable and reproducible way.

The paper, published in *Ceramics International*, is "Anti-spalling fibers for refractory castables: A potential application for recycling drinking straws" (DOI: 10.1016/j.ceramint.2020.02.122). ■

Two improvements in MXene processing

In the same month, two Drexel groups each published papers describing new ways to improve MXene processing.

Scaling production: From one to fifty grams

In the first paper published in *Advanced Engineering Materials*, Yury Gogotsi's group collaborated with researchers at the Materials Research Center in Ukraine to scale production of MXenes.

For many 2D materials, challenges to large-scale synthesis "typically stem from bottom-up approaches limiting the production to the substrate size or precursor availability for chemical synthesis and/or exfoliation," they write in the paper. MXenes are produced via a top-down synthesis approach, though, so "the process can be readily scaled with reactor volume."

Despite the theoretical possibility to scale MXene synthesis, no studies to date demonstrate large-scale production—until this study, that is.

Using a lab-scale reactor system developed at the Materials Research Center, the researchers created large batches (50 g) of the MXene titanium carbide ($Ti_3C_2T_x$). They then used X-ray diffraction, Raman spectroscopy, and X-ray photoelectron spectroscopy to compare the composition and structure of large-batch MXenes to MXenes prepared in a small batch (1 g).

"The characterization of the two MXene batch sizes indicates that there is essentially no difference between the produced materials," the researchers write.

In a Drexel press release, Gogotsi says usually producing nanomaterials in large quantities is only a first step toward industrialization. "…it often requires inventing completely new machinery and processes to get them in a form that can be inserted into the manufacturing process," he says.

However, integrating MXenes into the manufacturing line is fairly easy.

"One huge benefit to MXenes is that they can be used as a powder right after synthesis or they can be dispersed in water forming stable colloidal solutions," Gogotsi says. "Water is the least expensive and the safest solvent. And with the process that we've developed, we can stamp or print tens of thousands of small and thin devices, such as supercapacitors or RFID tags, from material made in one batch."

The paper, published in *Advanced Engineering Materials*, is "Scalable synthesis of $Ti_3C_2T_x$ MXene" (DOI: 10.1002/adem.201901241).

Credit: Shuck et al., Drexel University

Images from Gogotsi's group of the precursor Ti_3AlC_2 MAX (left) used in synthesis of 50 g $Ti_3C_2T_x$ batch (right).

Nonaqueous etching of MXenes

The second paper by Michel Barsoum's group addresses a part of the synthesis process that Gogotsi mentioned briefly above—using water as the solvent.

Water is used often to dilute the etching acid during MXene chemical synthesis. And while it may be "the least expensive and the safest solvent," it poses problems in certain applications.

"It is known that even slight presence of water in lithium or sodium ion batteries using organic electrolytes can be detrimental to their performance," Varun Natu, first author and doctoral researcher at Drexel University, says in a Drexel press release. When used as a solvent, traces of water can be left in the MXene, which is detrimental in these battery applications.

In light of this situation, the Drexel researchers decided to develop an etching process that would not require water.

For their study, the researchers used a variety of organic solvents and ammonium dihydrogen fluoride, a chemical commonly used to etch glass. "This solution does the etching, in part because it breaks down into hydrofluoric acid, but it does not require water to dilute it or to wash away the by-products of the etching process," the press release explains.

Not only did they show synthesis was possible with this process, they also demonstrated that electrodes made from MXenes etched in propylene carbonate resulted in sodium-ion battery anodes with nearly double the capacity to those etched in water.

"This finding opens up a huge new field of research: nonaqueous etching of MXenes," Barsoum says in the press release. "We believe that this work will prove useful not only to the MXene community, but also to researchers throughout the field of materials science."

The paper, published in *Chem*, is "2D $Ti_3C_2T_z$ MXene synthesized by water-free etching of Ti_3AlC_2 in polar organic solvents" (DOI: 10.1016/j.chempr.2020.01.019). ■

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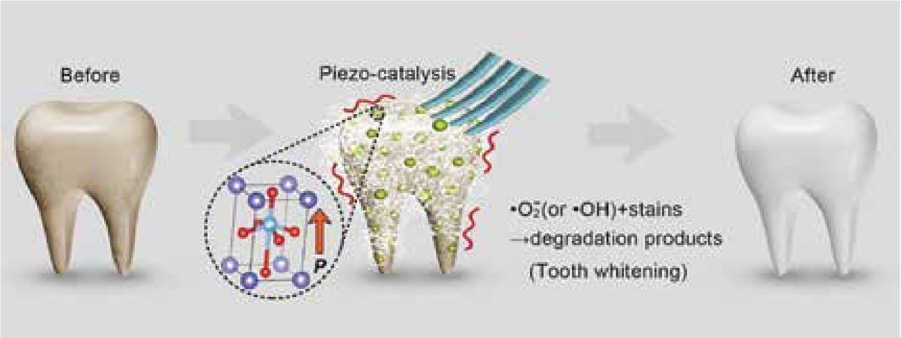
Piezocatalysis effect offers nondestructive tooth whitening



Credit: Wang et al., Nature Communications (CC BY 4.0)

A proposed piezocatalysis effect-based method for whitening teeth could be safer than current methods.

Researchers from several universities in China propose a new nondestructive method for whitening teeth.

Common methods for whitening teeth—including professional cleaning and polishing, coverage with crowns or veneers, daily brushing with abrasive toothpaste, and bleaching—all can damage teeth.

"Both professional procedural cleaning and coverings require grinding or other enamel-cutting steps, which cause irreversible damage," the researchers write in the paper. Also, "abrasive cleaning exhibits limited efficacy and, furthermore, causes slight scratches to the surface of teeth."

While bleach treatment is highly efficient, "bleaching with hydrogen peroxide may cause serious side effects, i.e., loss of organic matrix and increase of enamel micro-roughness," they add.

Their method uses a mechanism similar to bleaching. During bleaching, hydrogen peroxide decomposes in water and releases unstable, reactive oxygen species. These species attack organic pigment molecules on the surface of teeth and degrade staining compounds by oxidation.

"This mechanism suggests that a material with the capability to excite and release reactive oxygen species could be effective as a tooth whitening agent," they write.

A 2018 study explored producing reactive oxygen species using the photocatalysis effect of blue-light-activated TiO_2 nanoparticles. While this method was nondestructive to teeth, it "may cause various photo-toxic and photo-allergic reactions, and in turn lead to damage to oral tissue, because blue light is required as a stimulus to produce reactive oxygen species," they explain.

In their new study, the researchers looked to produce reactive oxygen species using the piezocatalysis effect instead. In contrast to photocatalytic reactions, which are induced using light, piezocatalytic reactions are mechanically induced.

The researchers explain that in application, piezoelectric nanoparticles would replace nanosized abrasive particles in toothpaste; mechanical vibrations caused by normal tooth brushing would trigger the piezocatalytic reaction. For this study, though, the researchers created liquids of piezoelectric nanoparticles and used ultrasonic vibration to simulate daily tooth brushing.

The researchers used barium titanate ($BaTiO_3$, BTO) in both poled and unpoled conditions to investigate the differences because "piezoelectric properties can be significantly improved by electric poling."

The researchers stained teeth with either black tea, blueberry juice, wine, or a combination of these liquids. They then placed the teeth in either water or (un)poled BTO liquids and vibrated the samples up to 10 hours.

The poled BTO liquid noticeably whitened teeth after vibration for 3 hours. In contrast, the unpoled BTO liquid and water showed negligible whitening effect.

To further verify these results, the researchers then carried out an experiment using a lab-made electric toothbrush setup. The toothbrush cleaned teeth by vibrating water or poled BTO liquid periodically at 2-minute intervals for 10 hours. As with ultrasonic vibration, the poled BTO liquid showed a whitening effect while water did not.

While these results showed piezocatalytic reactions led to whitening, the researchers needed to verify the method was nondestructive to teeth.

To verify, they compared scanning electron microscopy images of teeth cleaned with either poled BTO or hydrogen peroxide. Results were as expected—the tooth whitened using hydrogen peroxide showed erosion and extensive damage in its enamel, while the BTO-whitened tooth did not.

"The relative lack of enamel deterioration using BTO nanoparticles further indicates that the reactive species created by piezo-catalysis of BTO nanoparticles are less than that created by 3% H_2O_2 during the tooth whitening process," they write.

In the conclusion, the researchers discuss the potential this method holds for daily life.

"Unlike existing techniques, piezo-catalysis tooth whitening has the potential to be widely adopted for home use, without requiring significant investment from consumers in either time or resources," they write.

In particular, the proposed method "can be effective when incorporated in a daily toothbrushing regime that replaces toothpaste made using traditional, passive abrasives with piezoelectric particles—particularly when used in conjunction with the strong, high frequency excitation present in traditional electric toothbrushes."

The open-access paper, published in *Nature Communications*, is "Piezo-catalysis for nondestructive tooth whitening" (DOI: 10.1038/s41467-020-15015-3). ■

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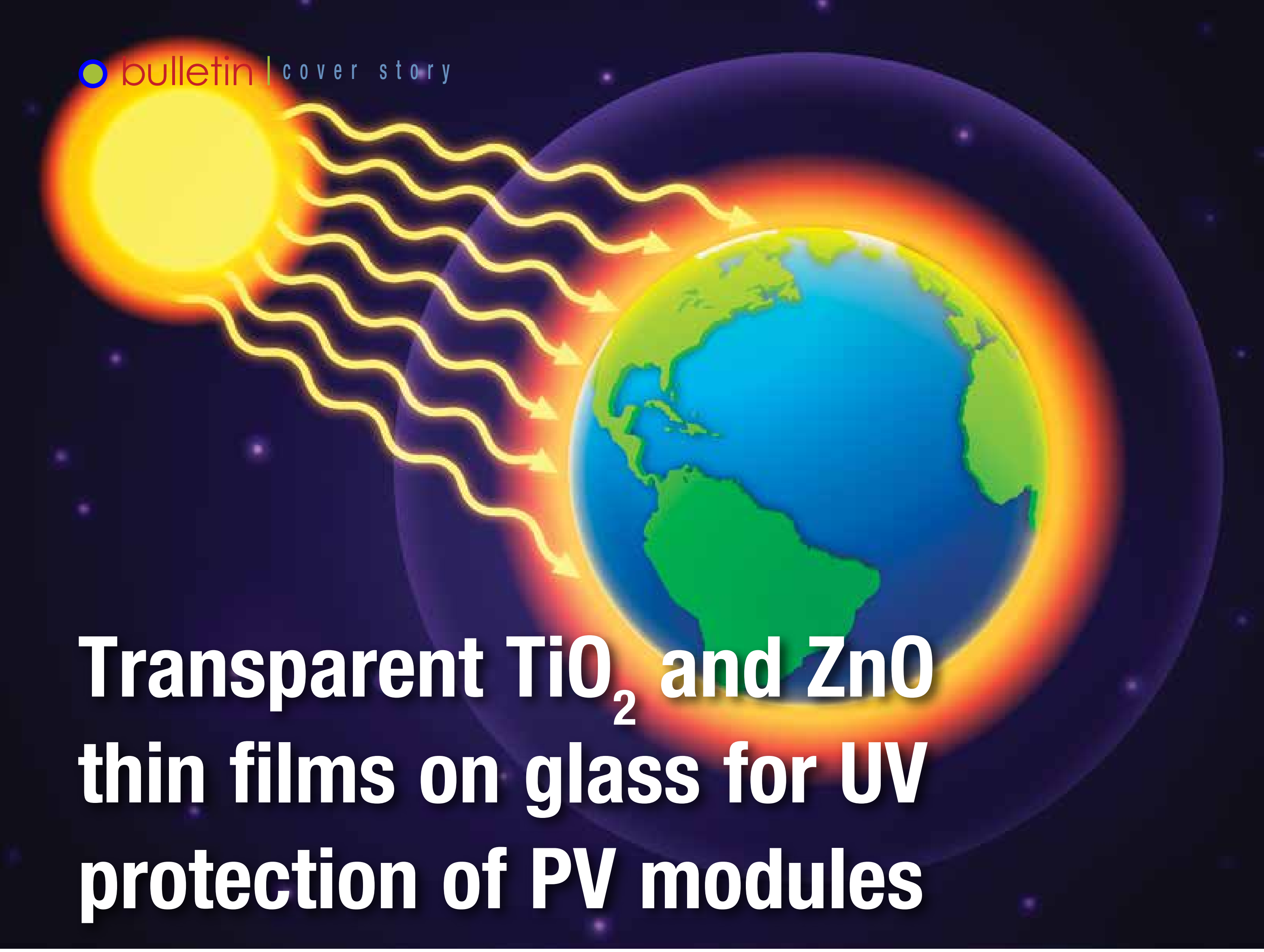

Transparent TiO_2 and ZnO thin films on glass for UV protection of PV modules

By Wilhelm Johansson, Albert Peralta, Bo Jonson, Srinivasan Anand, Lars Österlund, and Stefan Karlsson

Failure of photovoltaic modules frequently occurs as a result of degradation of their encapsulation material by destructive UV radiation. Transparent TiO_2 and ZnO thin films could protect against these harmful wavelengths.

To stabilize the global temperature and mitigate climate change, the emission of anthropogenic greenhouse gases will have to be greatly reduced. To make it possible, the energy sector will have to transfer from fossil energy to environmentally friendly and carbon neutral sources.[1]

Solar energy exists in abundance. In roughly 90 minutes, the solar energy that reaches the earth equals the consumption of all human societies globally during one year.[2] Only a fraction of this energy is captured today, and photovoltaic (PV) modules account for a marginal part of the electricity production worldwide, around 1.8% at the end of 2016. In recent years, however, the sector has been growing exponentially at a rapid rate, which means that the ability to increase efficiency and lifespan of PV modules is interesting from an energy perspective.[3]

PV modules consist of a number of interconnected PV-cells, embedded in an encapsulant and a protective cover glass on the top. One of the issues facing the PV modules available today is the degradation of their encapsulant, which most often consists of ethylene vinyl acetate (EVA).

This article is excerpted from “Transparent TiO_2 and ZnO thin films on glass for UV protection of PV modules,” *Frontiers in Materials*, October 2019 (CC BY 4.0). https://doi.org/10.3389/fmats.2019.00259

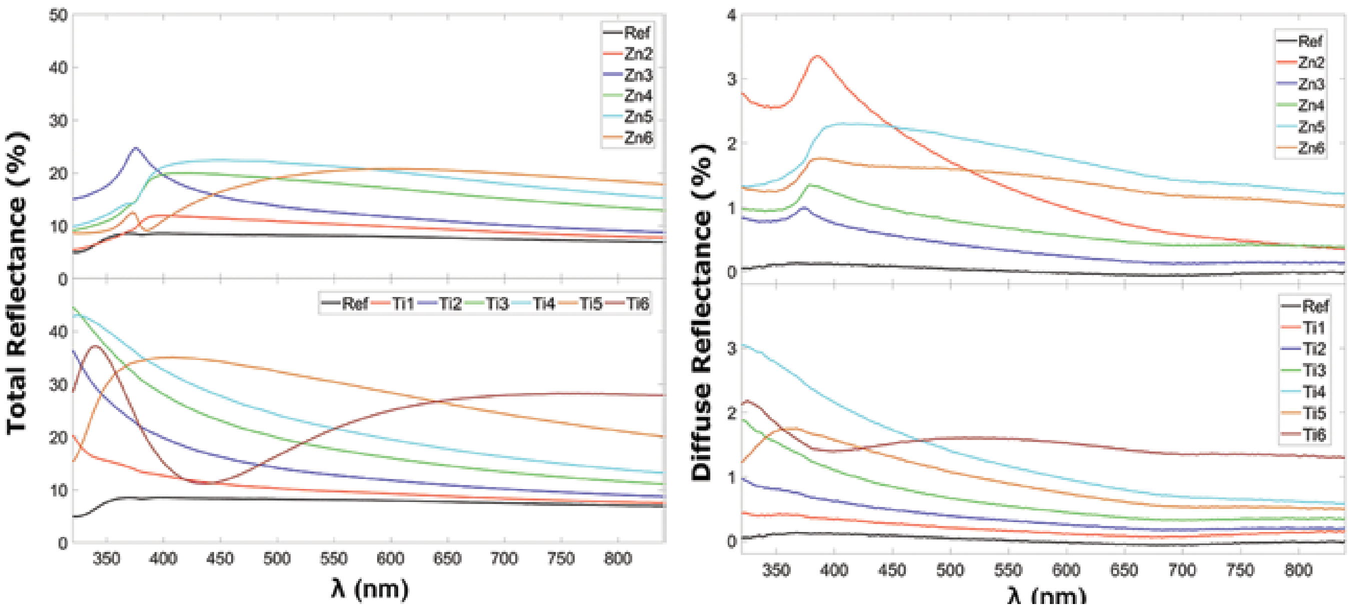

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Figure 1. (a) Total reflectance and (b) diffuse reflectance of thin film-coated glass samples.

It is damaged by UV radiation with wavelengths below 350 nm. The UV radiation makes the encapsulant degrade and acquire a yellow and eventually brown hue, which reduces the efficiency of the PV modules.[4,5]

Developing the cover glass has become increasingly important as the share of cost for the cover glass is high.[6] The cover glass[7,8] has several important functionalities, e.g., providing optimal light capture, rigidity, mechanical protection, and chemical protection. Optimal light capture depends on the optical properties of the cover glass, such as absorption and reflection. The latter comprises the largest part, about 8% for a typical flat glass, which can be minimized by employing antireflective coatings.[9]

The optical properties of flat glass[10,11] are affected by the presence of iron impurities in the glass melt as the iron in the glass increases the absorption of light in the glass in the UV-Vis region of the electromagnetic spectrum. Iron can be used as a colorant of glass, giving the glass a green tint.[12] In some cases, this is a positive feature, e.g., when UV-protection is needed in beer and champagne bottles.[13] In other cases, as with PV-modules where transparency is coveted,[14] the iron in the glass is considered as a contaminant. In these cases, low-iron glass, where measures have been taken to reduce the iron in the glass, is frequently used.

Table 1. Composition of precursor solutions

	Isopropanol (ml)	Zn (acac)2 (g)	Ti-isopropoxide (ml)	Wt% metalorganic complex	Mol% metalorganic complex
Zn solution	150	0.62	-	0.5	0.12
Ti solution	100	-	2.5	3	0.64

Table 2. Sample series (amount of solution sprayed in grams)

Sample ID	1	2	3	4	5	6
Zn solution (g)	-	12	16	24	32	40
Ti solution (g)	2	4	6	8	12	18

In the case of cover glass for PV modules, the trend has been to use low-iron glass to increase transmitted light.[8] A drawback to this type of glass is that a larger amount of high-energy UV radiation is transmitted, which is harmful to the encapsulation material EVA that is used in most PV modules today.[15] When UV radiation below 350 nm reaches the PV module, both the semiconductor material[16] and the laminate[5,17] are degraded. The degradation of the EVA laminate is the major reason for the annual degradation of 0.6–2.5%.[17,18] As a result of the UV radiation, EVA degrades and loses some of its high transmissivity as it gets a yellow/brown hue and eventually starts to delaminate, letting moisture into the PV modules, which leads to failure of the PV module.[5]

In the current study we have investigated float glass coated with ZnO and TiO_2 thin films by spray pyrolysis of organometallic compounds of zinc and titanium (Table 1 and 2).

Results

Glass coated with ZnO showed a trend to shift the UV-cutoff to longer wavelength as well as lowering the optical band gap of the coated glass sample. The major reason for this is likely to be caused by tetrahedrally coordinated Fe^{3+} having an absorption peak at about 380 nm but also being sensitized by the presence of the ZnO coating. Such a trend is less clear for the samples coated with TiO_2.

Both sample series showed a significant increase in total reflection for the normal incident light due to the higher refractive index of the thin film oxide coatings (Figure 1a). However, the increase in diffuse reflection was significantly lower, less than 4% (Figure 1b); this is an advantage for application on the cover glass of PV-modules where most of the incoming light will be of diffuse character.

The coated glass showed a potential improvement in life expectancy of PV modules through a decrease of destructive UV-radiation transmission to the encapsulant up to a relative 36.0% and 54.3% for TiO_2 and ZnO coatings, respectively. Additionally, although the coated samples have shown a relative transmission reduction at the useful spectral region up to 21.8 and 12.3% for TiO_2 and ZnO coatings, respectively, the transmissivity degradation of the encapsulant should be effectively prevented.

For ZnO it is evident that the Fe^{3+} content plays an important role for the UV-blocking activity, which would be a tradeoff between limiting the glass's iron content while still having enough UV protection. Furthermore, ZnO-coated glass also showed potential regarding down conversion of UV light to visible wavelength with peaks at 377 nm and 640 nm. Thus, ZnO is feasible to be investigated for application as coating to cover glasses of PV modules but must be optimized as there is a tradeoff between UV-blocking and transmittance in the useful spectral region for PV modules (Table 3).

Implications for PV modules

We have shown that UV blocking can be achieved with the cost of reducing the transmittance. This opens the possibility for maintaining UV protection and gaining useful energy for the PV by lowering the Fe_2O_3 content in the glass without compromising the service lifetime of the PV module. The energy balance for transmitted and useful light for PV modules will be possible to model and optimize in future studies based on information as, for instance, possible limits for Fe_2O_3 content, cost, and efficiency.

Furthermore, photon energy downconversion, i.e., photoluminescence, can be an advantage and a route to utilizing UV light while still not exposing the PV cells to UV light. As for disadvantages, we can list higher reflectivity and scattering. If the surface coating is properly structured, it might not be a serious disadvantage or perhaps even an advantage,[19] as the diffused light contains in fact more photons than the direct light of normal incidence. This is especially valid for façade-applied PV modules where there is in fact very little solar radiation of normal incidence.

Another parameter not previously mentioned is the factor of heat. A photon's energy that is not converted into electricity is transformed into heat that in fact lowers the efficiency of the PV module. Beyond the scope of the current paper we would also like to draw the attention to making crystalline ZnO or TiO_2 coatings having similar beneficial properties but with the added value of photocatalysis[20,21] and hydrophilic behavior with UV exposure,[22,23] thereby giving PV-covered glasses reduced maintenance. Doped ZnO also offers another dimension as a transparent conductive coating offering possible IR reflection for wavelengths nonconvertible to energy for PV modules.[8]

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Table 3. Optical properties of coated glass samples

Sample	Fraction of UV light blocked (%)	Transmittance (%)	Optical bandgap, EG (eV)	UV cutoff wavelength (nm)	RMS roughness (nm)
Estimated error	±2	±2	±0.01 (±2)	±2	±1
Reference	54.6	85.2	3.53 (351 nm)	322.7	0.5
Zn2	73	79.8	3.57 (347 nm)	325.6	31.0
Zn3	73	80.3	3.58 (346 nm)	325.6	4.2
Zn4	83.4	75.7	3.58 (346 nm)	329.6	8.4
Zn5	84.7	74.1	3.58 (346 nm)	330	8.0
Zn6	84.2	74.7	3.59 (345 nm)	330.4	8.0
Ti1	57.3	83.9	3.54 (350 nm)	323	2.0
Ti2	63.6	81.6	3.52 (352 nm)	323.6	2.7
Ti3	70	76.9	3.51 (353 nm)	324.1	5.4
Ti4	71.5	75.2	3.53 (351 nm)	324.2	4.4
Ti5	67.5	69.8	3.55 (349 nm)	323.6	11.6
Ti6	74.2	66.7	3.54 (350 nm)	324.8	4.8

manager at RISE Research Institutes of Sweden, Glass section (Sweden). Contact Karlsson at stefan.karlsson@ri.se.

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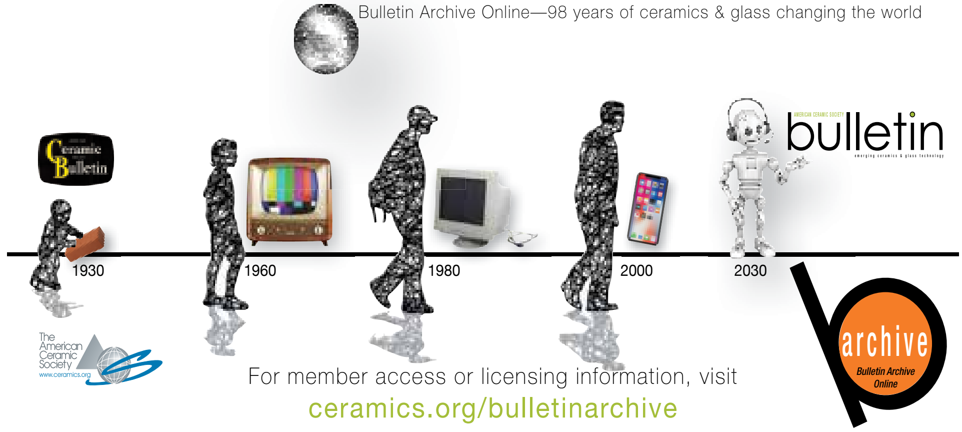

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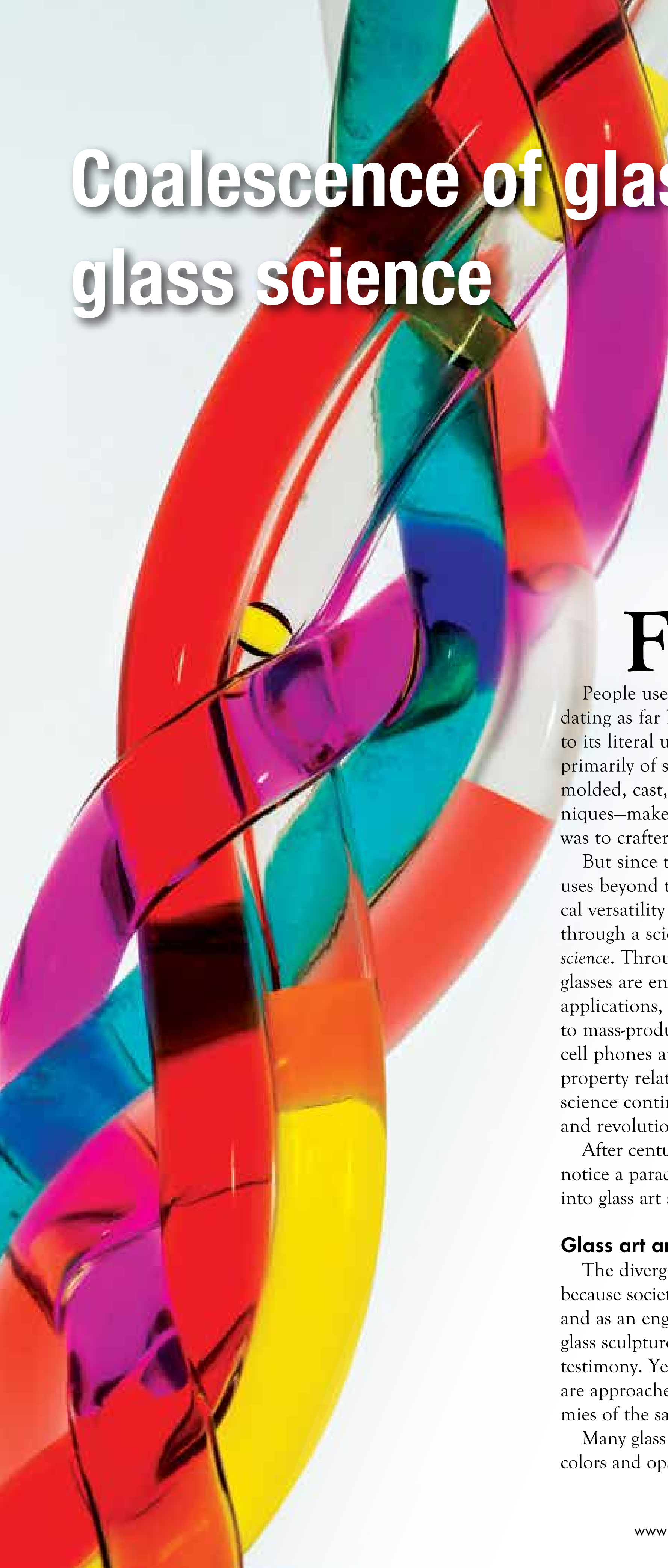


Coalescence of glass art and glass science

By Nadia A. Elbaar, Briana L. Bennett, Jane B. Cook, and John C. Mauro

Glass art and glass science often are viewed as dichotomies of the same material study. But these two areas complement each other in theory and utility—which makes promoting a dialogue between the two disciplines a fulfilling endeavor.

For millennia, glass has played an integral role in our daily lives.

People used glass to craft objects both functional and artistic dating as far back as 2000 BCE in Mesopotamia,[1] partially owing to its literal ubiquity—the most common silicate glasses consist primarily of sand. And the material's shape versatility—it can be molded, cast, blown, cut, and flameworked, among other techniques—makes it a highly appealing medium to artists today as it was to crafters in antiquity.

But since the latter part of the 19th century, glass found many uses beyond the artistic realm. Its structural strength and chemical versatility provided incentive to study glass and its properties through a scientific framework and to inculcate the term *glass science*. Through precise chemical modifications, common silicate glasses are enhanced and transformed to serve in a wide array of applications, from float glass panes used in building construction to mass-produced drink bottles to tactile devices used in today's cell phones and electronic screens. But the multitude of structure-property relationships in glass leaves much still to study, so glass science continues to be a prolific field with impact both ordinary and revolutionary.

After centuries of both artistic and scientific advancement, we notice a paradigm shift in today's world: the divergence of glass into glass art and glass science.

Glass art and glass science: A recent dichotomy

The divergence between glass art and glass science is interesting because society excels in working with glass as an artistic medium and as an engineering material—we can look easily to numerous glass sculptures and patents generated over the recent century as testimony. Yet, broadly defined, modern glass art and glass science are approached by many glass makers and researchers as dichotomies of the same material study.

Many glass artists discerningly select glass frits in a spectrum of colors and opacity, with less interest in the composition control of

Figure 1. Modern glass mosaic. Chris Wood's *Light Wall* at the National Convention and Exhibition Center in Taipei, Taiwan. Over 2,500 large "fins" made of glass and dichroic film are installed along the perimeter of the top floor. Done in collaboration with Hu's Art in 2019. From artist's website, with permission.[4]

Credit: Chris Wood

additive elements that made their creative palette. On the other hand, many glass scientists in their experiments narrow their focus on a single material parameter to control for a specific predetermined purpose, indifferent to or unaware of potential array of corollary applications that would delight the glass artist.

This dichotomy was not always the status quo and, indeed, only appeared relatively recently. At the end of the Renaissance period, i.e., Europe in the 1600s, glassworking was the domain of trained artisans engaged in the apprentice-journeyman-master craft structure and rarely documented on paper. In 1612, Florentine glassmaker, alchemist, and Catholic priest Antonio Neri published *L'Arte Vetraria (The Art of Glass)*, revealing in detail previously unwritten procedures for artistic and functional glass formulation we now attribute to Renaissance art.[2]

L'Arte Vetraria is more than a field manual of medieval glass how-tos; it is a detailed record of Neri's experiments and results in formulating glass—not unlike a lab notebook in research today. He was neither decisively glass artist nor glass scientist and yet, over 400 years ago, Neri created glass with the discipline of both. In Neri's time, glassworkers applied skill as well as an aesthetic flourish, much like today's artists. It also suggests a rigorous practical component, as well as a scholar-like intuition for formulation details, much like today's scientists.

We suggest that, by today's dichotomous view, Renaissance glassblowers all the way to their predecessors in antiquity were both glass artists and glass scientists. As to the present dichotomy, we might suppose that the invention of borosilicate glass by Otto Schott cemented the role of the material not merely as decorative luxury but as a means to technology and industry and furthermore to a scientific field of its own: the eventual conception of glass science.[3]

To help bridge this perceived dichotomy of fields, in this work we feature pieces from several exemplary contemporary glass artists with special focus on interplaying scientific concepts.

Glass optics and *Light Wall*

Discussions of glass art often bring up the archetypal example of stained-glass windows in churches. Looking up at such stunning mosaics fills people with wonder—one persistently imprinted on our aesthetics since the Middle Ages, when crafters first used colored glass for this purpose. It affirms perhaps the most beloved property of glass in art: how beautifully light shines through the material. It is an essential quality that modern glass artists, such as Chris Wood (United Kingdom), continue to harness and elevate in their work today.

Visitors to Taiwan's National Convention and Exhibition Center can appreciate how Chris Wood harnesses light in his piece *Light Wall*, a large-scale installation spanning the perimeter of the building's top floor (Figure 1).[4] For this work, Wood arranged the placement of over 2,500 glass panels (affixed with dichroic film) that, together with ambient light, inspire moments of optical beauty with its surroundings. The result is a dynamic work of art that is constantly in movement, as sunlight is refracted in contrasting flickers of color: every moment brings an effervescence of chromatic beauty.

This visual pleasure is accomplished by optics, the physics governing light interaction with a material. What makes glass appealing, scientifically and artistically, is how easy it is to modify any desired optical property, such as reflection, transmission, and refraction. For example, color in glass can be created several ways, such as dissolution of transition metal ions into molten glass and precipitation of nanoparticles of gold, silver, and semiconducting chalcogenides. Each technique alters the range of wavelengths (colors) transmitted and absorbed. When natural light, which consists of not one but many colors (the visible spectrum of wavelengths), interacts with colored glass, the light is split into its different wavelengths

Credit: Flavie Audi

Figure 2. Flavie Audi's *Fluid Rocks* Series. (a) *Fluid Rock 26*, 2017, glass with fine gold; (b) *Fluid Rock 6*, 2016, glass with fine gold and silver. From artist's website, with permission.[5]

and provides unique ranges of hue and saturation. In this way optics makes an impressive artistic palette, in the very literal sense of the word, because artists have all the colors of the rainbow at their disposal.

Supercooled fluids and *Fluid Rocks*

Glass is a peculiar material, in its ability to appear fluid and yet firm and unyielding to the touch. Artist Flavie Audi plays with this paradoxical property in her series *Fluid Rocks* (Figure 2).[5] Each stone in *Fluid Rocks* artfully portrays glass as a noncrystalline "liquid-like" material, in the scientific definition as well as an aesthetic description.

From a materials science standpoint, a substance is noncrystalline when its atomic structure does not exhibit long-range order, in contrast to highly-ordered crystalline solids. Consider the simplest glass former, silicon dioxide (SiO_2), as an example. In its crystalline solid form, the bonding around every silicon atom is uniformly tetrahedral with an oxygen atom at the vertices, and periodic ordering of Si-O bonds is observed throughout the structure. As crystalline SiO_2 is heated close to its melting temperature, Si-O bonds that were previously rigid increasingly stretch and bend with disorder until it reaches beyond the melting point, where the arrangement of silicon and oxygen bonding is no longer uniform, and the structure thus loses the long-range order present in its crystalline phase. This disordered liquid configuration can be suspended in the material by supercooling, i.e., rapidly cooling the melt below its melting temperature (also its crystallization temperature), such that the disordered Si-O bonds become "frozen-in" and rigid at the lower temperature. The resulting solid-like material has a structural configuration that is like a liquid with no discernable long-range ordering.

Glass artists like Flavie Audi understand the "freezing-in" phenomenon in glass exceptionally well—they see it during glassblowing. Consider, for example, soda lime silicate, a common glass type. It has a liquidus temperature of 1,050°C and a glass transition temperature—the temperature where the transformation between liquid and glass is observed—of 570°C. Glassblowing this material involves melting sand inside a batch furnace at 1,100°C, at which point it is entirely liquid; it is then gathered, becomes glassy, flash-heated, and worked as it cools completely to a rock-like shape. Audi elaborates in an email that each piece in *Fluid Rocks* illustrates this process by "[appearing] like apparitions of the original form, returning to a rock-like physicality through a process of transformative material states; once rock, becoming sand into glass, appearing as rock once again."[6]

While individual glass artists may or may not know exactly the glass transition temperature of their creative medium (a value which varies based on numerous other factors), they are acutely and instinctively aware that glassworking affords a very hot, very narrow time window to do their work. Therefore, it would be categorically wrong to imply that a glass artist does not use glass science, but generally glass artists are disentangled from the myriad technicalities and terminologies of "supercooled liquids," "configurational entropy," "frustrated crystallization," and more that glass scientists routinely address in their study of the material.

Iridescent films: Kayleigh Young and cellulose nanocrystals

As previously suggested, an important aspect in appreciating glass art is through its interaction with light, i.e., its optical behavior. In the previous examples, this interaction mainly involved some wavelengths of light being absorbed (as light passes through glass, at the near-surface or in bulk) and refracted. Iridescence refers to the appearance of a surface to change color based on viewing angle or angle of incident light, a phenomenon that Kayleigh Young (West Midlands, U.K.) showcases in many of her works.

In Young's glass pieces (Figure 3), the striking iridescent shine plays with the viewer.[7] The glistening sheen of purples, blues, and greens that reflect off these sculptures can impel a second glance of disbelief and curiosity.

Iridescence in Young's glass art is due to light reflecting off metals on the glass surface. Silicate glasses and metals are materially totally distinct, as they have

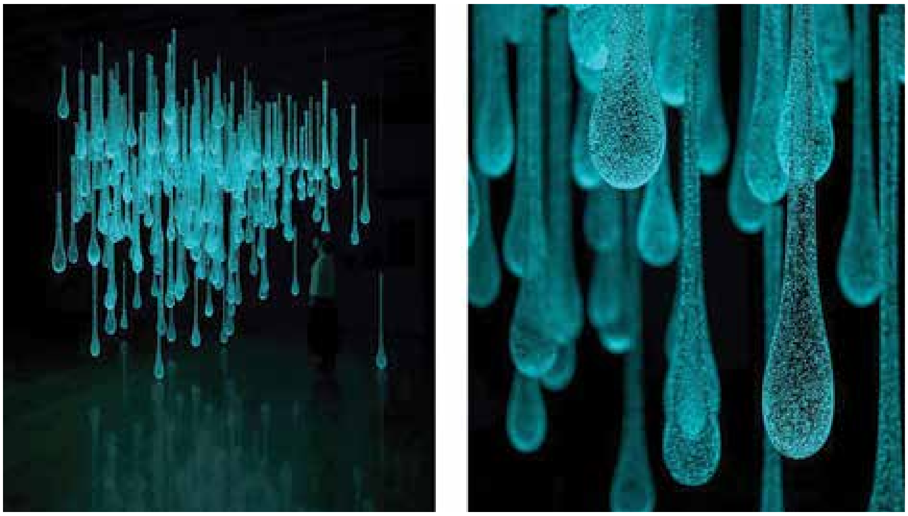
Credit: Kayleigh Young

Figure 3. Kayleigh Young's artwork catches the eye with beautiful metallic finish. The use of a chemical mixture sprayed onto a piece then placed into a reducing atmosphere allows these shimmering colors to be brought to life. From artist's website, with permission.[7]

different chemical bonding types. These metals are incorporated in the sculpture during the glassblowing process, slightly tweaked from a standard procedure to ensure the thin film dispersed on the surface imparts the desired iridescence. To finish the piece with a thin film exterior, Young sprays her shaped piece with a stannous chloride (or tin (II) chloride, $SnCl_2$) solution. Then the piece undergoes heat treatment in a reducing atmosphere. This process chemically reduces much of the tin to its metallic state, together with some transparent SnO_2 on the surface. Ultimately, the combination of transparent thin films of SnO_2 with an underlying metallic tin layer on the surface gives the piece its iridescent and reflecting qualities and the varying colors apparent with different viewing angles.

Glass research more rigorously explores the property of iridescence, such as one study at the University of British Columbia. Scientists there fabricated iridescent glass films that reflect certain wavelengths (such as visible, infrared, or ultraviolet) by tuning the shape and length of pores within the material.[8] This tuning is achieved by mixing nanocrystals of cellulose (a versatile natural polymer commonly extracted from wood pulp) with a silica former in an initially wet mixture that is then dried.[8,9] Cellulose nanocrystals in the wet mixture tends to arrange into a helical (chiral nematic phase) structure, which can suspend with long-range order configuration as the mixture dries in a glass transition-like process.[9] After drying, the samples are heated to burn off (pyrolize) the cellulose leaving helical pores in the silica microstructure.

The apparent iridescence of these films is due to their reported submicron pitch measurement and has a potential (photonics band gap) for novel optical uses.[8] That is, this nanocrystal cellulose-silica system iridizes due to Bragg reflection of visible light, which is possible only if 1) the helical pitch measurement is on the order of hundreds of nanometers and 2) incident light occurs along, not normal to, the helix structural axis.[9] This seemingly simple condition in practice challenges with experimental constraints and questions for tuning the process, including phenomenological explanations, relevant kinetic parameters, and considerations of best characterization methods.[9] Fortunately, this domain of experiments-and-results and sometimes-contradictions galvanizes scientific growth and drives the artist toward a deeper appreciation for the complex properties of the material.



Credit: Rui Sasaki, Corning Museum of Glass

Figure 4. *Liquid Sunshine / I am a Pluviophile*, Rui Sasaki, Japan, Kanazawa, Ishikawa, 2018. Blown glass with phosphorescent material, broad spectrum UV lights, motion detector. 33rd Rakow Commission. Photo by Yasushi Ichikawa. From Corning Museum of Glass website, with artist permission.[10]

Photosensitivity: Rui Sasaki and Don Stookey

In addition to the well-known optical properties on display in glass art, other properties can be showcased as well, such as phosphorescence.

Phosphorescence describes light emitted by a material without combustion or perceptible heat. The glass installation *Liquid Sunshine/I am a Pluviophile* (a Rakow Commission piece for Corning Museum of Glass) by Rui Sasaki (Japan) harnesses this property to create a truly interactive experience (Figure 4).

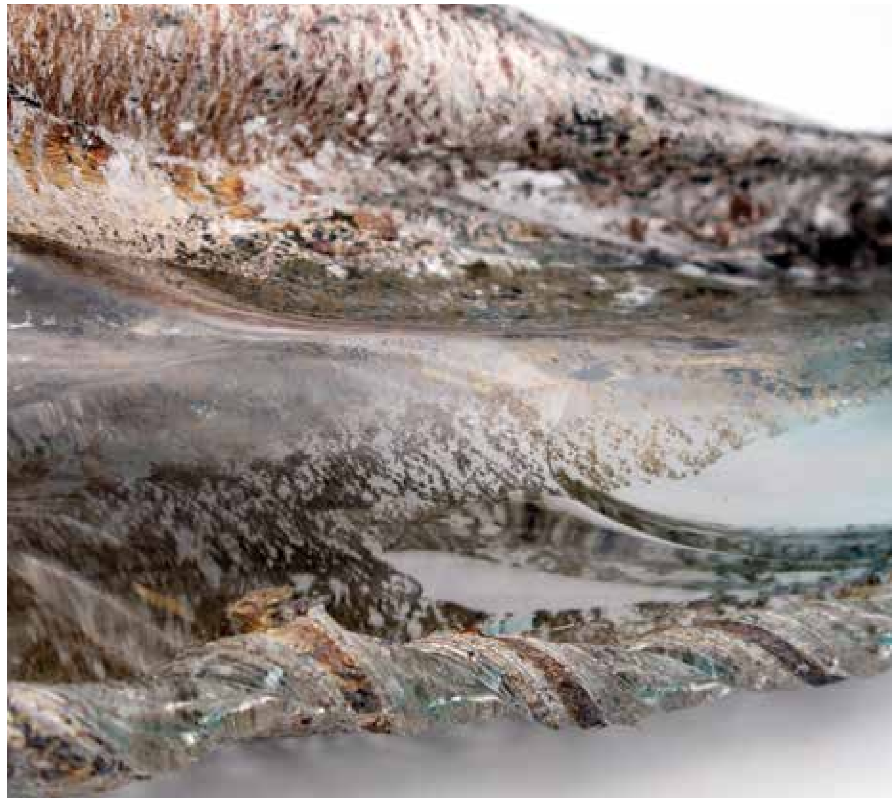
Sasaki's installation designs a small reality where the weather forecast is simultaneously sunny and rainy, bright and dark. Visitors step into a room to observe her glassblown "raindrops," each about 3 inches in diameter and 4 inches long. The over 200 droplets hang like stalactites in a roughly 13 square-foot area, in a room equipped with a motion sensor.[10,11]

The raindrops contain crystalline phosphorescent sand-sized grains of europium-doped strontium aluminate, which Sasaki incorporated into the glass during the glassblowing process. When the room lights with an invisible UV component are on, the raindrops absorb this surrounding light, which excites the phosphorescent materials into a higher-energy state. When visitors enter and the room goes dark, the raindrops release the absorbed energy as light and relax back into their favored low-energy state. The emitted light outlines the raindrops' shapes for a few minutes before fading, leaving the viewer in darkness.[11]

Sasaki infused this subtle light into exaggerated raindrops in reference to the showery weather of her hometown, projecting that the constant precipitation would not be so unappreciated if sunshine can also be recorded in drops.[11] These large, glass-blown, candescent raindrops convey the metaphors in the artist's message: changes in weather and seasons greatly affecting us all, the stark capture of something shining when the lights go out, the persistent promise of sunshine after rain, and the feeling of peace in the dark amidst the lambent raindrops.[11]

Phosphorescence is a subset of photosensitivity. Photosensitive glasses are important for a wide variety of commercial and research applications today, including construction of buildings, electronics fabrication, and consumer eyeglasses, to name a few.

Glass scientist S. Donald Stookey pioneered research on photosensitive glasses,



Credit: Jane Cook

Figure 5. Glass elementals in Vermaids by Jane Cook. Blown soda lime silicate glass with incorporation of aluminum foil and copper blue glass. Image courtesy of artist.

producing colors and effects caused by selection and tuning of elements precipitating out or changing redox states. Stookey invented various forms of photosensitive glasses, from copper and gold ruby glasses to photosensitive opalescent glasses. It is understood that sufficient amounts of oxidized metal (e.g., copper, gold) in the presence of tin and antimony oxides in the glass can reduce upon heating and impart color to the glass.[12] Stookey's photosensitive glasses remained transparent after this heating, yet the ruby effect could be precisely tuned with heat treatment and subsequent exposure to UV light. Masking areas of the glass during UV exposure limits development of the ruby effect to only the unmasked areas.[12]

Studies of this controlled process led to Stookey's invention of his first commercial success—Fotalite—in 1949, wherein cerium oxide in gold- and silver-containing glasses created nucleation sites (after heat treatment and UV exposure) for large NaF crystal growth, which was then used in industrial lighting applications.[12, 13] A prolific scientist, Stookey's later discoveries of glass-ceramics and Fotoceram also carved new pathways and applications for glass research.[3]

Jane Cook and glass expression

For any of its widespread applications, including art and science, it is highly critical to have stable glass recipes, i.e., pieces that remain functional and durable within utility specifications. And in order to create stable glass, an optimal combination of network formers (the chemicals composing the structural backbone of the network) and network modifiers (property enhancers) must be selected.

Silicate glasses comprise a predominant network of tetrahedral Si-O bonding, with elemental additives randomly situated within this network that can be engineered for certain material properties (e.g., metals and oxides to modify optics, ions to increase toughness, dopant elements to deter crystallization). A combination of covalent and ionic bonds joins this network together, stabilizing the glass throughout.

Working with glass (technically or otherwise) demands balancing contraposing physical principles: of crystallization versus noncrystallization, of highly rigid to highly fluid behavior, of heating and cooling, of oxidized then reduced states, just to name a few. Glass scientists hold this knowledge explicitly. We emphasize that glass artists also subscribe to this knowledge, perhaps with less precision but with no less empiricism, with their own creations to testify.

Vermaids, a sculpture by artist-scientist Jane Cook (Pennsylvania, U.S.), demonstrates the balance (Figure 5).[14] A piece made with copper blue glass and aluminum foil on and in transparent soda lime glass, *Vermaids* connects these counterbalances into a cycle of mending and disruption—of the glass shape as well as structural composition—in the glassblowing process.

When describing the process of *Vermaids*, Cook says she considers the glass "personality" as inhabited by its "elementals" (i.e., creatures inhabiting and made of molten glass).[14] As she works her piece, these elementals require sometimes coaxing, sometimes soothing, sometimes mediating between each other—each translating to a different handling technique. At the end of this process, Cook allows the glass to present as-is, to flow and harden and express itself as its captured form outside of the "melting pot" (batch furnace) suspended into finished *Vermaids*.

While this anthropomorphizing of glass reveals her artistic liberty with the material, Cook's materials science expertise guides her artistic creations. A glass scientist herself (she helped develop the glass in flat screen displays, cell phone screens, and more), Cook recognizes familiar glass processing challenges in her glass elementals in *Vermaids*, albeit with more scientific nomenclature.

For instance, Cook anticipates the general mismatch of bonding types between the silicate glass network and pure metal that leads to other mismatches, such as the coefficient of thermal expansion. As she picks up and rolls aluminum foil to incorporate it into hot glass, Cook is aware the pure metal disrupts the surface of her glass and generates a multilayer metal/metal oxide/glass interface, a sandwich of clashing thermal, chemical, and mechanical properties that alters the behavior of her workpiece. Copper ions present in the glass impart color dependent on oxidation state (Cook notes that the appearance of blue corresponds to its nominally +2 state and red to its metallic 0 state). Cognizant that the metals copper and aluminum can alloy with each other in a manner they do not with glass, Cook consults a Cu-Al binary phase diagram when preparing works like *Vermaids*.

Using her scientific savvy, Cook reins in glass properties, interfaces, and "elementals" with persuading approaches of twisting, pulling, and heating while still allowing the material to represent itself in its own way of cooling and remembering in *Vermaids*.

Conclusions

The field of glass has advanced considerably over millennia since ancient Mesopotamia and the centuries since the Middle Ages. From inventing and engineering sophisticated properties in glass to effortless infusion of color, iridescence, and phosphorescence in art, the tools we now possess to work and create with glass are impressive. Still, it is interesting that today this glass knowledge is too often further split into glass art and glass science.

Using glass science concepts (such as iridizing films, phosphorescent ceramics, and metallic coatings and inclusions), glass artists create masterpieces that not only inspire awe but also express the material behavior of their chosen media. This spotlight on glass and its technical properties is also fundamental to the work of glass scientists and drives them also to create functional and often aesthetic new glasses.

Glass art and glass science complement each other in theory and utility. Coalescing glass art and glass science is a celebration of glass. Glass art celebrates the material—its apparent utility and behavior—while glass science celebrates its accompanying knowledge—its potential applications and answers to empirical questions. Regardless of the origin of this dichotomy, glass art and glass science are very much coterminous.

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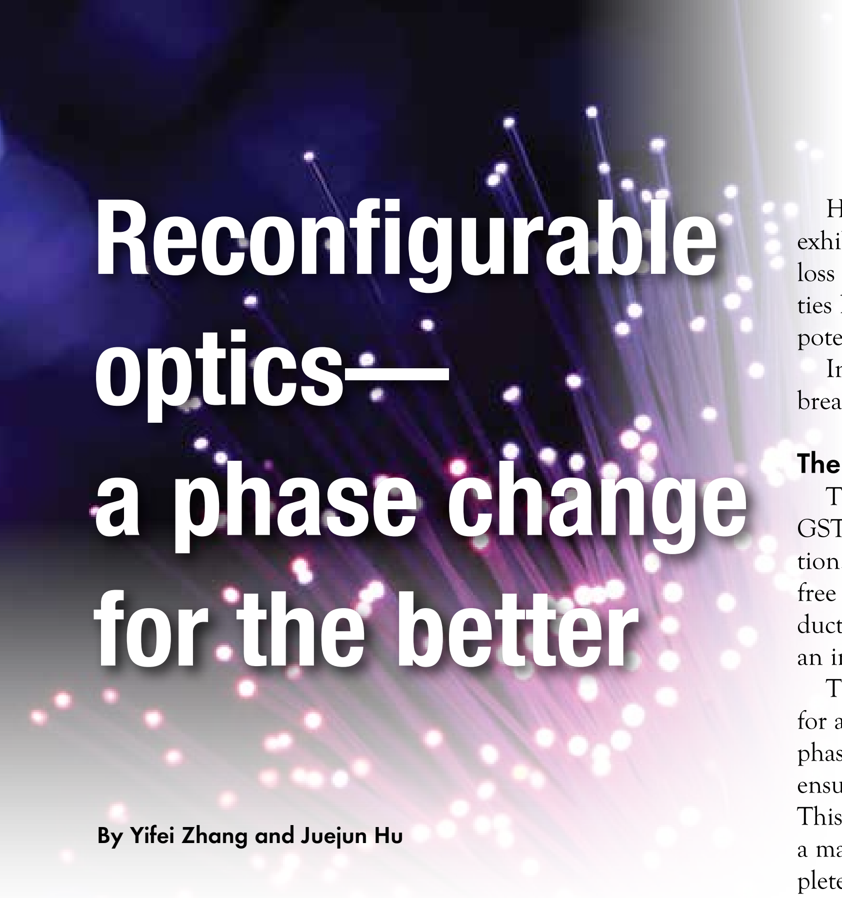

Reconfigurable optics—a phase change for the better

By Yifei Zhang and Juejun Hu

Breaking the coupling between index and loss changes in optical phase change materials opens up numerous reconfigurable photonics applications.

Optical phase change materials (O-PCMs) are a unique group of materials that feature drastic optical property changes upon solid-state phase transitions.[1] They have been widely adopted in photonic switches,[2–4] reconfigurable metasurfaces,[5–7] energy-efficient displays,[8] and optical memory.[9]

However, current material choices, such as Ge-Sb-Te (GST), exhibit large contrasts of both refractive index (Δn) and optical loss (Δk) simultaneously. The coupling of both optical properties limits the function, performance, and scalability of many potential photonic applications.

In this research, we report on a new class of O-PCMs that breaks this traditional coupling—Ge-Sb-Se-Te (GSST).

The search for a transparent phase change alloy

The large optical contrast in existing O-PCMs, such as the GST family, comes from a change in their bonding configuration. In their metallic or conductive state, large amounts of free carriers are introduced. While essential to the desired conductivity contrast for electronic applications, it also results in an increase of optical loss due to free carrier absorption (FCA).

The small size of the switching volume is another challenge for archetypal O-PCMs. For example, GST's poor amorphous phase stability requires cooling rates as high as 10^{10} °C/s to ensure complete re-amorphization during melt quenching.[10] This, combined with their low thermal conductivity,[11] stipulates a maximum film thickness of around 100 nm to achieve complete, reversible switching. Such geometric constraint limits optical devices to ultrathin film designs.

To tackle the aforementioned problems, isoelectronic substitution of tellurium by selenium is studied with GST. It is anticipated the substitution will increase the optical band gap, thus mitigating the interband absorption in the near-infrared. Additionally, selenium is a better glass former than tellurium, meaning it will promote glass formation and likely ease the geometric constraint.

A rationally engineered material solution

Density function theory (DFT) computations were implemented to predict the phase and electronic structures of the $Ge_2Sb_2Se_xTe_{5-x}$ alloys.[12] The DFT model suggests that alloys with $x \le 4$ retain the resonant bonding mechanism essential for large Δn and benefit from reduced interband optical absorption. The result suggests that the composition $Ge_2Sb_2Se_4Te_1$ (GSS4T1) likely offers the best balance between low loss and large index modulation.

We prepared $Ge_2Sb_2Se_xTe_{5-x}$ thin films via thermal evaporation and characterized their electronic and optical properties. In situ conductivity measurement during annealing (Figure 1a) shows the crystallization onset temperature for GSS4T1 is significantly higher than that of GST-225, signaling its enhanced amorphous phase stability. With selenium substitution, electrical resistivity of GSST increases

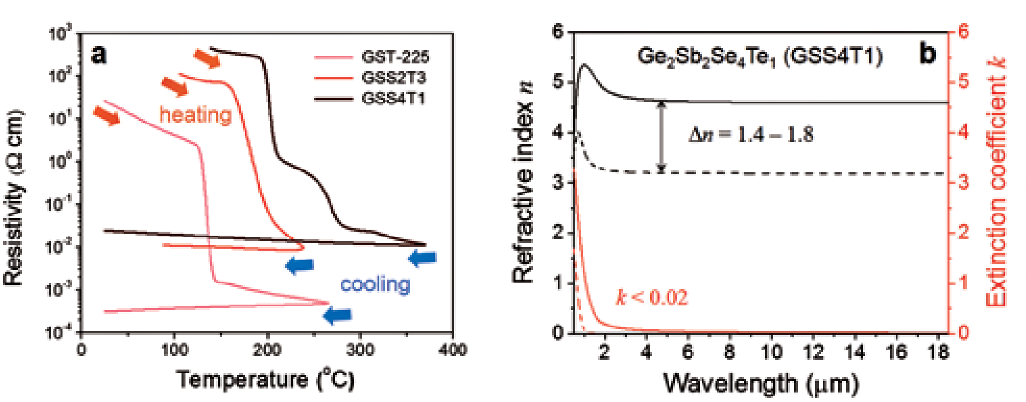

Fig. 1. Material characterization of $Ge_2Sb_2Se_xTe_{5-x}$ alloys. (a) Temperature dependence of resistivity of $Ge_2Sb_2Te_5$, $Ge_2Sb_2Se_2Te_3$, and $Ge_2Sb_2Se_4Te_1$ (GSS4T1) upon annealing. (b) Measured real (*n*) and imaginary (*k*) parts of refractive indices of the optimized composition GSS4T1. Dashed lines represent amorphous and solid lines represent crystalline. Graphs adapted from Zhang et al.[12]

Credit: Zhang et al., Nature Communications (CC BY 4.0)

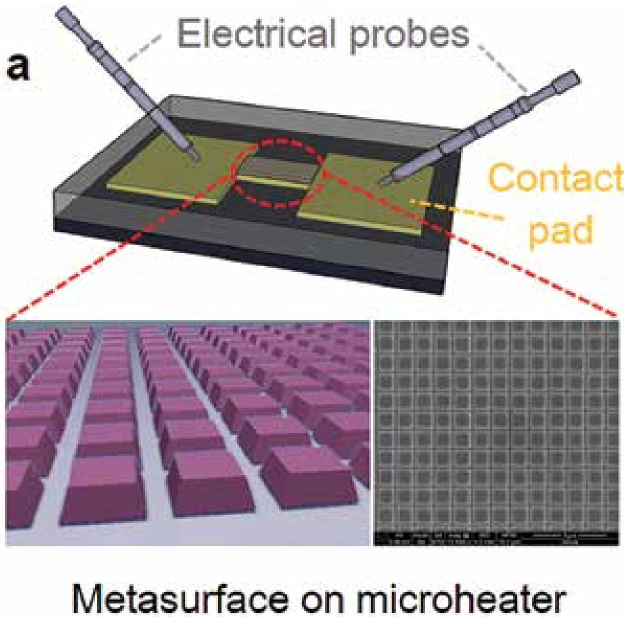

Fig. 2a. Nonvolatile photonics based on the novel O-PCM. Schematics and SEM image of a microheater enabling reversible electrothermal switching of active metasurfaces.

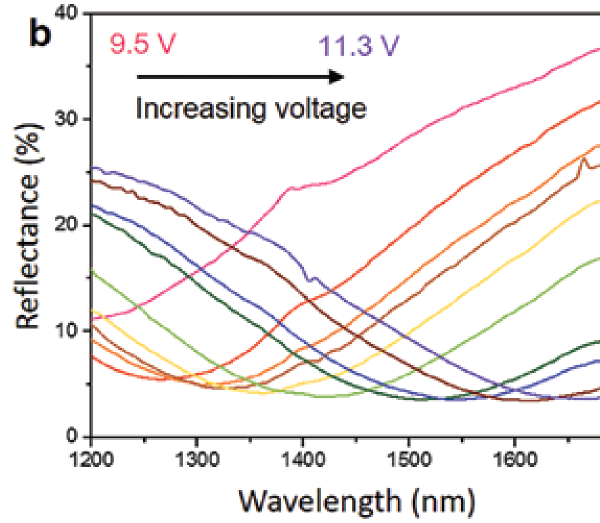

Fig. 2b. Reflectance spectra of a nonvolatile metasurface shows quasi-continuous tuning of the meta-atom resonance over 480 nm wavelength. Adapted from Zhang et al.[16]

drastically. Further study shows it can be mostly attributed to the reduction of carrier mobility.[12] Such a drastic resistivity increase means the FCA is successfully suppressed by selenium substitution. Furthermore, Kramers-Kronig consistent optical constants were obtained using coupled spectroscopic ellipsometry and transmittance/reflectance measurements from the visible through long-wave infrared. Specifically, GSS4T1 exhibits a large Δ*n* of 1.8 to 1.4 across the near- to mid-infrared bands as well as a broad transparency window (1–18.5 µm) owing to blue-shifted band edge and minimal FCA (Figure 1b).

From materials to devices

Leveraging the extraordinary optical properties of GSS4T1, we created a series of integrated[13-15] and free-space[16] photonic devices with record performances.

For example, to facilitate robust and scalable O-PCM switching for active metasurfaces, we invented a large-scale electrical switching platform[16] employing geometrically optimized microheaters, enabling large-area reversible electrothermal switching for PCM-based metasurfaces (Figure 2a). Based on the platform, quasi-continuous nonvolatile tuning was demonstrated through controlling the fraction of crystallization in the meta-atoms by changing pulse voltage. Figure 2b shows an ultra-broadband spectral tuning of the Mie resonance from 1,200 nm to 1,680 nm covering half an octave. Reconfigurable optical elements with advanced functionalities, such as varifocal lensing and nonvolatile beam steering, were also experimentally demonstrated.[1]

Acknowledgements

The authors gratefully acknowledge Kathleen Richardson's group at University of Central Florida, Hualiang Zhang's group at University of Massachusetts Lowell, as well as Steven Vitale, Vladimir Liberman, Jeff Chou, and their team at Lincoln Laboratory for help with the work.

About the authors

Yifei Zhang is a Ph.D. candidate in the Department of Materials Science and Engineering at Massachusetts Institute of Technology. He is working on reconfigurable photonic materials and devices under the supervision of Juejun Hu. Contact Zhang at yzhang94@mit.edu.

Editor's note

Zhang will present the 2020 Kreidl Award Lecture at the Glass and Optical Materials Division Annual Meeting in New Orleans, La., on Aug. 4, 2020.

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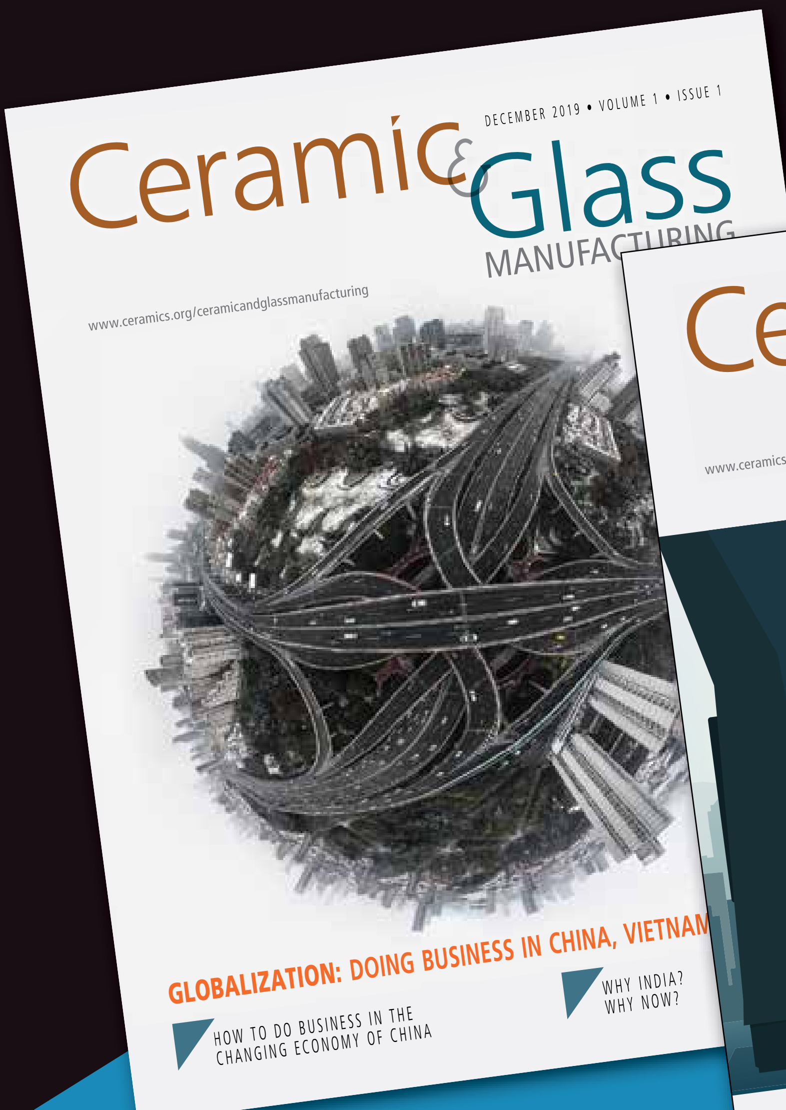

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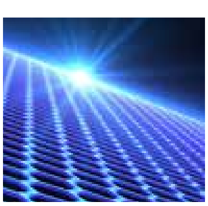
Updated meeting schedule

Due to the COVID-19 pandemic, some of ACerS meetings have been rescheduled or canceled. Please visit ceramics.org to get the latest updates regarding our meeting schedule.

ACerS 2020 Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting (SCPD 2020)
June 1–3, 2020

11th Advances in Cement-Based Materials (Cements 2020)
June 24–26, 2020

2020 Glass and Optical Materials Division Annual Meeting (GOMD 2020)
August 2–6, 2020 (RESCHEDULED)

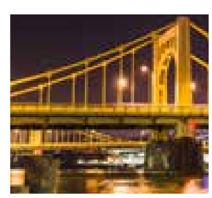


Materials Challenges in Alternative & Renewable Energy 2020 (MCARE 2020) combined with the 4th Annual Energy Harvesting Society Meeting (EHS 2020)
August 16–21, 2020

56th Annual St. Louis Section/ Refractory Ceramics Division Symposium on Refractories
September 8–10, 2020 (RESCHEDULED)

6th Ceramics Expo
September 22–23, 2020
(RESCHEDULED)
NEW DATE

Ceramic Manufacturing Solutions Conference
September 23–24, 2020
(RESCHEDULED)
NEW DATE



ACerS 122nd Annual Meeting at Materials Science & Technology 2020
October 4–8, 2020

Pan American Ceramics Congress and Ferroelectrics Meeting of Americas (PACC-FMAs 2020)
November 15–19, 2020 (RESCHEDULED)

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New Date!
August 2–6, 2020

REGISTER TODAY
2020 GLASS & OPTICAL MATERIALS DIVISION ANNUAL MEETING

www.ceramics.org/GOMD2020

Join ACerS' Glass & Optical Materials Division for GOMD 2020, August 2–6, 2020, in New Orleans, La., for a great technical program, award lectures, a strong student program, and more.

Please note that we at ACerS are monitoring the news and information related to COVID-19 on an ongoing basis. At this time, we are moving forward with GOMD 2020 at this postponed date. Because your safety and well-being are our top priority, we will follow all CDC guidance and make appropriate adjustments as necessary.

Technical sessions consisting of both oral and poster presentations led by technical leaders from industry, national laboratories, and academia will provide an open forum for glass scientists and engineers from around the world to present and exchange findings on recent advances in various aspects related to glass science and technology.

Hotel Monteleone is located right in the French Quarter of New Orleans, among a variety of specialty shops selling art and antiquities from around the world, and restaurants serving authentic New Orleans Cajun cuisine. Tourist attractions are located just steps from the hotel, including Jackson Square, Bourbon Street, the French Market, and the Riverwalk. New Orleans itself is steeped in European traditions and Caribbean influences. The Big Easy offers visitors sweet sounds and savory aromas fueled by three hundred years of history.

The GOMD Executive Committee, program chairs, and volunteer organizers sincerely hope you will join them in New Orleans for GOMD 2020 to find new collaborative opportunities and to exchange ideas in the international glass community.

WE LOOK FORWARD TO SEEING YOU IN NEW ORLEANS!

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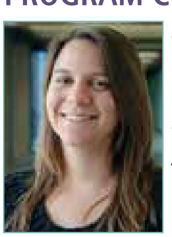

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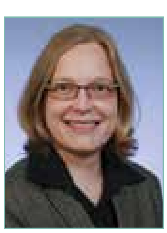

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SCHEDULE OF EVENTS	
Sunday, August 2, 2020	
Registration	4 – 6 p.m.
Welcome reception	5 – 7 p.m.
Monday, August 3, 2020	
Registration	7 a.m. – 5:30 p.m.
Stookey Lecture of Discovery	8 – 9 a.m.
Concurrent sessions	9:20 a.m. – 5:40 p.m.
Otto Schott Award luncheon sponsored by Schott AG	Noon – 1:30 p.m.
Poster setup	2:30 – 5:30 p.m.
Poster session and student poster competition	6:30 – 8:30 p.m.
Tuesday, August 4, 2020	
Registration	7:30 a.m. – 5:30 p.m.
George W. Morey Award lecture	8 – 9 a.m.
Concurrent sessions	9:20 a.m. – 6 p.m.
The Norbert J. Kreidl Award for Young Scholars	Noon – 1 p.m.
Lunch on own	Noon – 1:30 p.m.
GOMD general business meeting	5:45 – 6:45 p.m.
Conference banquet	7 – 10 p.m.
Wednesday, August 5, 2020	
Registration	7:30 a.m. – 5 p.m.
Varshneya Frontiers of Glass Science lecture	8 – 9 a.m.
Concurrent sessions	9:20 a.m. – 5:40 p.m.
Lunch on own	Noon – 1:30 p.m.
Thursday, August 6, 2020	
Registration	7:30 a.m. – 3 p.m.
Varshneya Frontiers of Glass Technology lecture	8 – 9 a.m.
Concurrent sessions	9:20 a.m. – 3:40 p.m.

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TECHNICAL PROGRAM

S1: FUNDAMENTALS OF THE GLASSY STATE

- Glass Formation and Structural Relaxation
- Glass Crystallization and Glass Ceramics
- Structural Characterizations of Glasses
- Topology and Rigidity
- Atomistic Simulation and Predictive Modeling of Glasses
- Data-based Modeling and Machine Learning for Glass Science
- Mechanical Properties of Glasses
- Non-Oxide Glasses
- Glass Under Extreme Conditions

S2: GLASS AND WATER: DEGRADATION OF AMORPHOUS MATERIALS

- Glass-water Interfacial Reactions and Dynamics During Initial Dissolution
- Soluble Glasses and Glasses as Ion Release Devices
- Glass-Water Interactions for Long-Term Durability

S3: OPTICAL AND ELECTRONIC MATERIALS AND DEVICES —FUNDAMENTALS AND APPLICATIONS

- Laser Interactions with Glasses
- Charge and Energy Transport in Disordered Materials
- Optical Fibers and Waveguides
- Glass-based Optical Devices
- Optical Ceramics and Glass-Ceramics
- Glasses and Glass-Ceramics in Detector Applications
- Rare-earth and Transition Metal-doped Glasses and Ceramics for Photonic Applications

S4: GLASS TECHNOLOGY AND CROSS-CUTTING TOPICS

- Glass Surfaces, Interfaces, and Coatings
- Sol-gel Processing of Glasses and Ceramic Materials
- Challenges in Glass Manufacturing
- Optical Fabrication Science & Technology
- Materials for Waste Immobilization

POSTER SESSION/RECEPTION & STUDENT POSTER COMPETITION

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Joy Banerjee, Corning Inc., U.S.A.
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Save the Date! August 16–21, 2020

Materials Challenges in Alternative and Renewable Energy 2020 (MCARE 2020)

Hosted and organized by: Energy Materials and Systems Division

4th Annual Energy Harvesting Society Meeting (EHS 2020)

Also organized by: KIChE The Korean Institute of Chemical Engineers

Hyatt Regency Bellevue | Bellevue, Wash. USA | ceramics.org/mcare2020

MCARE 2020, organized by The American Ceramic Society and its new Energy Materials and Systems Division, is the premier forum to address opportunities of emerging material technologies that support sustainability of a global society. MCARE 2020 brings together leading global experts from universities, industry, research and development laboratories, and government agencies to collaboratively interact and communicate material technologies that address development of affordable, sustainable, environmentally friendly, and renewable energy conversion technologies. If your research seeks sustainable energy solutions on a global scale, you should attend this conference.

This year, the Energy Harvesting Society Meeting (EHS 2020) will colocate with MCARE 2020. Since its inception, the EHS workshop has successfully brought the academic community from around the world together to openly discuss and to exchange ideas about energy harvesting, the key to the future of wireless sensor and actuator networks for a variety of applications. If you have research in this area, join us to freely discuss and network with colleagues from around the globe interested in energy harvesting solutions.

One conference fee gives you access to both of these important conferences, which will feature plenary lectures, invited and contributed talks, and student activities and a poster session.

ABSTRACT SUBMISSION INSTRUCTIONS

Visit **www.ceramics.org/mcare2020** to submit your 200-word abstract. Select "Submit Abstract" to be directed to the Abstract Central website. Please contact Marilyn Stoltz at mstoltz@ceramics.org or 614-794-5868 with questions.

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Frontiers of Solar Energy Harvesting: New Materials for Photovoltaics and Solar Fuels—International symposium in honor of Prof. Yoon-Bong Hahn, Jeonbuk National University

Yoon-Bong Hahn

Session topics

- **Innovative processing of nano- and heterostructured functional materials**
- **Functional metal oxide nano- and heterostructures for photocatalysis and solar fuels**
- **Advanced materials for next generation photovoltaic devices**

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PROPOSED SYMPOSIA TOPICS

- **Materials for Solar Fuel Production and Applications**
- **Advanced Materials for Energy Storage**
- **Challenges in Thermal-to-Electrical Energy Conversion Technology for Innovative Novel Applications**
- **Advanced Materials for Perovskite and Next Generation Solar Cells**
- **Spectral Conversion Materials for Energy Applications**
- **Materials for Nanogenerators and Self-Powered Electronics**
- **Advanced Materials and Nanodevices for Sustainable and Eco-Friendly Applications**
- **Advanced Materials for Fuel Cells and High Temperature Electrolysis**
- **Critical Materials for Energy Applications**
- **Life Cycle Impacts of Clean Energy Materials**
- **Materials for Super Ultra-low Energy and Emission Vehicle**
- **Materials and Process Challenges for Sustainable Nuclear Energy**
- **Young Scientists Forum on Future Energy Materials and Devices**
- **Frontiers of Theoretical and Experimental Insights in Energy Harvesting Materials**

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Calendar of events

June 2020

CANCELED

1–3 ➡ Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Charlotte, N.C.

CANCELED

24–26 ➡ 11th Advances in Cement-Based Materials – Northwestern University, Chicago, Ill.

August 2020

NEW DATE

2–6 2020 Glass and Optical Materials Division Annual Meeting – Hotel Monteleone, New Orleans, La.; www.ceramics.org/gomd2020

16–21 Materials Challenges in Alternative & Renewable Energy 2020 (MCARE2020) combined with the 4th Annual Energy Harvesting Society Meeting (AEHSM 2020) – Hyatt Regency, Bellevue, Wash.; www.ceramics.org/mcare2020

23–27 ➡ International Congress on Ceramics (ICC8) – Bexco, Busan, Korea; www.iccs.org

30–Sept.2 ➡ 2nd Global Forum on Smart Additive Manufacturing, Design and Evaluation (SmartMADE) – Osaka University, Nakanoshima Center, Japan; http://jwri.osaka-u.ac.jp/~conf/Smart-MADE2020

September 2020

NEW DATE

8–10 56th Annual St. Louis Section/Refractory Ceramics Division Symposium on Refractories – Hilton St. Louis Airport Hotel, St. Louis, Mo.

NEW DATE

22–23 6th Ceramics Expo – I-X Center, Cleveland, Ohio.; https://ceramics.org/event/6th-ceramics-expo

NEW DATE

23–24 Ceramic Manufacturing Solutions Conference – I-X Center, Cleveland, Ohio; https://ceramics.org/event/ceramic-manufacturing-solutions-conference

October 2020

4–8 ACerS 122nd Annual Meeting with Materials Science & Technology 2020 – David L. Lawrence Convention Center, Pittsburgh, Pa.; www.matscitech.org

November 2020

8–13 7th Int. Conference on Electrophoretic Deposition (EPD 2020) – Santa Fe, New Mexico; http://www.engconf.org/conferences/materials-science-including-nanotechnology/electrophoretic-deposition-vii-fundamental-and-applications

NEW DATE

15–19 Pan American Ceramics Congress and Ferroelectrics Meeting of the Americas (PACC-FMAs 2020) – Hilton Panama, Balboa Avenida Aquilino de la Guardia, Panama City, Panama; www.ceramics.org/PACCFMAs

29–Dec 3 2020 MRS Fall Meeting & Exhibit – Boston, Mass.; www.mrs.org/fall2020

January 2021

20–22 Electronic Materials and Applications (EMA2021) – DoubleTree by Hilton Orlando at Sea World Conference Hotel, Orlando, Fla.; www.ceramics.org

24–29 45th International Conference and Expo on Advanced Ceramics and Composites (ICACC2021) – Hilton Daytona Beach Oceanfront Resort, Daytona Beach, Fla.; www.ceramics.org

March 2021

NEW DATE

15–17 China Refractory Minerals Forum 2020 – InterContinental Dalian, Liaoning, China; http://imformed.com/get-imformed/forums/china-refractory-minerals-forum-2020

27–31 ➡ The Int'l Conference on Sintering 2021 – Nagaragwa Convention Center, Gifu, Japan; https://www.sintering2021.org

May 2021

NEW DATE

16–19 ➡ Ultra-high Temperature Ceramics: Materials for Extreme Environment Applications V – The Lodge at Snowbird, Snowbird, Utah; http://bit.ly/5thUHTC

23–28 14th Pacific Rim Conference on Ceramic and Glass Technology (PACRIM 14) – Hyatt Regency Vancouver, Vancouver, British Columbia, Canada; www.ceramics.org

June 2021

NEW DATE

28–30 MagForum 2020: Magnesium Minerals and Markets Conference – Grand Hotel Huis ter Duin, Noordwijk, Amsterdam; http://imformed.com/get-imformed/forums/magforum-2020

August 2021

29–Sept 2 ➡ 17th European Ceramic Society Conference – Dresden, Germany; www.ecers2021.org

Dates in RED denote new entry in this issue.

Entries in BLUE denote ACerS events.

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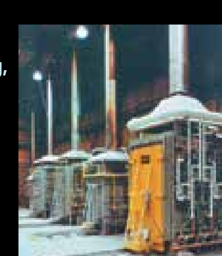
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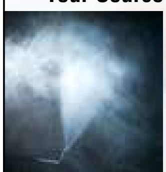
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Catalina Young
Guest columnist

Glass and you: How glass coatings can help your body heal

The basis of modern orthopedic implants began with the first implants created in the early 1900s.[1] Metallic plates for stabilizing fractures were some of the first implants used on the human body. As medical sciences, materials science, and engineering fields advanced, so did the development of orthopedic implants to create more biocompatible and better load-bearing implants.

One of the largest challenges with orthopedic implants is rejection of the implant by the human body.[2,3] The body rejects these implants for a myriad of reasons, such as bacteria, underlying health reasons, and long-term exposure to prosthetic debris due to metal-on-metal contact.[1] In recent years, glass- and ceramic-coated metallic implants have become more common because they overcome some of these issues (Figure 1).[4]

Another large issue with implant rejection is the inability for hard and soft tissues to grow on the implant, allowing for proper retention of the implant within the patient's body.[2,3] One new advancement for addressing this issue is developing rough surfaces on implants to allow for tissue growth into and around these implants. These rough surfaces can be made by taking the substrate material (i.e., the implant) and tailoring it during the development process or by applying a coating to the substrate surface.

These surface coatings often are made from bioactive glasses comprised of silicate, borate, or phosphate glasses.[2] They are applied to orthopedic implants by enameling, sol-gel techniques, electrophoretic deposition, thermal spraying, and laser cladding.[3] Each technique has pros and cons for applying coatings to the implants, but the four big factors to account for are the thermal expansion coefficients of the coating and the substrate, adhesion of the coating to the substrate, maintaining coating composition integrity, and ensuring final sintering process does not degrade either the coating or substrate.[3] Once the hurdle of deposition is overcome, these coated implants will better integrate within the human body, letting patients heal potentially quicker and with fewer complications than before.

As a former nursing student turned engineering student, what drew me into engineering was the field of biomimetic and biocompatible materials, such as these bioactive glass coatings. The idea of creating materials and then putting them in the human body fascinated me, especially cases in which biocompatible scaffolds replaced bone that was removed due to illness or injury. This fascination led me into the field of ceramics, which I fell in love with and now work in.

While I currently conduct research in the field of ultrahigh-temperature ceramics at my university, I still like to read and keep up to date on research happening within the field of ceramics that overlaps with the field of medicine.

Credit: Herrera et al., BioMed Research International (CC BY 3.0)

Figure 1. X-ray image of a ceramic-coated hip implant (the ABG I prosthesis) inside of a patient. Hydroxyapatite-coated implants have been in use for nearly 30 years.

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Catalina "Cat" Young is an undergraduate student pursuing a degree in mechanical engineering at Florida International University. Her research mainly focuses on ultra-high temperature ceramics, spark plasma sintering, and sintering of ceramic by SPS. Outside of school and lab work, Cat enjoys going to the beach with her dog Gadget and trying out new recipes of different cuisines at home.

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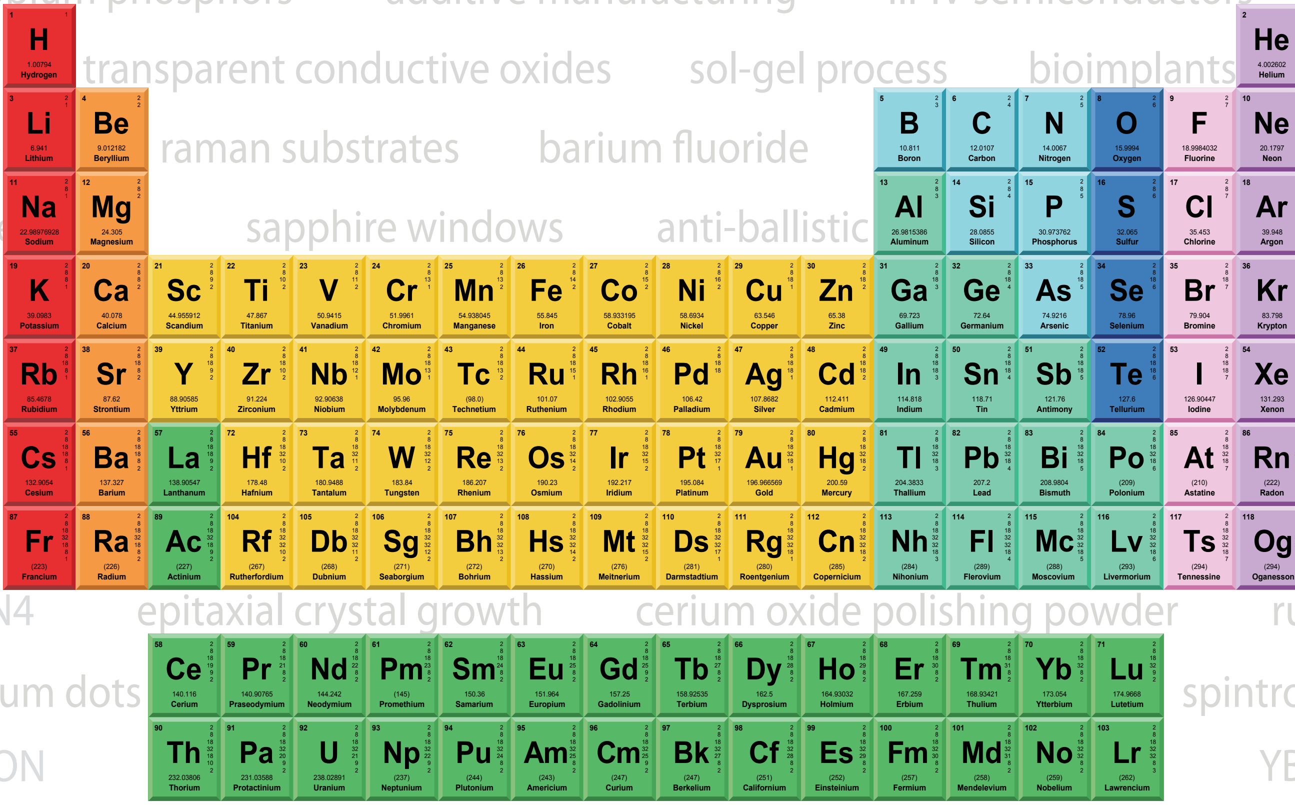

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