Celebrating 100 years

AMERICAN CERAMIC SOCIETY

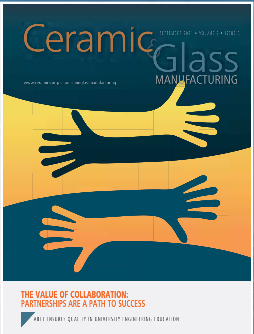
bulletin

emerging ceramics & glass technology

SEPTEMBER 2021

Laser-driven chemical vapor deposition for high-performance fibers and powders

New issue inside:



ACerS Awards of 2021 | Coe College glass research | Big science in aerospace

contents

September 2021 • Vol. 100 No.7

feature articles

department

columns

meetings

resources

AMERICAN CERAMIC SOCIETY
bulletin

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September 2021 • Vol. 100 No.7

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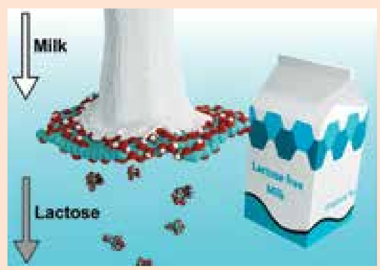
As seen on *Ceramic Tech Today...*



Credit: Morelos-Gomez et al., *Carbon* (CC BY 4.0)

Video: Filtration—another way to lactose-free milk

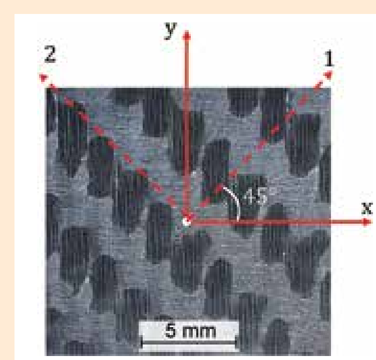
Lactose-free milk usually is created is by adding the enzyme lactase to regular milk—but filtration is another possible method that is gaining more attention. Researchers in Japan and Mexico developed new graphene oxide membranes that appear to filter lactose out of milk better than current commercial membranes.

Read more at www.ceramics.org/filteredmilk

Also see our ACerS journals...

A new process for creating a solid-phase sintered body using a unique densification process between powders
By T. Ishikawa and M. Naito
International Journal of Ceramic Engineering & Science

Direct ink writing of hierarchical porous ultra-high temperature ceramics (ZrB_2)
By M. L. Sesso, S. Slater, J. Thornton, and G. V. Franks
Journal of the American Ceramic Society



Characterizing environment-dependent fracture mechanisms of ceramic matrix composites via digital image correlation
By C. H. Bumgardner, F. M. Heim, D. C. Roache, et al.
Journal of the American Ceramic Society

Experimental evaluation and theoretical prediction of elastic properties and failure of C/C-SiC composite
By Y. Shi, S. Li, E. Sitnikova, et al.
International Journal of Applied Ceramic Technology

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). ©2021. 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. 100, No. 7, pp 1– 72. All feature articles are covered in Current Contents.

news & trends

Cement production in Sweden

Despite concrete being the most consumed building material in the world—and second most consumed material overall, after water—the global construction industry currently is experiencing a cement shortage due to the COVID-19 pandemic.

Countries ranging from Jamaica, Georgia, the United States, and the United Kingdom are dealing with the shortage, which is driven by numerous factors including pent-up demand from infrastructure projects and limited production of raw materials due to restrictions put in place during the pandemic.

In Sweden, a recent decision by the Swedish Supreme Land and Environmental Court may complicate the country's cement production further in the coming months and years.

Environmental court shuts down cement factory

Swedish company Cementa is the sole producer of cement in Sweden, and it has plants in Slite and Skövde. The company is a subsidiary of the Germany-based HeidelbergCement Group, one of the largest building materials companies in the world.

In early July 2021, the Swedish Supreme Land and Environmental Court rejected Cementa's application to renew its permit to mine limestone at the company's existing quarries in Slite, Gotland.

Cementa originally received clearance from a lower court in January 2020 to renew its mining operations at the Slite site until 2041, but the clearance was challenged. The Supreme Land and Environmental Court based the recent decision on the grounds that there is insufficient evidence to assess the environmental impact of the site.

According to a Dezeen article, the Slite plant produces about three-quarters of all the cement used in Sweden. "It is also the second-largest source of greenhouse gas emissions in the country, responsible for three per cent of all CO_2 emissions," the article continues.

Cementa says the decision would jeopardize construction projects throughout Sweden—including, ironically, a plan to upgrade the Slite plant to capture and store CO_2 emissions.

Credit: Calistemon, Wikimedia (CC BY-SA 4.0)

The Slite cement quarry in Gotland, Sweden. Swedish company Cementa planned to upgrade the site to reduce CO_2 emissions, but a recent Supreme Land and Environmental Court decision may shutter the plant instead.

HeidelbergCement has pursued carbon reduction projects through some of its other subsidiaries, including one in Norway that can be read about at https://ceramics.org/carbon-capture. According to a Dezeen article, the proposed upgrade at Slite would capture and store up to 1.8 million tonnes of CO_2 per year.

The original plan was to complete the upgrade by 2030. However, "The situation in Sweden could at least challenge or postpone the CCS [carbon capture and storage] project at Slite," says Per Brevik, director of alternative fuels at HeidelbergCement, in the Dezeen article.

The Supreme Land and Environmental Court decision does not occur in a vacuum. In 2017, Sweden passed legislation that legally binds the country to reach net-zero emissions by the year 2045, five years earlier than previously planned. Learn more about Sweden's climate policy framework, which contains climate goals and plans for a climate policy council, at https://bit.ly/3s12CQV.

Even earlier, in 2015, Sweden launched an initiative called Fossil Free Sweden (Fossilfritt Sverige) to drive work on reducing emissions. A YouTube channel for the initiative features several videos on their goals for various sectors, which can be found at https://www.youtube.com/channel/UC0ZFB1L11Qks38YczBz5WcA. 100

Corporate Partner News

Kyocera celebrates 50 years of US manufacturing

The City of San Diego honored Kyocera International, Inc. for 50 years of U.S. manufacturing. At its founding in Silicon Valley in July 1969, the U.S. company was Kyocera Corporation's first subsidiary outside of Japan. In 1971, Kyocera International, Inc. acquired facilities in San Diego and started producing ceramic semiconductor packages, becoming the first Japanese-parented technology enterprise with manufacturing operations in the State of California. A proclamation honoring Kyocera International, Inc.'s 50-year manufacturing anniversary was signed by San Diego Mayor Todd Gloria and all nine city councilmembers. 100

Kyocera International, Inc. president Bob Whisler (left) and San Diego councilmember Chris Cate.

Corporate Partner News (cont)

Lithoz further expands production with opening of a second base in Austria

Lithoz GmbH opened their newest location in the form of a secondary site in Vienna, Austria. After only recently launching their new Lithoz China headquarters in Shanghai, this fourth location will allow the company to greatly expand their production capabilities. 100

By Lisa McDonald

Into the Bulletin Archives—A look back at our 100 years in print

Since May 1922, the *ACerS Bulletin* has served the ACerS community, providing them updates on member news, Division meetings, and the latest research in ceramics and glass.

In celebration of Volume 100 this year, the *Bulletin* editorial team is running a special column in each issue of the 2021 *Bulletin* that looks at the history of the *Bulletin* by decade. This issue highlights the 1980s.

We hope you enjoy following the journey of the *Bulletin* from its early years to today. As an ACerS member, you have access to all 100 years of the *Bulletin* on the *Bulletin Archive Online* at https://bulletin-archive.ceramics.org. 100

Into the Bulletin Archives—1980s

During the 1980s, The American Ceramic Society made two notable changes to its branding that are still in use today. One, the Society adopted ACerS as its official acronym in 1981, during the December meeting of the Board of Trustees. The reasoning for this adoption was that several other organizations, notably the American Chemical Society, already used "ACS" as their initials. However, the recommended pronunciation of ACerS will likely surprise members of today.

> "The Board did not intend these initials to form a word or acronym to be pronounced, 'ay sirs.' Rather, the initials 'ACerS' should probably be pronounced, 'ay sir ess,' replacing the 'ay see ess' for the initials 'ACS."
>
> –*ACerS Bulletin, Vol. 61., Iss. 3., March 1982 (p. 291)*

Two, the Society debuted its current globe-based logo in the January 1987 issue. The announcement included a description of what each part of the logo represents.

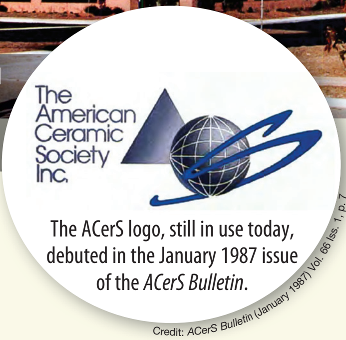
- The triangle represents phase diagrams.
- The globe stands for the Society's international membership.
- The sweeping "S" pertains to the Society and how it pulls together all aspects of the ceramic community.

The inclusion of phase diagrams in the new logo makes sense considering that in December 1982, the Society and the National Bureau of Standards signed a three-year agreement instituting a joint program "to provide improved, evaluated phase diagrams for use by ceramic scientists and engineers," as reported in the February 1983 issue. Originally marketed as the "Phase Diagrams for Ceramists," the program continues to this day under the name ACerS-NIST Phase Equilibrium Diagram Products (https://ceramics.org/phase).

The 1980s also saw the introduction of two new publications by the Society—*Ceramic Source* and *Advanced Ceramic Materials*. The June 1985

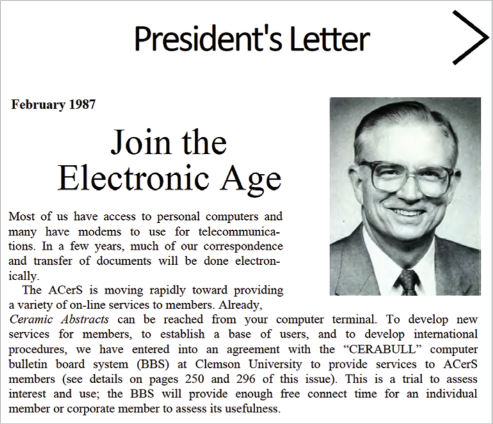
The American Ceramic Society and the National Institute of Ceramic Engineers moved to new headquarters in December 1986. Located in Westerville, Ohio, the one-story brick-and-glass building was 28% larger than the previous headquarters building, providing plenty of space for a growing staff, the Ross C. Purdy Museum of Ceramics, and the Society library.

Credit: *ACerS Bulletin* (January 1987) Vol. 66 Iss. 1, p. 6



The ACerS logo, still in use today, debuted in the January 1987 issue of the *ACerS Bulletin*.

Credit: *ACerS Bulletin* (January 1987) Vol. 66 Iss. 1, p. 7



President's Letter

February 1987

Join the Electronic Age

Most of us have access to personal computers and many have modems to use for telecommunications. In a few years, much of our correspondence and transfer of documents will be done electronically.

The ACerS is moving rapidly toward providing a variety of on-line services to members. Already, *Ceramic Abstracts* can be reached from your computer terminal. To develop new services for members, to establish a base of users, and to develop international procedures, we have entered into an agreement with the "CERABULL" computer bulletin board system (BBS) at Clemson University to provide services to ACerS members (see details on pages 250 and 296 of this issue). This is a trial to assess interest and use; the BBS will provide enough free connect time for an individual member or corporate member to assess its usefulness.

Credit: *ACerS Bulletin* (February 1987) Vol. 66 Iss. 2, p. 249

1980s

The rise of the personal computer took off in the 1980s, following the microcomputer revolution of the 1970s. As seen in this "President's Letter" from February 1987, the Society took note of the trend and began exploring online offerings for its members.

"President's Page" announced both publications, the former to be an annual publication debuting that September, and the latter to be a quarterly publication debuting in January 1986.

As described in the September 1985 "President's Page" column, *Ceramic Source* "represents the beginning of a long-sought, comprehensive data base for ceramics including technical, product, and service information and a company index." In January 1990, the company directory section of the *ACerS Bulletin* was removed and incorporated into *Ceramic Source* to provide all company information in one location and also provide more room for technical coverage of ceramics in the *Bulletin*.

Advanced Ceramic Materials published as a self-standing publication until being incorporated into the *Journal of the American Ceramic Society* in 1989.

The Society changed the name of the Ceramic-Metal Systems Division in 1985. In the July issue, the Society explained that the change was made because "The Division's scope has broadened phenomenally during the last ten years, according to Frank D. Gac, Division chairman. He noted the new name better represents all the activities of the Division."

DIVISIONS OF THE SOCIETY

During the 1980s, the Society had 11 Divisions.

- Basic Science
- Cements
- Design
- Electronics
- Engineering Ceramics (previously Ceramic-Metal Systems)
- Glass
- Materials & Equipment
- Nuclear
- Refractories
- Structural Clay Products
- Whitewares

Big science in the aerospace industry

By Jason Chen

Big science is a term used to describe large-scale scientific research consisting of projects funded frequently by a national government, group of governments, or an international agency.

A big science project could require equipment and constructions that cost hundreds of millions or even billions of dollars, far beyond what an individual or even a company can afford.

Aerospace and space exploration projects attracted the largest investment among all big science segments in 2020 with $11.8 billion, which accounts for 40.5% of investments in big science projects. The most notable projects include the Artemis program launched by the United States and the Chang'e project by China.

- **Artemis program:** The Artemis program is a U.S. government-funded international human spaceflight program that has the goals of landing the first woman and the next man on the moon by 2024 and preparing the way to send humans to Mars in the 2030s. According to the NASA Office of Inspector General, approximately $35.2 billion has been spent on the Artemis program as of June 2020, and another $50.5 billion will be used through 2025. The investment will be spent on Orion, Space Launch System, Exploration Ground Systems, Lunar Gateway, Human Landing Systems, and other R&D efforts.
- **Chang'e project:** The Chinese Lunar Exploration Program, also known as the Chang'e project after the Chinese moon goddess Chang'e, is a space exploration mission being carried out by the China National Space Administration and its contractors. Since 2007, the Chang'e project has seen the launch of a series of orbiters, landers, and rovers, with the sixth mission planned for 2023. As of 2020, China has invested a total of $2 billion in the Chang'e project.

Many big science projects require instruments or materials that provide excellent performance and can withstand the harsh environment. Metals and alloys account for 55.2% of the advanced materials used in big science projects. Some of these advanced metals and alloys include

- **Cryogenic treated metals and alloys:** Cryogenic treatment is a process of cooling materials to cryogenic temperatures to change the material structure so as to improve the materials' performance. Cryogenic treatment is mostly used for treating metals and alloys in spacecraft components and other aerospace products. Cryogenic metals and alloys represented a global market of $37.3 billion in 2020, with 0.8% of that figure for big science applications.
- **Shape memory alloys:** A shape memory alloy (SMA) is an alloy that is plastically deformed at one temperature but reverts back to its original shape when heated or cooled. In big science projects, SMAs are used often to make antennas in spacecrafts, as well as fasteners and connectors in aerospace components and nuclear components. SMAs represented a global market of $14.4 billion in 2020, with 0.7% of that figure for big science applications.
- **Superplastic alloys:** A superplastic alloy is an alloy that exhibits superplasticity, a state in which the alloy or a solid crystalline material is deformed beyond its usual breaking point at a certain temperature. Superplastic alloys were first used in the aerospace industry in the late 1960s, and today aerospace accounts for about half of the global superplastic alloy market. Superplastic alloys represented a global market of $697.7 million in 2020, with 1.3% of that for big science applications.

The aerospace and defense industries are also significant sources of demand for transparent ceramics. A major application in this sector is the production of windows or domes used to protect sensitive components and electronics from extreme external conditions.

About the author

Jason Chen has been an analyst and consultant for the polymer, composite, fiber, textile, and energy industries for 18 years. Contact BCC's analyst at info@bccresearch.com.

Table 1. Global market for big science, by sector, through 2025 ($ billions)

Sector	2019	2020	2025	CAGR% (2020–2025)
Aerospace	11.4	11.8	17.2	7.8%
Energy	10.6	10.9	15.2	6.9%
Physics and astronomys	4.5	4.6	6.6	7.5%
Others	1.8	1.8	2.6	7.6%
Total	**28.3**	**29.1**	**41.6**	**7.4%**

Resource

J. Chen, "Big Science: Global Markets" BCC Research Report MFG087A, May 2021. www.bccresearch.com. 100

SOCIETY DIVISION SECTION CHAPTER **NEWS**

FOR MORE INFORMATION:

ceramics.org

Welcome new ACerS corporate partners

ACerS is pleased to welcome its newest Corporate Partners:

– 3M Technical Ceramics, Inc.

– General Shale

To learn about the benefits of ACerS corporate partnership, contact Kevin Thompson, membership director, at (614) 794-5894 or kthompson@ceramics.org.

Spain Chapter to participate in the SECV-Zero Emissions

The Spain Chapter will participate in the SECV-Zero Emissions Conference on Oct. 4 and 5, 2021. This hybrid event will offer an overview of promising technologies in the generation, storage, and distribution of renewable hydrogen, and the sources of financing for its industrialization. For more information, visit https://secv.es/emisiones0.

Korea Chapter hosted meet-and-greet

The Korea Chapter hosted a virtual meet-and-greet on Tuesday, July 20, 2021. Chapter members networked and discussed plans for future Korea Chapter activities.

U.K. Chapter hosts webinar

Free to ACerS members

Frontiers of Ceramics & Glass Webinar Series

SEPTEMBER 23, 2021
2 P.M. EASTERN U.S. TIME

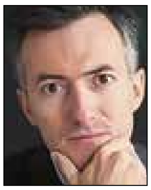
Title: *Cold Sintering of Functional Materials*

PRESENTER:

CLIVE RANDALL – Distinguished Professor of Materials Science and Engineering and Director of the Materials Research Institute at The Pennsylvania State University

Hosted by the United Kingdom Chapter

ACerS Colorado Section to host Jean Luc Doumont webinar, "Making the most of your presentation," Sept. 22, 2021


Doumont

Strong presentation skills are a key to success for researchers and other professionals alike, yet many speakers are at a loss as to how to tackle the task. This lecture proposes a systematic way to prepare and deliver an oral presentation. It covers structure, slides, and delivery, as well as stage fright.

For more information, visit the ACerS Colorado Section webpage at https://ceramics.org/members/member-communities/sections/colorado.

Volunteer spotlight

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


Hellmann

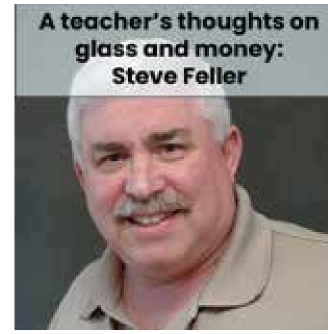
John R. Hellmann is Professor Emeritus of Materials Science and Engineering at The Pennsylvania State University, where he received both a bachelor's and a Ph.D. in ceramic science. He began his career at Penn State in 1986 as assistant professor of ceramic science and engineering and assistant director of the Center for Advanced Materials. Prior to his retirement in 2021, Hellmann was the senior associate dean for graduate education and research. His responsibilities included oversight of a $65 million annual research and education portfolio on earth, energy, materials, and environmental science, comprising over 150 faculty and 600 graduate students in the College of Earth and Mineral Sciences.

Hellmann joined ACerS in 1973. His numerous contributions to ACerS include serving on ACerS Board of Directors and being awarded the Ceramic Educational Council (CEC) Outstanding Educator (2008), the Greaves-Walker Roll of Honor (2018), and the Arthur L. Friedberg Ceramic Engineering Tutorial and Lecture (2020). Hellmann also served as the Central Pennsylvania Section chair and as president of the Ceramic Educational Council, the National Institute of Ceramic Engineers, and Keramos National Professional Ceramic Engineering Fraternity.

We extend our deep appreciation to Hellmann for his service to our Society!

more SOCIETY DIVISION SECTION CHAPTER NEWS

Ceramic Tech Chat: Steve Feller



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

In the July episode of Ceramic Tech Chat, Steve Feller, B.D. Silliman Professor of Physics at Coe College, describes the benefits of pursuing teaching opportunities during his physics graduate studies, his use of nuclear magnetic resonance in glass research, and how his interest in numismatics led to numerous research projects and publications in that field as well.

Check out a preview from his episode, which features Feller explain why NMR is so useful in glass research.

> *"So [NMR] uses the very nucleus of the atom as the probe, so that's already a plus. The other spectroscopies are good, but let me compare it, for example, to Raman and Fourier transform infrared spectroscopy. Those vibrational spectroscopies are inherently qualitative because, in order to understand the responses from different environments, we have to know how light interacts with a given environment. And that is not known in principle. So you can get qualitative comparison. You can say this unit's there, this unit's there. But it's hard to say this is 60% of the glass, this is 40% of the glass. NMR is completely quantitative, so you don't have that problem. If you see a certain response that's twice the area under the curve as another, then it's twice as abundant. That's super useful."*

Listen to Feller's whole interview—and all of our other Ceramic Tech Chat episodes—at http://ceramictechchat.ceramics.org/974767.

AWARDS AND DEADLINES

FOR MORE INFORMATION:

ceramics.org/members/awards

ACerS/BSD Ceramographic Exhibit & Competition

The Roland B. Snow Award is presented to the Best of Show winner of the 2021 Ceramographic Exhibit & Competition organized by the ACerS Basic Science Division. This unique competition, held at the ACerS Annual Meeting at MS&T21 in Columbus, Ohio, is an annual poster exhibit that promotes the use of microscopy and microanalysis in the scientific investigation of ceramic materials. Winning entries are featured on the back covers of the *Journal of the American Ceramic Society*. Learn more at http://bit.ly/RolandBSnowAward.

Attend your Division business meeting at MS&T21

Six of ACerS Divisions will hold executive and general business meetings at the ACerS Annual Meeting at MS&T21 in Columbus, Ohio. General business meetings will be held Monday or Tuesday in the Columbus Convention Center. Plan to attend to get the latest updates and to share your ideas with Division officers.

The Division Executive Committee meetings will be held Sunday afternoon, Oct. 17, in the Hilton Columbus Downtown. For times and locations, contact the Division chair or Erica Zimmerman at ezimmerman@ceramics.org.

Monday, Oct. 18:

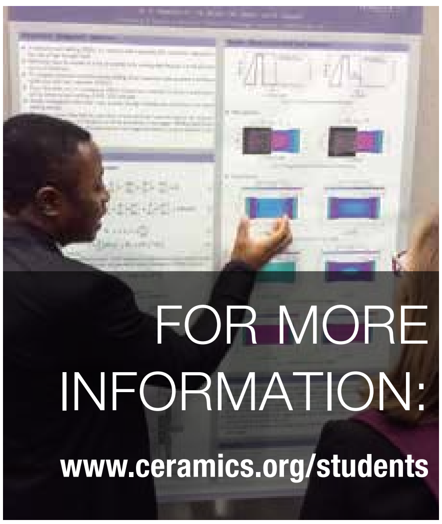
- Glass & Optical Materials Division: 11 a.m.–12 p.m.
- Basic Science Division: Noon–1 p.m.
- Electronics Division: Noon–1 p.m.
- Engineering Ceramics Division: Noon–1 p.m.
- Energy Materials and Systems Division: 5:30–6:30 p.m.

Tuesday, Oct. 19:

- Bioceramics Division: 1–2 p.m.

Plan to attend ACerS Annual Meeting at MS&T21 in Columbus, Ohio. "Where materials innovation happens" matscitech.org

STUDENTS AND OUTREACH



FOR MORE INFORMATION:

www.ceramics.org/students

Material Advantage Student Competitions at MS&T

Detailed information on all student competitions can be found at bit.ly/MSTstudents.

• **The Undergraduate Student Poster Contest** provides an opportunity for students to present their undergraduate research experiences and to put their communication skills to work.

Contest awards will be provided in the amounts of $250, $150, and $100. All undergraduate students are eligible to enter the poster contest. To enter, submit an abstract of no more than 150 words by **Sept. 20, 2021**, to the symposium titled "2021 Undergraduate Student Poster Contest."

• **The Undergraduate Student Speaking Contest** encourages undergraduate students to present technical papers and to improve their presentation skills.

Only one contestant per university is able to compete in this contest. The presentation subject must be technical but can relate to any aspect of materials science and engineering.

Cash prizes will be awarded in the amounts of $500, $250, $150, and $100. Undergraduate speaking contestants must be reported to Yolanda Natividad by **Sept. 27, 2021**.

• **The Graduate Student Poster Contest** recognizes superior research performed during graduate study.

Contest awards will be provided in the amounts of $250, $150, and $100. Only those graduate students who have an accepted poster abstract at MS&T are eligible to enter the poster contest. Graduate Student Poster contestants must be reported to Yolanda Natividad by **Sept. 20, 2021**. 100

3rd Annual Humanitarian Pitch Competition

The ACerS President's Council of Student Advisors is hosting the 3rd Annual Humanitarian Pitch Competition for students to pitch their ideas to a panel of judges about how they can address a challenge that a community is experiencing. This year's theme will be "Use materials knowledge to address a health-related humanitarian issue locally or abroad."

Students may put together a team of up to four participants in order to develop a solution to a real-world problem using materials science. Both undergraduate and graduate students are eligible to participate. Submit abstracts at www.ceramics.org/pitchcomp by **Sept. 10, 2021.**

ACerS GGRN for young ceramic and glass researchers

Put yourself on the path toward post-graduate success with ACerS Global Graduate Researcher Network. ACerS 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.

Are you a current graduate student who could benefit from additional networking within the ceramic and glass community? Visit www.ceramics.org/ggrn to learn what GGRN can do for you, or contact Yolanda Natividad, ACerS membership engagement manager, at ynatividad@ceramics.org.

Deadline extended for CGIF grant proposals

The Ceramic and Glass Industry Foundation is extending the grant proposals deadline for outreach projects that incorporate the use of Materials Science Classroom Kits. The CGIF welcomes proposals that help to introduce students to ceramic and glass science. The grant will allow a recipient to develop or extend existing efforts to grow the base of ceramic and glass education, training, or outreach. The extended deadline is **Nov. 15, 2021**. For more information, visit the CGIF website at foundation.ceramics.org.

Machine learning framework accelerates exploration of elastic strain engineering

A yearslong international collaboration involving researchers at Skolkovo Institute of Science and Technology (Russia), Massachusetts Institute of Technology (U.S.), and Nanyang Technological University (Singapore) explored how elastic strain engineering (ESE) can be used to modify the properties of semiconductors.

ESE is an emerging technique for enhancing the performance of functional materials by tuning a material's properties through the introduction of controlled mechanical strain. ESE is of particular interest for modifying the properties of semiconductors, such as silicon and diamond, as researchers look to push the capabilities of next-generation electronics.

However, "The complexity of modulating the fundamental physical properties of materials, such as the electronic band structure and bandgap through ESE, calls for identifying preferred and actionable strain states within the general six-dimensional (6D) strain space," the researchers write in a recent open-access paper.

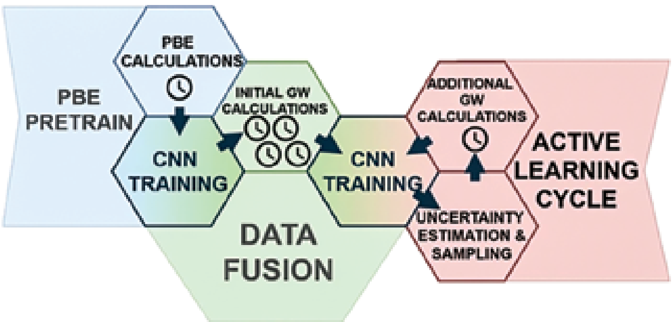
To address the challenge of calculating, analyzing, archiving, and visualizing material characteristics from high-dimensional data, they previously developed a machine learning method that combined a dataset extracted from density functional theory calculations invoking many-body perturbation theory with another dataset prepared with Perdew-Burke-Ernzerhof exchange functional correlations.

However, while this early machine learning method was adequate for rapid data collection in a highly specialized model, "[the calculations] do not offer sufficient flexibility and accuracy for optimizing a broader consideration of physical characteristics such as the effective mass of electrons and holes," they write.

In the new study, the researchers expanded their machine learning method to incorporate a priori physics-informed neural network architectures into the calculations in such a way that various performance characteristics and figure-of-merit estimates could be better optimized.

They tested their updated machine learning method by identifying energy-efficient pathways to "metallize" diamond, i.e., turn it into an electrical conductor while preserving phonon stability. "These results extend our deep learning analytical capabilities beyond those used previously to identify the conditions for the metallization of diamond using ESE," they write.

The researchers conclude that because the expanded method recognizes that the band dispersion is structured and



Credit: Tsymbalov et al., *npj Computational Materials* (CC BY 4.0)

The entire machine learning scheme involves pre-train, data fusion, and active learning. The solid arrows show the workflow, and clock symbols indicate the relative time required for ab initio calculations.

highly correlated with certain materials values, it provides better approximation and less uncertainty in the estimation of key figures of interest, such as curvature of the electronic band and the effective mass of electronics and holes.

"The general ML [machine learning] framework we propose here thus effectively alleviates the heavy dependence upon DFT [density functional theory] calculation, which takes up about 99% of the model construction time in an otherwise typical first-principles materials design project without ML," they write.

The open-access paper, published in *npj Computational Materials*, is "Machine learning for deep elastic strain engineering of semiconductor electronic band structure and effective mass" (DOI: 10.1038/s41524-021-00538-0). 100

Glass containers may degrade certain biomolecules

In a recent study, Purdue University researchers aimed to gain a deeper understanding of how glass surfaces can affect chemical reactions.

Glass vials often store volatile or sensitive materials such as pharmaceutical drug products, including the vaccines for fighting COVID-19. However, while generally the chemical durability of glass vials can be assumed, scattered throughout literature are some reports of chemical reactions being affected by glass containers.

To understand why, "Systematic study on glass catalyzed chemical reactions is needed to provide experimental evidence to support any proposed mechanism," the researchers write in the recent open-access paper.

The researchers are led by Robert Graham Cooks, the Henry Bohn Hass Distinguished Professor of Chemistry at Purdue University. They tested how various base-catalyzed chemical reactions—including elimination, solvolysis, imine formation, Katritzky reaction, and Knoevenagel condensation—are affected by the addition of glass microspheres.

The researchers screened a large set of glass-catalyzed reactions using a high-throughput system they developed in a previous study. The system is based on desorption electrospray ionization mass spectrometry (DESI-MS), a mass spectrometry technique developed by Cooks' group in the early 2000s that minimizes requirements for sample preparation.

The DESI-MS screening revealed significant differences in chemical kinetics between reactions with glass microspheres and those without. However, because "the acceleration factor seen in the DESI-MS data will include contributions from droplet acceleration as well as glass catalysis," the researchers write, they used nanoelectrospray ionization mass spectrometry (nESI-MS) in subsequent detailed analyses for its "superb" sensitivity and use as a reliable nonaccelerating analytical method.

The nESI-MS analysis supported the finding that reactions progressed much faster with glass microspheres than those without. The researchers suggest this acceleration occurs because glass surfaces can act as strong bases and convert protic solvents into their conjugate bases, which then act as bases/nucleophiles when participating in chemical reactions.

These findings "greatly broadened the scope of substrates affected by glass reactions," the researchers write, from positively charged molecules to neutral molecules, zwitterionic molecules, and negatively charged molecules as well.

In particular, they emphasize that the finding that certain biomolecules such as glutathione and acetylcholine can undergo significant amounts of chemical degradation when in contact with glass surfaces "raises awareness of the possible significance of the phenomenon considering that many important biomolecules are stored in solution in glass containers."

To further this point, they followed up on the mechanistic analyses by using nESI-MS to investigate degradation of phos-


Glass vials generally are a good way to store volatile chemicals—but new research shows that may not be the case for certain biomolecules.

Credit: Pxfuel

pholipids induced by glass. (Phospholipids are important biomolecules in many practical aspects of chemistry, including the mRNA-based COVID-19 vaccines.)

They found that all three phospholipids studied degraded when in contact with glass surfaces; lower concentrations of phospholipids gave higher percentages of degradation.

"These results should draw attention to possible deficiencies in current protocols involving storage of phospholipids in organic solvents in glass containers," they write. In general, "storage of base/nucleophile-labile biomolecules in glass containers should therefore be avoided."

The open-access paper, published in *Chemical Science*, is "Glass surface as strong base, 'green' heterogeneous catalyst and degradation reagent" (DOI: 10.1039/D1SC02708E). 100

ceramics in biomedicine

Bioactive glass demonstrates potential in treating giant cell tumor of bone

Researchers from Heidelberg University Hospital and University of Erlangen-Nuremberg in Germany explored using bioactive glass to treat the bone defects resulting from giant cell tumor of bone (GCTB).

GCTB is a noncancerous but aggressive tumor. These semi-malignant tumors often occur in younger adults (20–40 years old) and typically grow at the ends of the body's long bones, such as at the lower end of the femur (thighbone) or upper end of the tibia (shinbone), close to the knee joint.

GCTBs are considered aggressive because they can grow quickly and destroy bone close to a joint. Though the cause of these tumors is unknown, researchers do know that GCTBs are composed of three different cell types:

- Neoplastic (abnormally growing) stromal cells, or cells that makes up certain types of connective tissue;
- Osteoclast-like multinucleated giant cells, or cells that absorb bone tissue during growth and healing; and
- Macrophage-like giant cell precursors, or cells that use their plasma membrane to engulf other cells or particles.

Standard treatment for GCTBs involves intralesional resection, a procedure in which the tumor is entered and then removed piecemeal from the body. However, this procedure can leave behind microscopic and macroscopic amounts of tumor in the surrounding tissues. To minimize risk of recurrence, a comparably wide resection including healthy surrounding bone tissue is necessary—which can generate further large bone defects.

There are several approaches for treating bone defects resulting from tumor resection, the most common being to fill the defect with the biologically inactive material polymethyl methacrylate (PMMA). However, considering the young age of most GCTB patients, a biological reconstruction is preferable because PMMA will remain in the bone as an inert material for the patient's life and could cause some further problems, such as stress shielding at the PMMA/bone interface. Unfortunately, studies using cancellous bone as a biological grafting material show it is associated with much higher local tumor recurrence compared to PMMA.

"Therefore, when considering biologically active reconstruction aiming for consolidation of the bone after GCTB resection, the therapy option must commit to both, the lowest possible recurrence rate and the best possible osteogenic properties at the same time," the researchers write in the recent paper.

In their paper, they hypothesize that bioactive glass may be a good option for treating the bone defects resulting from GCTB. Researchers have extensively described the effects of bioactive glass on several bone precursor cells, such as bone marrow derived mesenchymal stromal cells. However, the interaction of bioactive glass with neoplastic stromal cells—a major component of GCTBs—is unknown.

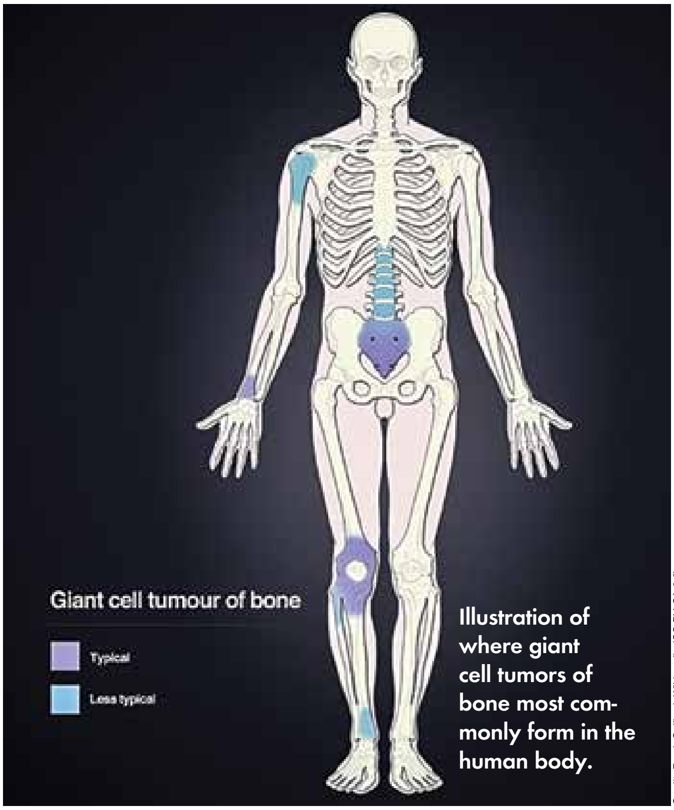


Illustration of where giant cell tumors of bone most commonly form in the human body.

Credit: Frank Gaillard, Wikimedia (CC BY-SA 3.0)

"Due to the known differences of neoplastic and normal cells concerning energy metabolism and pH-tolerance and the important role of ion channels in driving malignant cancer cell behavior, we hypothesized that neoplastic [stromal cells] might react differently, ideally more sensitive against [bioactive glass] treatment," the researchers write.

To test this hypothesis, they created bioactive glasses with five different compositions and observed the glasses in tissue samples over the course of 21 days. All analyzed bioactive glasses induced a significant decrease of neoplastic stromal cell viability, while the regular mesenchymal stromal cell viability was not affected and sometimes even improved after an initial decrease.

Currently, the precise underlying molecular mechanisms driving the bioactive glass and GCTB interaction is unknown. Aldo R. Boccaccini, head of the Institute of Biomaterials at University of Erlangen-Nuremberg, says in an email that the team is in the process of understanding the in vitro interaction better, including differences in behavior of the tumor cells compared to mesenchymal stromal cells.

"In the future, we are planning a close collaboration with the colleagues at Heidelberg University Hospital to design an in vivo model for GCTBs to explore interactions with bioactive glasses," he says.

This study was funded by a grant from German Cancer Aid (Deutsche Krebshilfe).

The paper, published in *Biomaterials*, is "Selective and caspase-independent cytotoxicity of bioactive glasses towards giant cell tumor of bone derived neoplastic stromal cells but not to bone marrow derived stromal cells" (DOI: 10.1016/j.biomaterials.2021.120977). 100

ceramics in energy

Glass-based sealants for solid oxide fuel cells

Several recently published studies explore various glass sealants for use in solid oxide fuel cells (SOFCs).

SOFCs are a type of fuel cell that uses a hard, nonporous ceramic compound as the electrolyte. Compared to other fuel cells, SOFCs operate at very high temperatures—as high as 1,000°C (1,830°F)—and so are typically investigated for use in stationary power generation.

The high operating temperature of SOFCs places stringent durability requirements on materials used in the SOFC, such as sealants. Sealants are used to join the various components of an SOFC together, keeping them electrically separated to avoid short circuits. Sealant materials must be electrically insulating and gastight, plus chemically and mechanically compatible with the adjoining elements to avoid interactions that lead to local changes of the sealant properties, causing cracks or delamination.

Glass and glass-ceramics are of great interest as sealants in SOFCs because of their ability to achieve good adhesion to metal substrates, gas tightness, high electrical resistance, ease of fabrication and application, and competitive costs.

In May 2021, researchers from China University of Mining & Technology-Beijing and University of South Carolina investigated the potential of a feldspar-based silicate glass sealant in SOFCs.

Among various glass materials, silicate glass sealants demonstrate good potential in SOFCs due to low leaking rate and high-temperature reliability. However, the properties of silicate glass are highly dependent on the proportion of the constituent oxides, and many studies that demonstrated successful sealing performance used silicate glass with alkaline oxides.

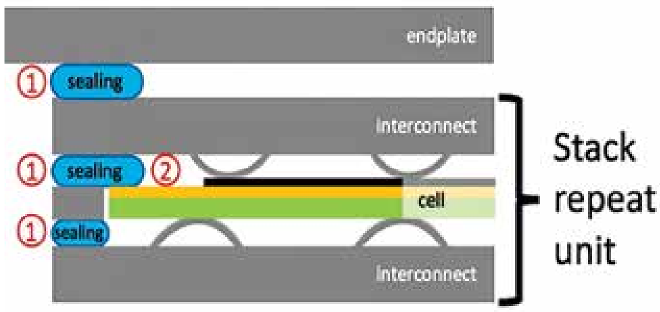
For their study, the researchers prepared a feldspar-based silicate glass that contains around 17 wt.% alkalis (K_2O and Na_2O). To evaluate applicability of the seals in an SOFC, they carried out single cell testing using a NiO-yttria-stabilized-zirconia anode supported cell.

They determined that the open circuit voltage of the glass-sealed single cells stayed stable at 750°C, with no observable voltage degradation after five thermal cycles. They attribute this observation to the crack healing capability of alkaline oxide silicate glass.

"This study indicates the obtained glass composition is a reliable and self-healing glass seal for intermediate temperature SOFCs," they conclude.

The paper, published in *Ceramics International*, is "Feldspar-based $CaO–K_2O–Na_2O–BaO$ silicate glass sealant for solid oxide fuel cells" (DOI: 10.1016/j.ceramint.2021.02.046).

To fine-tune the properties of glass sealants, researchers will add modifiers to a composition to interrupt the normal bonding between glass-forming elements and oxygen. In two



Credit: Spotorno et al., *Materials* (CC BY 4.0)

Detail of a stack scheme showing the position of sealants and its interfaces in a solid oxide fuel cell. 1) Sealing portions in contact with steel at both sides; 2) Sealing portions in contact with steel on one side and ceramic on the other side.

studies published in July 2021, two different research groups explored the use of mixed alkaline earth modifiers and vanadium-based compounds.

The first group consists of two researchers from Thapar Institute of Engineering and Technology in India. They synthesized a series of alkaline earth modified borosilicate glasses with the composition $(40-x)SrO-(x)BaO-45SiO_2-10B_2O_3-5ZrO_2$ (x=0, 10, 20, 30, and 40 mol%) via a melt quench technique.

Through testing, they clearly observed that the alkaline earth modified borosilicate glasses exhibited increased thermal stability and insulating properties and decreased mechanical properties.

"Based on observed properties, it is concluded that the present glasses can be used as sealants in SOFC except SB-20 and SB-0 glasses," they write.

The paper, published in *Journal of Non-Crystalline Solids*, is "Mixed alkaline earth modifiers effect on thermal, optical and structural properties of $SrO-BaO-SiO_2-B_2O_3-ZrO_2$ glass sealants" (DOI: 10.1016/j.jnoncrysol.2021.120812).

The second group consists of researchers from the Bhabha Atomic Research Center in India and the Laboratory of Catalysis and Solid-State Chemistry near Lille, France. They investigated the effects of adding vanadium pentoxide (V_2O_5) to a barium-aluminosilicate sealing glass and a vanadium diboride-based self-healing composite.

They found that V_2O_5 addition lowers the glass transition temperature, but it also leads to a decrease in peak crystallization temperature. "[This effect] is why 2% V_2O_5 content was found as an optimum value to carry out densification before crystallization occurs [compared to 4 and 6 mol.%.]," they write.

They then used a 15 vol.% vanadium diboride self-healing sealant containing 2 mol.% V_2O_5 to seal a ferritic stainless steel interconnect with good results—the microstructure at the seal's interface showed "good bonding with no bubble or crack," they write.

The paper, published in *Solid State Sciences*, is "Influence of V_2O_5 on a sealing glass and self-healing VB_2-glass composites" (DOI: 10.1016/j.solidstatesciences.2021.106706). 100

Origami techniques unfold new opportunities for complex glass shaping

Researchers from Zhejiang University in China investigated the possibility of shaping glass via origami techniques in a recent study.

Conventional glass shaping techniques often operate under harsh conditions such as high temperature or chemical etching. Sol-gel chemistry allows defining glass shapes under milder conditions, but the geometric complexity is inherently limited by the molding technique involved.

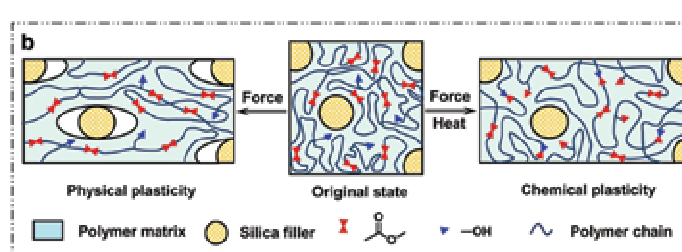
In the past few years, research on using silica-polymer composites as the precursor for glassmaking has offered opportunities to create glass with more complex geometries. These composites can be molded at low temperatures through subtractive or additive manufacturing processes, and then heat treated to remove the polymer, leaving behind the complex-shaped glass.

While 3D printing of precursor composites has resulted in some successes, the approach still runs into limitations, including resolution and surface roughness (in the case of stereolithography) and compromised print size and productivity (in the case of two-photon polymerization).

Origami is another shaping technique that has experienced new life in recent years in many engineering areas, including soft robotics, wearable electronics, aerospace structures, and medical devices.

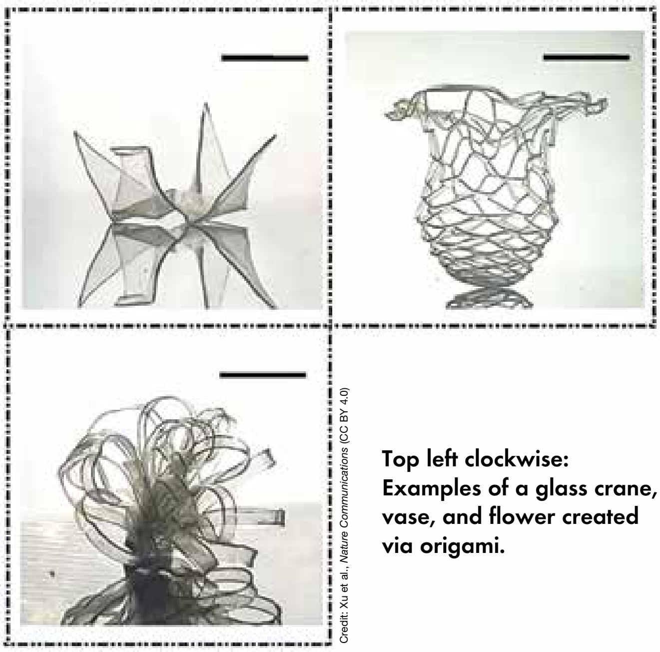
Origami involves converting a planar sheet into 3D geometries. Though at first it may appear a contradictory choice for brittle glass, "with the delicate molecular design of the precursor composite, it is possible to introduce mechanisms that make it deform in such a way that permits origami-shaping of transparent glass," the researchers of the open-access paper write.

They start by noting that for the composite to be foldable like paper, it must have plasticity, or the ability to change shape permanently when subjected to stress.



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

Two mechanisms for permanent deformation via plasticity. The physical plasticity is due to particle cavitation, while the chemical plasticity is due to dynamic bond exchange.



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

Top left clockwise: Examples of a glass crane, vase, and flower created via origami.

Both physical and chemical mechanisms can induce plasticity, and the researchers designed their composite to exhibit both.

"The physical plasticity is more convenient since it does not require heating during the folding. By comparison, chemical plasticity is more favored when high shape retention is needed," they write.

They fabricated the composite sheet by curing a silica nanoparticle-filled liquid precursor. Then, after cutting the sheet into the desired shape, they folded it using manual techniques similar to actual paper origami. "Further pyrolysis and sintering remove the polymer binder and convert the 3D object into glass," they write.

The researchers succeeded in creating several impressively complex shapes via origami techniques, including a crane, vase, and flower. In particular, the crane relied on physical plasticity whereas the vase and flower relied on chemical plasticity.

"These origami glasses are challenging to produce with 3D printing as it would require extensive support structures that are cumbersome to remove. The surface smoothness is also difficult to achieve with regular 3D printing," they write.

The researchers note that while they manually folded the composite sheets in this study, the process could be automated and thus is suitable for large-scale manufacturing. "More importantly, our process does not use molds, thus the geometric complexity is not bound by traditional molding techniques," they write.

The open-access paper, published in *Nature Communications*, is "Transparent origami glass" (DOI: 10.1038/s41467-021-24559-x). 100

advances in nanomaterials

Metalens improves production of GaN-based LEDs

Researchers from National Taiwan University in Taipei and National United University in Miaoli looked to develop a metalens to serve a very specific purpose in the production of gallium nitride-based LEDs.

Gallium nitride is a wide bandgap semiconductor that revolutionized development of white and blue LEDs in the 1990s. Gallium nitride is still the material used in many LEDs today, and researchers expect gallium nitride to play an important role in next-generation high-power electronics, high-frequency devices, and laser diodes as well.

Gallium nitride-based blue LEDs are typically grown on micro/nano-sized patterned sapphire substrates (PSSs) to improve light extraction efficiency of the final LED. PSSs are examined using a scanning electron microscope or optical microscope to ensure the substrate has the correct structure. However, SEM systems can be costly and slow, while optical microscopes are bulky and complex devices.

Thus, "There is a need to develop ultra-light and thin optics to replace current conventional objectives" for imaging PSSs, the researchers write.

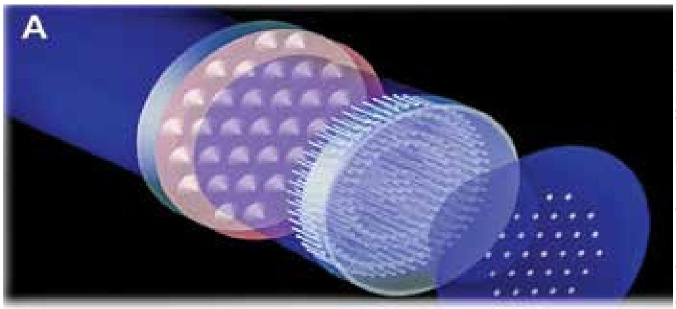
Metalenses are flat, engineered lenses constructed of nanoscale arrays of columns or fin-like structures. Because of their design, metalenses focus light without causing chromatic aberrations, a type of image distortion that conventionally requires multiple curved lenses to correct.

The researchers note that highly efficient metalenses were recently constructed with a Pancharatnam-Berry phase rotational morphology, but these metalenses required circularly polarized light as an excitation incidence to reach their full-phase control.

"Although this obstacle can be circumvented by using nanostructures with symmetric cross-sections, polarization-insensitive metalenses of high performance for the desired wavelength require the development of highly efficient building blocks along with carefully selected subwavelength periods and well-established fabrication processes," they write.

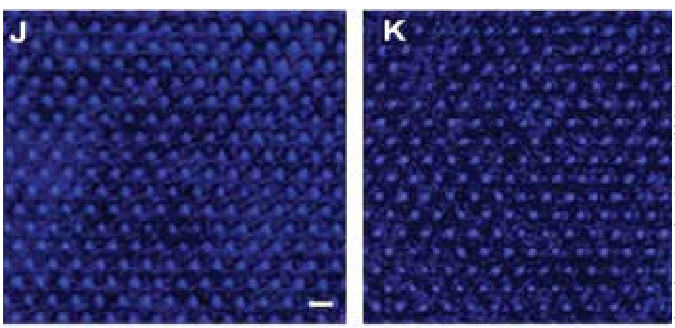
They decided to develop metalenses using high-aspect-ratio gallium nitride hexagon-resonated elements as the building blocks. Using a metal–organic chemical vapor deposition system and electron-beam lithography, they fabricated three metalenses that work at three distinct wavelengths of 405, 532, and 633 nm, with respective diffraction-limited focusing efficiencies of 93%, 86%, and 92%.

Testing revealed the 405-nm metalens capable of taking "exceptional clear" images of line features, with the smallest resolvable features having widths of 870 nm. In contrast, line



Credit: Chen et al., *Scientific Reports* (CC BY 4.0)

Schematic of patterned sapphire substrates inspected by the metalens.



Credit: Chen et al., *Scientific Reports* (CC BY 4.0)

Images of the PSS on which the blue LED is grown. Images taken by (J) SEM (numerical aperture = 0.4) at the laser wavelength of 450 nm, and (K) the 450-nm-designed metalens (numerical aperture = 0.3) at the laser wavelength of 450 nm. Scale bar: 3 μm.

features in images formed by the 532-nm metalens lost clarity when approaching line widths of 0.98 μm, while the 633-nm metalens blurred due to the larger diffraction-limited value of the metalens.

The researchers fabricated another metalens working at the wavelength of 450 nm and compared its imaging capabilities to an SEM. "Unsurprisingly, the one taken by the [SEM] shown in Fig. 5J, is vaguer than the image pictured by the 450-nm-designed metalens, as verified in Fig. 5K, which can clearly and sharply visualize the post apexes in the PSS," they write.

The researchers conclude that "This work demonstrates the tremendous capacity for the ultra-thin and light-weight metalenses being used for fabricated structure inspection of the patterned substrates and offers another novel and advanced optics based on semiconductor manufacturing."

The open-access paper, published in *Scientific Reports*, is "Polarization-insensitive GaN metalenses at visible wavelengths" (DOI: 10.1038/s41598-021-94176-7).

Honoring the ACerS Awards Class of 2021

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

The most prestigious of ACerS awards is Distinguished Life Member designation, a recognition bestowed upon only two or three members each year. In 2021, three individuals will receive DLM honors: William E. Lee, Kathleen A. Richardson, and Anil Virkar.

The Society will elevate 17 members to Fellow and recognize many more outstanding members with various Society, Division, and Class awards will during the ACerS Annual Honor and Awards Banquet Reception on Oct. 18, 2021.

2021 DISTINGUISHED LIFE MEMBERS

William E. Lee

As a self-described "studious little kid," Bill Lee spent a lot of time with his nose in books. At the age of 16, he read one that was particularly influential for him, a thin volume titled "Metals in the Service of Man."

"It's not a title you would use now," he says. "But it got me interested in metals."

With his interest in science sparked, the teenager applied to Aston University, in the city of Birmingham in his home country of England, to study metallurgy. The studious kid did well in his undergraduate work and was admitted to study for a doctorate degree at Oxford University. When it came time to prepare for a final project, the department head, the famed British scientist Sir Peter Hirsch, suggested he study radiation damage in ceramics. That was the beginning of a distinguished career in ceramic science and education that continues today.

While at Oxford, Lee met Arthur Heuer, the renowned materials researcher at Case Western Reserve University, who suggested he come to CWRU for postdoctoral work. It was off to Cleveland, Ohio, for two years, and then to Columbus for a faculty position at The Ohio State University.

While at OSU, Lee joined The American Ceramic Society. "I got into the community of the Society, which is its core strength," he says. "I got involved in the local Section and enjoyed the friendly nature of the Society and the networking opportunities it gave me."

He maintained his membership after he and his wife, Jacky, an OSU graduate, moved back to England, where Lee joined the faculty at Sheffield University. He researched and taught there for 17 years before taking a position as head of the Department of Materials at Imperial College London in 2006.

Lee was invited to join the ACerS board and then to climb the ladder to become president of the Society, which he accomplished in 2017, becoming the first Society president who was residing outside the U.S. during his term.

Ever the educator, during his term he succeeded in getting board representation for a student member and in establishing an award to recognize outstanding doctoral research in the ceramics and glass discipline, the Morgan Medal and Global Distinguished Doctoral Dissertation Award.

His service to the profession and the industry will be lasting, having supervised 67 Ph.D. students to the completion of their theses. "For me, that's a big deal," he says. "It's a very intense relationship when they're studying for a Ph.D. You get to know the students and what makes them tick."

He and Jacky live in Devon, on the southwest coast of England, and have a daughter, Alexandra, who is studying history at the University of Exeter.

At 63, Lee is currently "sort of retired," serving part-time at Imperial College London as codirector of its Institute for Security Science and Technology, and at Bangor University in Wales, where he is developing a nuclear engineering research group.

Those days devouring scientific books as a child set him on the path. "It was always my ambition to be a mad professor," he says, "and I think I achieved it."

Kathleen A. Richardson

Photography is one way that children become interested in optics, through roles either in front of or behind the lens. For Kathleen Richardson, her interest came from studying the science of what's inside the camera instead.

"I had a high school research experience, an after-school Science Explorer program at Kodak in optics, that really motivated me to understand the chemistry and the science behind issues related to optical materials," she says.

Growing up in Rochester, N.Y., where Kodak is based, Richardson originally entered Alfred University as a chemistry major. However, after seeing that her friends in ceramic engineering were having "way more fun," she transferred to the New York State College of Ceramics during her second semester and eventually went to work in an optical materials lab at the University of Rochester's Lab for Laser Energetics. Little did she know this experience would start her life-long track of straddling the optics and materials science communities, bringing interdisciplinary breadth and perspective to both.

After returning to Alfred for a master's and Ph.D., Richardson accepted a faculty position at the University of Central Florida, a position she has consistently returned to following opportunities at Schott Glass and Clemson University. These experiences provided opportunities to "test drive" both academic leadership and industry research environments, a strategy of exploring career directions that Richardson reinforces when mentoring her own students.

"That experiential part of learning… keeps them truer to themselves and truer to whatever they are working on. It gives them a clear perspective of the project, the good and the difficult, with an eye toward where and how those skills will prepare and transition them to their next career stop," she says.

Richardson's research in infrared optical materials, chalcogenide glasses and glass ceramics has led to her publishing more than 250 peer-reviewed papers and being granted 21 patents, with direct benefits to many industrial applications. For example, IRradiance Glass, a company that Richardson cofounded through her research group at Clemson and then UCF, was recently acquired by Rochester Precision Optics to aid in their manufacturing of molded optics based on infrared glass.

Richardson knew of ACerS since her undergraduate years when she was a part of Keramos, the national professional ceramic engineering fraternity. Then, during her early research years at the University of Rochester, she joined ACerS and became heavily involved through the Western New York Section, which she chaired. She has since served in numerous leadership roles, including on the Executive and Program committees of the Glass & Optical Materials Division, as GOMD chair (2005–2007), as National Institute of Ceramic Engineers president (2008–2009), and as ACerS president (2014–2015). Plus, she was a founding member of the Board of the Ceramic and Glass Industry Foundation (2014–2018).

Richardson's approach to serving ACerS, and a motto she instills in her students, is that "the more you give to your community, the more you get back." She says the strong collegiality of the Society is proof of this approach.

"That's the part of what we've done and, and I say 'we' because it's me as an individual member, but it's also based on all the interactions I've had with leadership in the Society and our members. It is this 'community,' now more multidisciplinary than ever before, that I believe is what keeps our Society strong and vibrant and keeps us relevant going forward," she says.

Anil Virkar

Anil Virkar, like many other young boys growing up in India, focused his energy on honing his cricket skills. As the teen years approached, he took more interest in his studies. His father held a Ph.D. in organic chemistry, and his older brother earned a Ph.D. in mathematics, so his interests took a natural turn toward the sciences.

The opportunity to study ceramic materials science presented itself when he went to graduate school at Northwestern University in Illinois after completing his B.S. in metallurgy in India. Not that he knew much about ceramic materials at the time. "I knew about refractories and furnaces, but that was about it," he says.

Virkar considers himself fortunate that the job situation in 1973 was not very good, saying he would have taken a position in industry had that been an option. Instead, he took a post-doctoral position at the University of Utah, which proved to be an opportunity that worked out very well when it led to a faculty position at Utah, where he is still.

Virkar says, "In my experience, if you take advantage of the opportunities you get, it works out very good for you."

His post-doctoral work measuring strength of materials for sodium-sulfur batteries led to an interest in electrochemical batteries, which led to an interest in other electrochemical devices such as solid oxide fuel cells. Over the years, his research interests spanned a wide range of technologies: aluminum nitride semiconductor packages, nitrogen oxide sensors, oxygen delivery devices, and more.

What is the common thread for an academic career that covers such a wide range of technical interests?

"Actually, remarkably, it was my teaching," he says. Teaching advanced courses in the materials science and engineering department piqued his curiosity and sparked research ideas. "Teaching drove my research rather than the other way around," he says.

Virkar says he benefited greatly from having an excellent mentor in Ronald Gordon, who was also on the faculty at Utah. "He instilled in me that you want to try to develop technology and do your best to commercialize it," Virkar recalls. Gordon, Virkar, and several others embraced this attitude by founding Ceramatec, Inc., which today is owned by CoorsTek, and employed at its peak about 150 people. Virkar went on to found three other companies.

Virkar attended his first ACerS Annual Meeting in 1969 while in graduate school at Northwestern. The meeting was also in Chicago, and his advisor gave him money for a train ticket and lunch and sent him off to his first conference. Since then, Virkar has been a regular at many Annual Meetings and especially at the International Conference on Advanced Ceramics and Composites in Daytona Beach.

More than 30 Ph.D. and 20 M.S. students earned their degrees under Virkar's guidance. His advice for the rising generation? "Do what you want to do. Take advice from others in a positive way."

And, as his career demonstrates, that can lead to opportunities that may work out very well for you. 100

The 2021 Class of Fellows

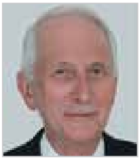
Arvind Agarwal is Distinguished University Professor and chair of the Department of Mechanical and Materials Engineering at Florida International University. He also is director of the Advanced Materials Engineering Research Institute. He obtained his B.S. from the Indian Institute of Technology Kanpur in materials and metallurgical engineering and Ph.D. in materials science and engineering from the University of Tennessee, Knoxville. Agarwal is a member of the Engineering Ceramics Division. He was the founding faculty advisor of FIU's Materials Advantage Chapter and has worked with many students in ceramics, many of whom were a part of ACerS President's Council of Student Advisors.

Csaba Balázsi is scientific advisor of the Centre for Energy Research of Eötvös Loránd Research Network, Centre of Excellence of Hungarian Academy of Sciences. He obtained his M.Sc. degree in materials science and metallurgical engineering from Transilvania University of Brasov, Romania. He received his Ph.D. in materials science from University of Miskolc, Hungary. Balázsi joined the Engineering Ceramic Division in 2004 and has been an invited speaker, session chair, or co-organizer of many ACerS symposia, roles in which he supported colleagues and students to join ACerS-ECerS activities. He is an ACerS Global Ambassador (2020) and an associate editor of *International Journal of Applied Ceramic Technology*.

Suresh Baskaran is director of research partnerships at Pacific Northwest National Laboratory in Richland, Wash. Baskaran received his M.S. in materials engineering from Virginia Tech and Ph.D. in ceramic engineering from University of Illinois at Urbana-Champaign. Baskaran first joined ACerS in the early 1980s and is affiliated with the Engineering Ceramics Division. In his current role at PNNL, Baskaran helped expand opportunities at the PNNL for university faculty and graduate students and worked with ACerS in outreach to students.

Emmanuel E. Boakye is an onsite senior research scientist at UES Inc. His work supports the high-temperature ceramics team efforts at the Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio. He received his M.Sc. in chemistry from the University of Calgary and Ph.D. in materials science and engineering from The Pennsylvania State University. Boakye belongs to the Engineering Ceramics and Basic Science Divisions. He chaired the Dayton/Cincinnati/Northern Kentucky section of ACerS (2018–2020) and helped organize 2019 GFMAT-2 in Toronto, Canada, in 2019 and ICACC 2022.

Alicia Durán is research professor at the Spanish Research Council (CSIC), Madrid, Spain. She received a Ph.D. in physics at the Universidad Autónoma de Madrid, Spain. Durán was associate editor of *International Journal of Applied Glass Science* in 2015 and has been co-editor of the journal since 2018. She also was a guest editor for two special issues in *IJAGS*: Phosphate Glasses (January 2020) and Women in Glass (June 2020). She is the current president of the International Commission on Glass.



Wolfram Hoeland (retired) was a researcher at Ivoclar Ltd. and later at Ivoclar Vivadent Ltd, Schaan, Liechtenstein. He conducted fundamental and applied research to develop dental biomaterials. He belongs to the Glass & Optical Materials and Bioceramics Divisions. Hoeland is associate editor of the *International Journal of Applied Glass Science* as well as a reviewer for *Journal of the American Ceramic Society*. He also chaired the Jeppson Award Committee from 2013 through 2015 and co-organized the Norbert Kreidl Symposium in 1994. Hoeland received the 2018 Stookey Lecture of Discovery Award of GOMD.

Amitabha Kumar is vice president of innovation and R&D at Boral IP Holdings LLC, San Antonio, Texas. He received his M.S. and Ph.D. degrees in solid state science from The Pennsylvania State University in 1982 and 1985. Kumar has been a member of the Cements Division since 1981. He has served as a page, published and presented papers, and chaired a meeting.

Cato Laurencin is Albert and Wilda Van Dusen Distinguished Endowed Professor of Orthopaedic Surgery at the University of Connecticut and university professor in three departments: chemical engineering, materials science and engineering, and biomedical engineering. Laurencin is chief executive officer of The Connecticut Convergence Institute for Translation in Regenerative Engineering at UConn. He earned his M.D. from the Harvard Medical School and Ph.D. in biochemical engineering/biotechnology from Massachusetts Institute of Technology. He was honored previously as the Edward Orton, Jr. Memorial Lecturer and as the Rustum Roy Lecturer.

Anne Leriche is full professor at Université Polytechnique Hauts-de-France and researcher at the Laboratory of Advanced Ceramic Materials and Processes in Maubeuge, France. She obtained her M.S. in chemistry in 1981 and Ph.D. in engineering ceramics at Mons (Belgium) and at Leeds (U.K.) universities in 1986. Leriche fostered stronger engagement with ACerS by initiating the ACerS-ECerS student exchange program (2013) and supporting the attendance of European young researchers to the ACerS Winter Workshops. She received the first ACerS-ECerS Award in 2020.

The 2021 Class of Fellows (continued)

Jeffrey Rickman is professor of physics and materials science and engineering at Lehigh University. He earned his undergraduate degrees in physics and mathematics from Miami University, and M.S. and Ph.D. in physics from Carnegie Mellon University. Rickman joined ACerS in 1998 and has been active in both the Basic Science and Electronics Divisions. He has served as an organizer and program chair for EMA in 2019 and 2020, and as a member of the Sossman Committee in 2019. He also co-organized materials informatics symposia at MS&T 2020.

Federico Rosei is professor at the Centre Énergie, Matériaux et Télécommunications, Institut National de la Recherche Scientifique, Varennes, Quebec, Canada. He received his M.Sc. and Ph.D. degrees from Sapienza University of Rome, Italy. Rosei is a member of Engineering Ceramics Division, as well as Basic Science, Bioceramics, Electronics, Energy Materials and Systems, and Glass & Optical Materials Divisions. He is chair of ACerS Canada Chapter.

Paul Salvador is professor of materials science and engineering at Carnegie Mellon University in Pittsburgh, Pa., where he also directs the master's program in Energy Science, Technology & Policy. He received his Ph.D. in materials science and engineering from Northwestern University in 1997. Salvador joined ACerS in 1994 and is an active member of the Basic Science Division. He was the faculty advisor to the CMU Material Advantage Chapter from 2001 to 2006 and was a Ceramics Education Council Officer from 2005–2008. He organized conferences, participated in BSD award committees, and served as a BSD officer 2015–2020. He has been an associate editor of *JACerS* since 2014.

Tobias Schaedler is manager of the Architected Materials and Structures Department at HRL Laboratories, LLC in Malibu, Calif. He received his Ph.D. in materials from the University of California, Santa Barbara, in 2006. His service to ACerS includes organizing a new symposium, Additive Manufacturing of Glass, Ceramics and Composites, at the 2019 MS&T conference and co-organizing the Symposium on Additive Manufacturing at the ICACC conference in 2020 and 2021. He is a member of the Engineering Ceramics Division.

Hisayuki Suematsu is professor in the Extreme Energy-Density Research Institute and Nuclear System Safety Engineering Department at Nagaoka University of Technology, Japan. He earned his M.S. and Dr. Eng. degrees in nuclear engineering from Nagaoka University of Technology in 1988 and 1991. Suematsu has been a member of the Engineering Ceramics Division, on the ECD Executive Committee, and is current chair-elect of ECD. He served as program chair of ICACC 2021 Virtual.

Tohru Suzuki is group leader of the Ceramics Processing Group, Research Center for Functional Materials at the National Institute for Materials Science in Tsukuba, Japan, and professor in the Department of Nanoscience and Nanoengineering, Waseda University, Japan. He received his Ph.D. in materials science and engineering from Waseda University in 1995. Suzuki is a member of the Engineering Ceramics Division and received the Global Star Award in 2017. He has served as a symposium organizer for ICACC, PACRIM, GFMAT, and ICC.

Setsuhisa Tanabe is professor of material chemistry in the Graduate School of Human and Environmental Studies, Kyoto University, Japan. He received his Ph.D. in industrial chemistry at Kyoto University in 1993. He joined ACerS in 1996 and has been active in the Glass & Optical Materials Division, and he has served as an organizer at many meetings, including GOMD. He is the recipient of the Darshana and Arun Varshneya Frontiers of Glass Science Award and presented the lecture at GOMD 2018.

Alberto Vomiero is chair professor of experimental physics at the Luleå University of Technology, Sweden, and full professor of industrial engineering at Ca' Foscari University of Venice, Italy, where he also directs the Ph.D. program in science and technology of bio- and nanomaterials. He received his M.Sc. in physics from the University of Padova, Italy, and Ph.D. in electronic engineering from the University of Trento, Italy. He belongs to the Engineering Ceramics Division, received the Global Star Award in 2017, and organizes symposia at ICACC and PACRIM conferences. 100

Visit https://ceramics.org/awards/society-fellows to learn more about the 2021 Fellows

Society Awards

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


Ohji

Tatsuki Ohji is a Fellow of the National Institute of Advanced Industrial Science and Technology (AIST), Japan, and ACerS president 2019–2020. He received his B.S. and M.S. in mechanical engineering from Nagoya Institute of Technology and Ph.D. in inorganic materials engineering from Tokyo Institute of Technology. He is an editor of *Journal of the American Ceramic Society* and *Ceramics International*, a governor of *Acta Materialia Inc.*, in addition to serving as an editorial board member of many international journals.

His research interests include mechanical property characterization of ceramics, ceramic composites and porous materials, microstructural design of ceramic materials for better performance, structural control of meso/macro porous ceramics, and green/additive manufacturing of ceramic components.

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


Wicks

George Wicks retired in 2013 from the Savannah River National Laboratory in Aiken, S.C., in the position of consulting scientist, the highest technical level in the organization at that time. He currently serves as an independent consultant with his own company, is adjunct professor at several universities, and works as CTO at the Applied Research Center and VP/CTO of SpheroFill, a new biotech company. Wicks has worked extensively in many areas of ceramics and glass science, as well as in other fields and disciplines during his career. His research activities include nuclear waste management, remote glass melters, environmental remediation, sensor development, corrosion of materials, hydrogen storage systems, alternative and renewable energy, nuclear disarmament activities, C&B agents, hybrid microwave technology, and a variety of new medical initiatives.

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


Blair

Victoria L. Blair is materials engineer at DEVCOM Army Research Laboratory, at Aberdeen Proving Ground, Md. She received her Ph.D. in ceramics from Alfred University (New York State College of Ceramics) in 2014. Blair joined ARL as a post-doctoral fellow in 2014 and conducted research on processing functional materials for solid-state batteries and laser gain media. Her current research focuses on transparent ceramics for Army applications. Blair serves as an ARL technical lead for high-temperature materials. In 2020, she earned the ARL Early Career Award, which includes financial support for a new research area.

ROSS COFFIN PURDY AWARD recognizes authors who made the most valuable contribution to ceramic technical literature in 2019.

First-principles study, fabrication, and characterization of $(Hf_{0.2}Zr_{0.2}Ta0_{.2}Nb_{0.2}Ti_{0.2})C$ *high-entropy ceramic*

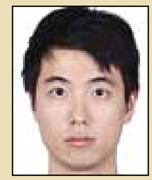
Published in *Journal of the American Ceramic Society* 2019, 107(7):4344–4352.


Ye

Beilin Ye lives in Hong Kong and plans to pursue her doctoral degree after July 2021 at City University of Hong Kong, Hong Kong, China.


Wen

Tongqi Wen as a distinguished postdoc at the Hong Kong Institute for Advanced Study at City University of Hong Kong, Hong Kong, China.


Huang

Kehan Huang is working on his master's degree in chemistry at the Imperial College London, U.K.

Cai-Zhuang Wang is senior scientist at the Ames Laboratory in Ames, Iowa.


Chu

Yanhui Chu is professor in the School of Materials Science and Engineering at South China University of Technology, Guangzhou, China.

RICHARD AND PATRICIA SPRIGGS PHASE EQUILIBRIA AWARD honors authors who made the most valuable contribution to phase stability relationships in ceramic-based systems literature in 2020.

Thermodynamic descriptions of the light rare-earth elements in silicon carbide ceramics.

Published in *Journal of the American Ceramic Society* 2020, 103:3812–3825.


Xu

Kai Xu is research associate at Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, in Ningbo City, China.


Chang

Keke Chang is professor at Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, in Ningbo City, China.

Society Awards (continued)


Zhou

Xiaobing Zhou is professor at Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences.

Leilei Chen, Engineering Laboratory of Advanced Energy Materials, Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Ningbo, Zhejiang, China

Junwen Liu, Engineering Laboratory of Advanced Energy Materials, Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Ningbo, Zhejiang, China

Zixuan Deng, Engineering Laboratory of Advanced Energy Materials, Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Ningbo, Zhejiang, China


Huang

Feng Huang is currently a principal investigator and professor at the Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences.


Huang

Qing Huang is professor at the Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences.

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


Backman

Lavina Backman is materials engineer and Karles Fellow in the Spacecraft Engineering Division at the U.S. Naval Research Laboratory in Washington, D.C. She completed her Ph.D. in Department of Materials Science and Engineering at the University in Virginia in May 2020. Her dissertation focused on the oxidation behavior of high-entropy ultrahigh-temperature ceramics. She continues to specialize in the development and characterization of ultrahigh-temperature materials for extreme environments.

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


Jiang

Shibin Jiang is founder and president of AdValue Photonics Inc. in Tucson, Ariz., and adjunct research professor at College of Optical Sciences, University of Arizona. He was co-founder and CTO of NP Photonics Inc. before founding AdValue Photonics in 2008. Jiang served on many award committees for ACerS, OSA, SPIE, and is associate editor for four scientific journals. He chaired the Glass & Optical Materials Division in 2014. His research activities generated more than a dozen of the world's first commercial products in rare-earth doped glasses, fibers, fiber lasers, and amplifiers.


Kato

Kazumi Kato is vice president of National Institute of Advanced Industrial Science and Technology (AIST). She is a member of the Science Council of Japan, and a committee member for the Environmental Dispute Coordination Commission, Ministry of Internal Affairs and Communication since 2017. Kato has served as a key research scientist of AIST and project leader for many national Japanese R&D projects.

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


Blair

Victoria L. Blair is materials engineer at DEVCOM Army Research Laboratory, at Aberdeen Proving Ground, Md. She has been a member of ACerS since 2007, when she first joined Material Advantage as a student. In 2008, she supported the founding of the President's Council of Student Advisors and initiated many of the student programming that ceramics students now enjoy at ACerS meetings. Blair currently serves as mentor-at-large for the PCSA. She served on multiple committees within ACerS, including the Member Services Committee, Strategic Planning and Emerging Opportunities Committee, Educational and Professional Development Council, and the Young Professional Network. Blair co-leads the ACerS D.C./Baltimore/NoVA Section and is a member of the Basic Science and Engineering Ceramics Divisions. 100

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


Cesarano

Joseph Cesarano is president of Robocasting Enterprises LLC, which he founded in 2007 in Albuquerque, N.M., and serves on the Board of Trustees for Alfred University. His research interests include colloidal science and manipulation of fine particles for the development of material manufacturing technologies and process improvement. In 1996, Cesarano co-invented robocasting technology (i.e., direct-ink writing) for extrusion-based additive manufacturing of ceramics. His current focus is on commercialization of robocasting for large-scale manufacturing of ceramics and composites.

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

Favorable redox thermodynamics of $SrTi_{0.5}Mn_{0.5}O_{3-\delta}$ *in solar thermochemical water splitting*

Published in *Chemistry of Materials* 2020, 32:9335-9346. Qian, Xin; He, Jiangang; Mastronardo, Emanuela; Baldassarri, Bianca; Wolverton, Christopher; Haile, Sossina M.

Qian

Xin Qian is a postdoctoral Fellow in the School of Materials Science and Engineering at the Georgia Institute of Technology. He continues to explore alternative pathways for renewable energy storage using solid state ionic materials and devices, with a particular focus on developing a hybrid fuel cell system based on proton conductors for power generation and reversible hydrogen production.

Awards Banquet

Join us to honor the Society's 2021 award winners at **ACerS Annual Awards and Honors Banquet, Monday, Oct. 18 at MS&T21**. Banquet tickets may be purchased with conference registration or by contacting Erica Zimmerman at EZimmerman@ceramics.org. Tickets must be purchased by **noon on Oct. 18, 2021**.

KARL SCHWARTZWALDER-PROFESSIONAL ACHIEVEMENT IN CERAMIC ENGINEERING (PACE) AWARD honors the past president of the National Institute of Ceramic Engineers, focusing on public attention on outstanding achievements of young persons in ceramic engineering and illustrates opportunities available in the ceramic engineering profession.

Hubert

Mathieu Hubert is glass development associate at the Corning Research & Development Corporation in Corning, N.Y. He received his M.Sc. and Ph.D. in chemistry from the University of Rennes 1, France, and Ph.D. in materials science and engineering from the University of Arizona, Tucson, Ariz. Hubert joined Corning in 2016, working on the development of new glass and glass-ceramic products. He holds two patents, plus six pending patent applications. A member of ACerS Glass & Optical Materials Division since 2011, Hubert served as session chair at several meetings, lead organizer of the Symposium on Glass Technology and Manufacturing at the 2019 ICG/GOMD conference, and co-program chair for the upcoming 2021 GOMD Conference in Vancouver, BC, Canada.

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

Richardson

Kathleen Richardson is Pegasus Professor of Optics and Materials Science and Engineering and Florida Photonics Center of Excellence Professor at CREOL/College of Optics and Photonics at the University of Central Florida, where she runs the Glass Processing and Characterization Laboratory. Richardson and her research team carry out synthesis and characterization of novel glass and glass-ceramic materials for optical applications, examining the role of structure–property relationships on resulting optical function and performance in bulk, planar, and fiber optical materials. This year's ECerS-ACerS Joint Award will be presented at the ECerS XVII annual meeting in 2022.

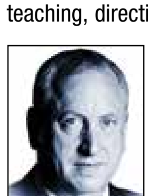
Class Awards

ACerS/EPDC ARTHUR FREDERICK GREAVES-WALKER LIFETIME SERVICE AWARD recognizes an individual who has rendered outstanding service to the ceramic engineering profession and who, by life and career, has exemplified the aims, ideals, and purpose of the former National Institute of Ceramic Engineers.

Medvedovski

Eugene Medvedovski is R&D manager at Endurance Technologies Inc., Calgary, AB, Canada. He earned his B.Sc./M.S. degree in Ceramic Engineering from the Mendeleev Moscow Chemical Engineering University (Russia) and his Ph.D. degree in ceramic engineering/ electroinsulating materials from the All-Union Research and Manufacturing Centre of Cable Industry (Moscow, Russia). His R&D and manufacturing activity for over 40 years includes advanced ceramics, composites and coatings and their technology for wear-, corrosion- and thermal shock-resistant products, ballistic armor, sputtering targets and semiconductors, electrical insulators, catalyst carriers, and membranes.

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



Speyer

Robert F. Speyer is professor of materials science and engineering at the Georgia Institute of Technology and CEO of Verco Materials, LLC, both in Atlanta, Ga. He earned his B.S, M.S., and Ph.D. degrees in ceramic engineering from the University of Illinois at Urbana-Champaign. Over the most recent decade, Speyer developed three courses at Georgia Tech: Chemical Thermodynamics; Transport Properties of Materials; and Ceramic Processing, Properties, and Applications.

Class Awards (continued)

ENERGY MATERIALS AND SYSTEMS DIVISION D.T. RANKIN AWARD, in memory of Tom Rankin, recognizes a member of the former Nuclear & Environmental Technology Division who has demonstrated exemplary service to the division.


Priya

Shashank Priya is professor in the Department of Materials Science and Engineering at The Pennsylvania State University. In 2019, he was lead organizer of the 3rd Annual Energy Harvesting Society Meeting. He also served on the organizing committee for Materials Challenges in Alternative & Renewable Energy 2020 combined with the 4th Annual Energy Harvesting Society Meeting. Priya leads programs in the area of energy harvesting and bioinspired materials and devices.

Richard M. Fulrath Symposium and Awards

promote technical and personal friendships between Japanese and American ceramic engineers and scientists.

Due to COVID-19 travel restrictions, this award symposium will take place at ACerS 124th Annual Meeting at MS&T22 in Pittsburgh, Pa.


Gupta

American Academic
Surojit Gupta
Design paradigm for sustainable manufacturing of ceramics by analyzing different case studies

Gupta is associate professor of mechanical engineering at the University of North Dakota. He researches advanced materials processing, high-temperature materials, nanotechnology, and sustainability research from applied and fundamental perspectives. Gupta has been a member of ACerS since 2003. His ACerS activities include serving on the Coble Awards Committee, ACerS Member Services Committee, Meetings Committee, Du Co Awards Committee, and Awards and Nomination Committee for the Engineering Ceramics Division. Gupta previously chaired the Engineering Ceramics Division and was program chair for the ICACC conference.


Paisley

American Industrial
Elizabeth Paisley

Paisley is a principal member of the technical staff at Sandia National Laboratories in Albuquerque, N.M. Her work includes thin film oxide growth for ultrawide bandgap gate dielectrics and tunable thermal conductors, spectroscopic analysis of interface- and surface-mediated effects of oxide systems and oxide thin film growth. She serves as project manager and lead in several areas related to electronic materials applications. She is the chair of the Electronics Division's Outreach Committee.


Honma

Japanese Academic
Tsuyoshi Honma
Fabrication and morphology control of advanced glass-ceramics for next-generation all-solid-state batteries

Honma is associate professor in materials science and technology at the Nagaoka University of Technology in Niigata, Japan. His research focuses on crystallization of glass and fabrication of functional devices using glass-ceramics. In particular, Honma works on developing all-solid-state sodium oxide-based batteries and processing of crystallized glass by laser irradiation. He is a member of the Glass & Optical Materials Division and a TC07 member of the International Commission on Glass.


Okazaki

Japanese Industrial
Kenichi Okazaki
Displays having FETs with crystalline oxide semiconductor materials

Okazaki is director of the COS Division at Semiconductor Energy Laboratory Co., Ltd. in Atsugi-city, Japan, and a researcher of thin-film transistor devices using crystalline oxide semiconductor materials. He maintains an important role in the research of crystalline oxide semiconductor materials, used in more and more display products, and devoting himself to the fundamental studies and optimization of the technology for further commercialization.


Sasaki

Japanese Industrial
Hirokazu Sasaki
Development of new process for mass-producing nanoparticles and industrialization of quantum dots materials for display

Sasaki is general manager of the quantum dots business department at Shoei Chemical Inc., Japan. He succeeded in establishing the new mass-production process and expanding its capacity rapidly. Sasaki's hopes to apply this new process to various kinds of nanomaterials, especially to nano metal powders for electronic industries.

Check www.matscitech.org for latest updates.

ACerS Award Lectures

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

Elizabeth J. Opila is the Rolls-Royce Commonwealth Professor of Materials Science and Engineering at the University of Virginia in Charlottesville, Va.

Environmental barrier coatings—Enabling materials for extreme environments

Elizabeth Opila's current research interests focus on the thermochemical stability of materials for extreme environment applications, including oxide stability in high-temperature water vapor, oxidation of ceramic matrix composites, ultrahigh-temperature ceramics, and refractory alloys as well as environmental barrier coating development.

EDWARD ORTON JR. MEMORIAL LECTURE

Clive A. Randall is Distinguished Professor of Materials Science and Engineering and has served as director of the Materials Research Institute at The Pennsylvania State University from 2015.

Turning down the heat in sintering to enable the unification of all materials

Clive Randall's research ranges from material processing, defect and crystal chemistry, material physics, and electrical properties of a broad number of electroceramics, with a particular focus on dielectrics and piezoelectrics and their behavior under extreme conditions. He also introduced a number of novel processing methods for fabricating bulk nanocomposites, including dielectrophoretic assembly of ceramic polymer composite, and more recently, the introduction of the cold sintering process.

ACerS FRONTIERS OF SCIENCE AND SOCIETY RUSTUM ROY LECTURE

Alexander Michaelis is president of Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany, and full professor for ceramics at University of Dresden, Germany.

Advanced ceramics for energy and environmental technology

In 2009, Michaelis was elected as academician of "World Academy of Ceramics." In 2012, he received the Engineering Ceramics Division's Bridge Building Award for his contribution in the field of energy and environmental technology. In 2014, he received the Fraunhofer Medal for outstanding achievements in the field of applied materials research, and in 2015, the LEE HSUN Award on Materials Science of the Chinese Academy of Science. In 2016, he became a Fellow of ACerS due to his long commitment and outstanding contributions to applied research and development of advanced ceramics.

BASIC SCIENCE DIVISION ROBERT B. SOSMAN AWARD AND LECTURE

Wayne D. Kaplan holds the Karl Stoll Chair in Advanced Materials at the Department of Materials Science and Engineering at the Technion–Israel Institute of Technology, Haifa, Israel.

Combining atomistic and continuum approaches to interfaces

Kaplan's research focuses on fundamental interface science, with a strong emphasis on metal–ceramic interfaces via a combination of interface thermodynamics and advanced electron microscopy. In recent years, he focused on solute adsorption affecting grain boundary mobility in ceramics. The results of these fundamental studies are then applied toward metal–ceramic composites and joins.

GLASS AND OPTICAL MATERIALS DIVISION ALFRED R. COOPER AWARD SESSION

COOPER DISTINGUISHED LECTURE PRESENTATION

Efstratios I. Kamitsos, director of research, Theoretical and Physical Chemistry Institute, National Hellenic Research Foundation, Greece

Structure and ion dynamics in glass

2021 ALFRED R. COOPER YOUNG SCHOLAR AWARD

Jacob M. Lovi, undergraduate research assistant, materials engineering, Iowa State University, USA

Study of the anomalous viscosity in invert NaPSO glass for the development of thin solid-state electrolytes

2021 ALFRED R. COOPER YOUNG SCHOLAR AWARD

Graham Beckler, Coe College Chemistry, USA

Relationship between number of non-bridging oxygens and ionic conductivity discontinuity in $x{\cdot}Li_2O\text{-}(1\text{-}x){\cdot}B_2O_3$*, with* $x \leq 0.67$

Lauren Y. Moghimi, Ph.D. student, materials science & engineering, Stanford University, USA

ESolution-processed telluride glass for far-infrared application

Check www.matscitech.org for latest updates.

Laser-driven chemical vapor deposition for high-performance fibers and powders

By Shay Harrison and Mark Schaefer

Laser-driven chemical vapor deposition is a remarkably innovative technology that significantly improves the quality of high-performance fibers and powders and broadens the catalog of compositions available to the materials community.

The company Free Form Fibers (FFF), located in Saratoga Springs, New York, has spent 15 years perfecting the process of fiber growth using laser-driven chemical vapor deposition (LCVD), with particular expertise and understanding in fabricating silicon carbide fibers.

The integral development at FFF in transitioning LCVD from a laboratory-scale technique to a scalable manufacturing process was the parallelization of the input laser into hundreds of parallel beams, allowing for simultaneous fabrication of many fibers. This patented opto-mechanical design unlocked the potential for the LCVD technology to positively impact a range of material-focused markets, including semiconductors, jet engines, power turbines, hypersonics, ceramic windows, nuclear cladding, armor material, and lightweighting of polymer matrix composites for the aircraft and aerospace industry.

What is LCVD?

The fundamental basis of LCVD entails a laser directed at a substrate located in a reaction chamber that also contains a planned mixture of precursor gases. The focused laser beam induces a heterogeneous chemical reaction amongst the precursors, leading to a solid deposit forming on the substrate. As solid material deposits, the laser or the substrate can be pulled away to continuously form the fiber format. Similarly, solid coatings can be formed on the fiber surface using the same LCVD concept in subsequent stages, creating layers of uniform thickness. In this manner, LCVD can be viewed as the only gas-to-solid additive manufacturing-based approach to high-value material fabrication.

LCVD technology is part of a family of chemical vapor deposition (CVD) based processes that differ primarily in the energy delivery approach used to drive the gas phase reaction. The most well-known example is hot wall CVD, employed in microelectronics chip fabrication, in which the entire volume of a large chamber is uniformly heated to drive deposition of precisely controlled layers on a substrate positioned in the chamber. Similarly, a number of related techniques use various energy sources, such as microwaves, heat lamps, ultraviolet radiation, and plasma enhancement of the hot wall approach, to achieve different deposition aims. Most of these microelectronics-focused methods yield deposition rates that range from tens to several hundreds of microns thickness per hour.[1,2]

In contrast to these techniques, LCVD uses a focused laser beam with a spot size on the order of 20 microns to deliver the energy required for gas decomposition. The resulting temperature gradient is on the order of 10^5 K/m, whereas CVD is essentially isothermic.[3] This temperature gradient drives fiber deposition rates that can range from 30 to 300 microns per second, with rates in the millimeter/second range for some material systems such as carbon.

Because of the CVD "DNA" that is central to LCVD, the range of materials that can be fabricated in fiber format is broad, based on 70+ years of precursor development for the semiconductor industry, which required delivery of specific chemical elements to the functional layers needed for chip operation. This delivery method provides an essential difference from polymer precursor-based approaches to fiber fabrication, which are limited to polymer chemistries that can be developed to successfully yield the targeted final composition.

LCVD fiber composition is tailored through the selection of gas precursors and only those desired elements are incorporated. Polymer-derived fibers contain unreacted or partially reacted contaminant species, in addition to the possible inclusion of metal catalysts in some fiber products to drive the polymer conversion process, that negatively impact the ultimate temperature capability. Precision control of the fiber composition also allows LCVD to produce complex chemistries that are essentially impossible using the polymer-based route. Similarly, precision control of the fiber diameter offers a flexibility of production not available in spinneret-based production.

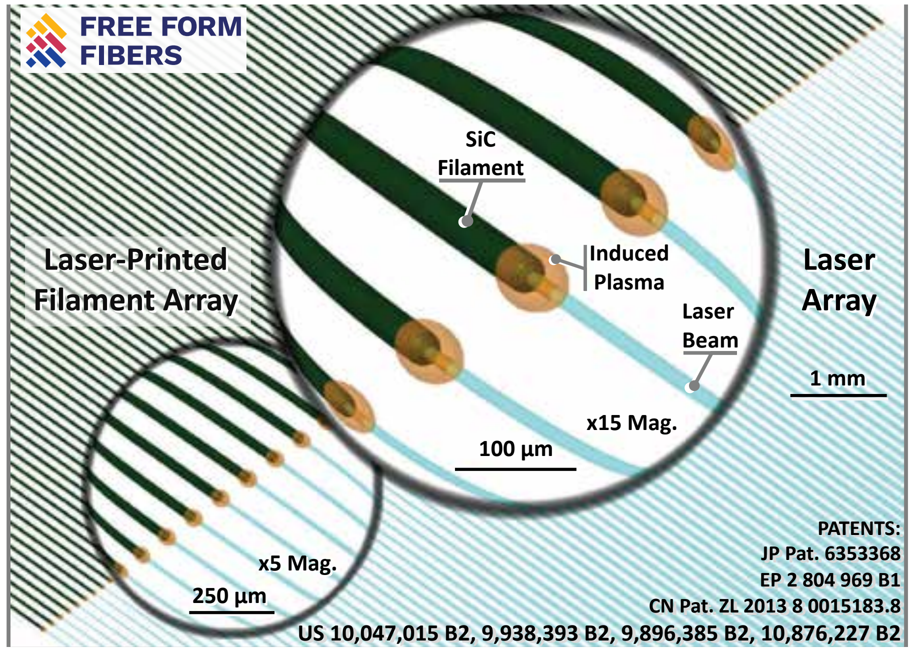


Figure 1. Schematic of the laser-driven chemical vapor deposition process.

As stated previously, a significant technical advance made by FFF in scaling LCVD is the parallelization of the input laser beam (Figure 1), which allows for multiple fibers to be grown simultaneously. Fibers are self-seeded. The pull rate of the substrate matches the deposition rate of material onto the formed fiber. Because material builds from the bottom up, LCVD is analogous to additive manufacturing (AM), but the main difference is the capability of LCVD to produce solid material directly from the gas phase. Also similar to AM, through its efforts to recycle the gas precursors and access maximum utilization of these raw material feedstocks, FFF aims to achieve a waste-less process with any produced by-product gases capable of being employed in other applications, such as redirecting extra hydrogen generated from the production of silicon carbide products for use in the H_2-based transportation sector.

Advantages of LCVD

LCVD technology stands in significant contrast to the chemical conversion processing that was patented in the late 1970s, known as the Yajima method,[4,5] and developed into commercial SiC fiber products by Nippon Carbon and Ube. The use of polymer-based polycarbosilanes as a precursor unlocked the promise of a high-temperature nonoxide composite material system, leading to various SiC fiber reinforcement products; however, there are material limitations inherent in batch chemical mixing and forming and the subsequent thermal processing of green fibers. A broad array of advantageous features and properties arise from LCVD-based fabrication of fibers.

The most fundamental characteristic, particularly evident in SiC fibers, is the presence of a gradient microstructure across the fiber radius. The center reveals elongated grains in the direction of the fiber axis, on the order of 50 nm long and 10 nm wide. At the mid-radial point, the grains are nominally 5 nm and equiaxed, transitioning to amorphous at the fiber edge. This feature stands in contrast to the homogeneous, invariant microstructure found in the polymer precursor-based SiC fibers.

The impact of this inhomogeneous distribution is hypothesized to drive the tensile and creep behavior found in the LP30-SC material. For other materials, understanding and control of the LCVD process parameters can yield variations in the fabricated microstructure. For example, boron fiber has been produced

Laser-driven chemical vapor deposition for high-performance fibers and powders

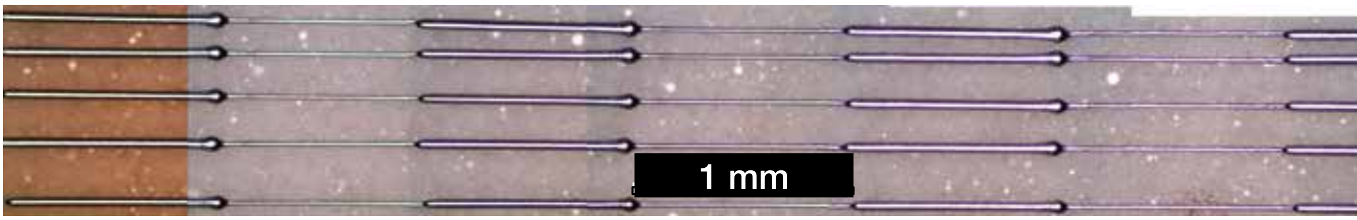


Figure 2. "Sausage-link" variable diameter LP30-SC fibers.

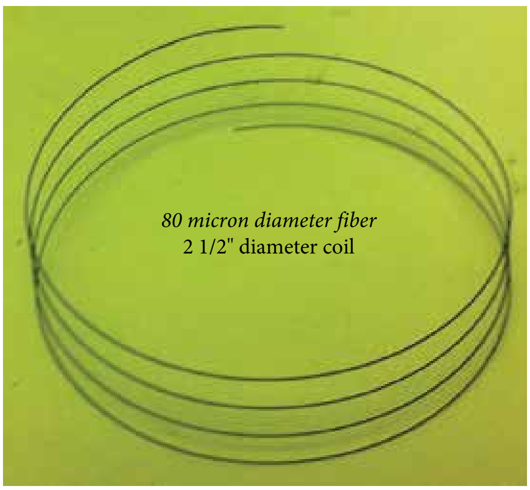


Figure 3. LP30-SC fiber coil.

in both amorphous and nanocrystalline states by using different precursor gases.

Another critical capability of the LCVD technology, harnessed through years of developed expertise, is the precise control of the final stoichiometry of the produced fibers, which reveals itself in several ways. Focusing on the SiC chemistry, a nominally stoichiometric fiber will have a composition of 70 weight percent silicon and 30 weight percent carbon (referred to as 70:30). FFF has produced fibers in the range from 70:30 to 77:23, a high silicon content fiber, through the finely calibrated introduction and control of the constituent gas precursors. A 71:29 fiber has proven to be the most appropriate for 1,500°C applications, through high-temperature exposure and creep testing. Also, the fiber is adaptable to handling and composite fabrication processing, demonstrated by its 1/16" bend radius. Based on microscopy evaluation of the 71:29 material, the excess silicon present appears to be distributed in the grain boundaries throughout the microstructure, as opposed to being concentrated at the outer edge of the fiber diameter.

The data presented in this article for the FFF LCVD silicon carbide fiber material, named LP30-SC, is from the 71:29 composition. The 77:23 fiber chemistry, while limited to temperatures below the silicon melting temperature of 1,412°C, revealed a very high single fiber tensile strength at room temperature, on the order of 7–8 GPa. This flexibility opens up design considerations for composites in tailoring the fiber composition to the desired property performance by component function and location.

Related to the fiber composition, the LCVD process yields materials without contamination of undesired chemical species. For instance, a LCVD silicon nitride fiber has only silicon and nitrogen present. This advantage is crucially important in reference to oxygen, which drives deleterious oxidation behavior at high temperatures in a range of ceramic materials. In particular, oxygen contamination impacts the temperature capability range for SiC fibers. NGS, the U.S. manufacturer of Hi Nicalon-Type S, presently reports the level of residual oxygen at 0.8 wt.%.[6] This oxygen content remains even after electron beam processing and subsequent thermal cycling of the green fibers for chemical conversion of the polymer.

Conversely, as-produced LP30-SC fibers and stoichiometric powder materials have undergone several evaluation techniques, including Auger electron spectroscopy (AES), electron energy loss spectroscopy (EELS), and Leco oxygen analysis. Neither the AES nor EELS revealed detectable oxygen in the cross section of many fiber samples while the Leco measurements on powder showed approximately 0.1 wt.%, which is consistent with surface absorption upon exposure to air. This minimal level of oxygen content is an important characteristic of the LCVD SiC being a functional 1,500°C material.

The physical characteristics of fibers produced by LCVD also highlight the unique capabilities of the technology. Electron microscopy at multiple laboratories showed a very high cross-sectional density with no porosity evident. This structure obviously drives mechanical performance by limiting the number of internal crack initiation sites. Precision control of the laser leads to a range of functional modifications that can be embedded into the fiber geometry. The filament diameter can be varied during growth. Figure 2 illustrates a SiC fiber produced with periodic discontinuous diameter changes. Similarly, the filament axis needs not be straight. Lateral motions of the laser can be tracked (within limits) via fiber growth to create a curvilinear filament. This feature is illustrated by the coil shown in Figure 3.

LCVD products and performance

FFF has embraced LCVD technology to deliver state-of-the-art high-performance materials in either fiber or powder format to the high-tech marketplace, where these products can fill unique gaps critical to furthering material performance in a range of applications.

An important focus area has been silicon carbide (SiC) fibers for the reinforcement phase in SiC-based ceramic matrix composites (CMCs), in particular optimizing the LCVD process to create a scalable path to fabricating 1,500°C-capable SiC fibers. The need for this demanding thermal capacity is driven by the long-desired operational parameters of turbo machinery in the aviation propulsion field.

Crucially, the SiC fiber product LP30-SC is an overwhelmingly beta-phase material, a necessity for high performance in thermomechanical applications. LP30-SC underwent several evaluations to determine its suitability for the 1,500°C

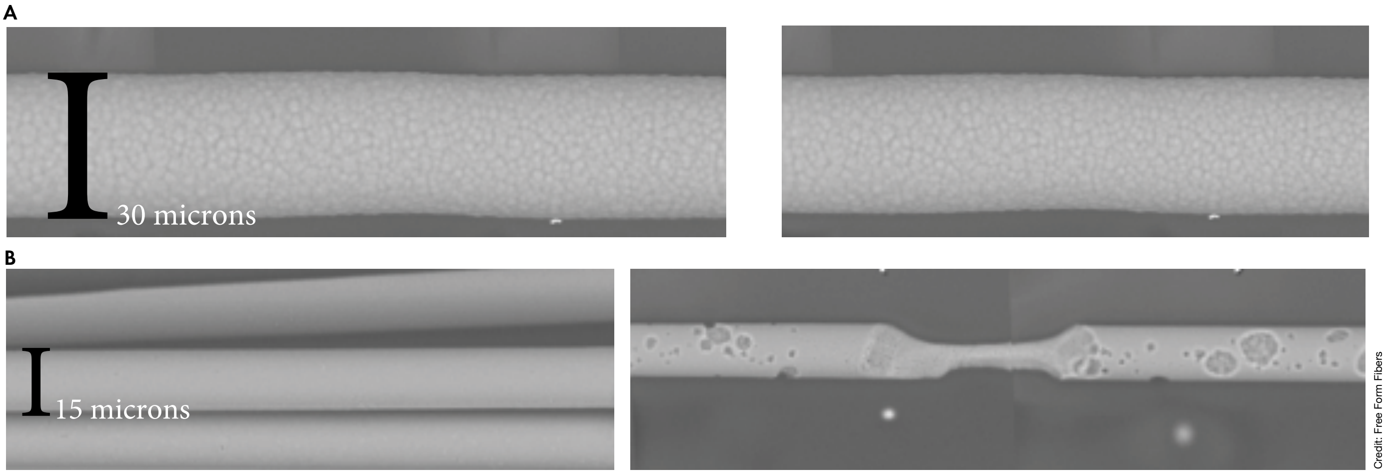


Figure 4. A) LP30-SC (FFF) SiC fiber before (left) and after (right) flame test exposure. B) HNS SiC fiber before (left) and after (right) flame test exposure.

environment. First, a new single fiber tensile testing protocol was designed in-house to address misalignment issues when testing using paper tabs for attachment to the grips of a mechanical test rig.[7,8] In using Spectra fishing line and polyacrylate adhesive to secure the fiber sample, this evaluation approach revealed tensile strengths in the 3 to 6 GPa range. Using the same sample attachment procedure, researchers at FFF also devised a single fiber creep testing method to understand the fundamental high-temperature performance behavior of SiC fibers, including commercial products like Hi-Nicalon Type S (HNS) as well as the LP30-SC.[9] The data from this creep rig revealed several interesting results.

- HNS samples fractured in a brittle manner in testing in an argon gas environment (with oxygen levels measured at ~ 0.15% using a residual gas analyzer) with 700 MPa stress applied at 1,500°C, over an approximate range of 75 to 150 hours exposure time.
- LP30-SC samples survived comparable testing conditions for 175 hours without failure.
- In cyclic fatigue testing, LP30-SC fiber went through eleven 24-hour exposure cycles after an initial 100-hour cycle (for a cumulative total of 364 hours at elevated temperature) at 1,500°C and 550 MPa applied stress in an open air environment, producing a residual creep strain of 0.96%.

Extreme environment testing on LP30-SC and other SiC fiber products (HNS and Sylramic) was conducted using an oxy-acetylene torch. The experimental setup involved tautly securing a number of fiber samples across a metal frame, then exposing these samples to the flame tip of the torch while video recording the setup to document the precise time of fiber failure and thus time span of exposure. Figures 4A and 4B show the comparative behavior of the LP30-SC and HNS through a series of these environmental exposure tests.

Proof-of-concept evaluations demonstrated that the LP30-SC fiber could survive high-temperature composite fabrication processing steps without degradation. The aim of this effort was to determine whether the SiC fiber (employed without an interphase coating) showed evidence of chemical interaction with the matrix or reactive breakdown, such as a stream of gas bubbles emanating from the fiber into the matrix (CO/CO_2 released by oxidation of the SiC). This work was done in collaboration with Exothermics, Inc. and performed at its facility in Amherst, N.H., in two separate studies.

- Study one: A glass-ceramic matrix composite produced with a barium strontium aluminosilicate (BSAS) matrix using hot pressing at a 1,550°C hold temperature for 30 minutes in an argon atmosphere with 10.3 MPa applied load.
- Study two: A SiC-zirconium diboride (ZrB_2) matrix composite formed by reaction of constituent powders during hot pressing at 1,900°C hold temperature for 60 minutes in an argon atmosphere with 30 MPa applied pressure.

Cross-sectional microscopy images from each composite coupon fabricated are shown in Figures 5 and 6. Both cases demonstrate that the LP30-SC fiber can successfully endure the high-temperature processing steps required for composite fabrication.

In an interesting development, subsequent flexural mode fracture of the BSAS composite sample showed evidence of fiber pullout and corresponding residual rabbit holes, even without the application of an interphase coating to enable fracture toughened behavior. This response is believed to have arisen because of the relative mismatch of elastic moduli between the BSAS glass-ceramic matrix (~80 GPa) and the SiC fiber (~400 GPa).

The LCVD technology is capable of producing fibers in user-determined lengths, whether on the order of several millimeters or in long, continuous parallel arrays. FFF demonstrated continuous fiber out to 32-foot strands, with typical 50-fiber array production at 2 feet. These parallel arrays are appropriate for two-dimensional CMC tape preforms.

Efforts to grow short fibers are directed to developing a nonwoven fiber architecture for the CMC reinforcement phase, as these fibers would be processed into a veil (analogous to wood pulp in paper production) then sectioned into the desired layer layup shape and size to produce the component design. Nonwoven architecture is a promising reinforcement design because of the resulting interlayer locking of adjacent veil layers, enhancing the interlaminar shear strength and reducing the risk of delamination or other deleterious interlayer boundaries and inhomogeneities. In addition, the simplicity of

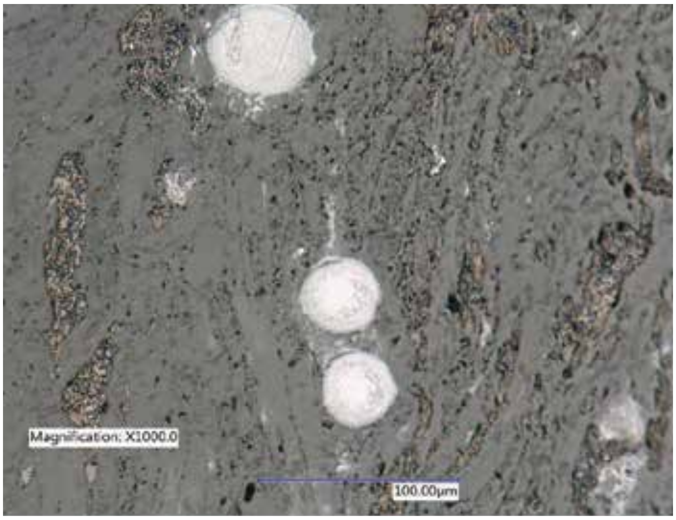


Figure 5. Cross-section micrograph of BSAS matrix glass-CMC with LP30-SC SiC fibers.

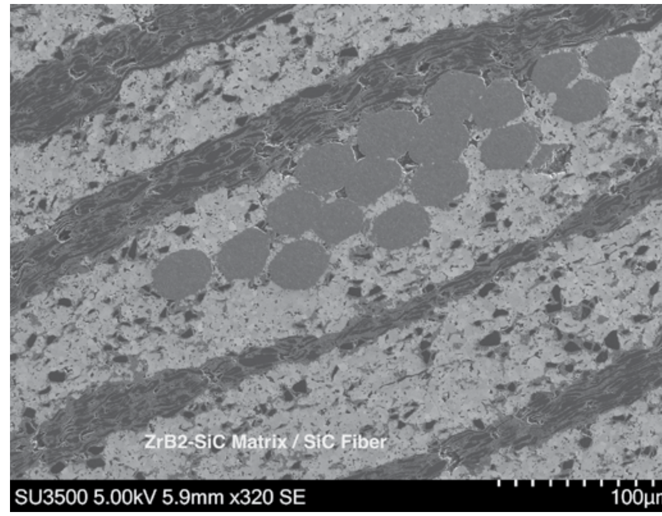


Figure 6. Cross-section micrograph of ZrB_2-SiC matrix CMC with LP30-SC fibers.

manufacturing nonwovens, the lack of damage imparted to the constituent fibers compared to processes that work with woven or crushed fiber tows, and efficient matrix introduction processing due to the accessible porosity are important advantages for this architecture, all of which contribute to the economic case for short fiber-based veils as a path to make SiC-SiC composites cost competitive.

FFF is partnering with Southeast Nonwovens (Clover, S.C.) to form veil products from the LP30-SC short fibers (Figure 7). These veils are employed in the fabrication of CMC components for property evaluation and thin-wall, composite-based fuel rod cladding samples for in-pile irradiation exposure and subsequent study.

Beyond SiC: LCVD of other materials

While SiC is an important area of focus of fiber development and production at FFF, a range of other materials also were demonstrated as unique fiber material products. Silicon nitride (Si_3N_4) fibers were produced in two feet arrays and then included as a reinforcement phase in a boron nitride matrix, processed to form a composite at Exothermics. Similar to the demonstrations with SiC fiber, the intent was to determine the fiber viability through the aggressive hot-pressing conditions (1,800°C hold temperature for one hour in a nitrogen atmosphere with 6.9 MPa applied load). Microscopy revealed that the Si_3N_4 successfully survived the fabrication process intact, which opens the possibility of composite applications for electromagnetic windows and radomes.

Boron fiber also was fabricated at FFF with the aim of providing a lightweighting replacement for carbon fiber used in structural applications of polymer matrix composites. The crucial difference and benefit of the LCVD boron fiber compared to other commercial boron fiber products is that it is core-less, meaning it does not have a dissimilar, heavier material core on which the boron material is deposited. A 25-micron diameter fiber contains only boron throughout. In applications where component weight comes at a premium cost, such as aerospace and aviation, the higher strength-to-weight ratio of amorphous boron compared to carbon can lead to greater than 2X reductions in overall structural weight.

A final example of demonstrated fiber material production is boron carbide, which revealed an elastic modulus greater than 600 GPa during evaluation. Protective armor, whether personal or vehicle, is the obvious application for such a boron carbide fiber-reinforced composite material system.

An important feature of LCVD technology is the ability to overcoat fibers with the same laser-based processing. CMC material systems generally require an interphase coating on the fiber to separate the fiber from the matrix and achieve fracture toughened mechanical behavior that improves on that of monolithic ceramics. The coating must have a layered structure to promote crack energy dissipation along the length of the fiber, as opposed to the crack propagating through the fiber. In SiC_{fiber}-SiC_{matrix} composites, the two generally agreed upon interphase materials are boron nitride and carbon. To date, the application step of the coating layer typically has occurred on the SiC fiber tow, which leads to incomplete coating coverage and therefore underperforming toughened mechanical behavior. With LCVD, each individual fiber, whether in short or long length format, can be fully coated around the entire circumference. The thin diameter nature of the LCVD-formed fibers allows for essentially instantaneous heat transfer, which enables homogenous deposition.

The key advantage, as with the material agnosticism of the process, is the simplicity of the processing step required—a straightforward changeover of the gas precursor environment, from the chemistry required for fiber fabrication to that needed for the coating. FFF demonstrated multiple coating materials, including boron nitride, carbon, SiC, and hafnium carbide, as well as multilayer coatings of different materials. The ability to coat fibers leads to several unique product concepts in the nuclear field, such as a fuel-in-fiber multilayer structure with an active uranium layer akin to TRISO fuel pellets; and embedded sensors, in which functional layers are added consecutively on a fiber base to produce a desired electromagnetic behavior, such as is needed for a thermocouple.

An offshoot of the SiC fiber effort is to establish the capability to produce high-purity, high beta-phase content SiC powder from the LCVD stoichiometric fiber feedstock. The capacity for the LCVD technology to yield the kind of clean powder with the appropriate beta-phase composition presents a significantly simpler manufacturing path when compared to the multiple processing steps necessary from the traditional Acheson approach (or modified reaction driven techniques using silica and coke-based raw material) with subsequent phase conversion required. The availability of such a high-quality powder material will impact the CMC market, as a matrix filler to reduce residual porosity, and the burgeoning SiC-based high power semiconductor field. FFF is also exploring other technical areas where the requirements for high-purity powder are critical and the availability is limited, such as materials for the microelectronics industry.

In addition to some of the ceramic and boron materials discussed, other demonstrated fiber compositions at FFF include tungsten carbide and carbon as well as materials of interest in the nuclear fuel field, such as uranium, uranium carbide, and uranium disilicide. This compositional flexibility is actually even broader as 'composite' fiber chemistries can be formed as bulk mixtures or dopant level additions to a primary composition.[10] As a demonstration example, FFF fabricated SiC fibers with boron additions at dopant levels and at a 20% constituent precursor gas mixture. This effort, along with similar evaluations, was focused on understanding how to enhance high-temperature performance for use in mechanically loaded applications like turbine blades. Fibers with complex chemistries can be explored with LCVD using binary, ternary, and quaternary phase diagrams, among others, as a foundational scientific basis for demonstration of manufacturability.

FFF is entering the commercialization stage, after extensive research and development efforts, through scale-up of production capacity by bringing on-line the first full-scale manufacturing tools. One tool, consisting of multiple opto-mechanical heads each including a laser and reactor chamber, can be operated with upwards of 1,200 beams. A critical feature and advantage of these LCVD production tools is that the same equipment can manufacture any of the possible material compositions available through the extensive catalog of gas precursors. The only adjustment to be made in making silicon carbide and then silicon nitride in a subsequent run, for instance, is to change the input gas feed to the tool.

Figure 7. Nonwoven veils produced from LP30-SC short SiC fibers.

Next-generation technology with LCVD

Laser-driven chemical vapor deposition is an innovative, extremely flexible technology that produces materials which will drive significant advancements in high performance fields, in particular in the aerospace composites and high-power electronics industries. The high-purity products produced by the laser-based process and the material agnostic capability to form nearly limitless chemistries, among other important advantages, offer a unique opportunity to tailor fibers and powders with precisely tuned properties, thereby maximizing application-specific performance.

As Free Form Fibers enters the commercialization phase, manufacturing materials for system-level evaluations in a range of applications and markets is the key next step to bring the capabilities of LCVD to bear. For instance, SiC fiber nonwoven veils for thermomechanical applications of composites, in particular at use temperatures greater than 1,400°C, are being manufactured and implemented in composite test articles for benchmarking of mechanical performance. Similarly, Si_3N_4 materials for electromagnetic transparency in high-temperature environments are in evaluation for fiber properties and composite component performance.

As composites of all matrix types find broader use, LCVD will open new, previously unavailable fiber reinforced composite material systems while also improving on the application performance of established systems.

About the authors

Shay Harrison is the CEO of Free Form Fibers, formerly senior materials scientist, and has been a member of the team since 2012. Mark Schaefer is materials scientist at Free Form Fibers since 2020, having recently completed his Ph.D. at Rutgers University. For more information, please contact Jeff Vervlied, director of sales and business development, at jvervlied@fffibers.com.

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History of Free Form Fibers

Free Form Fibers was established in 2006 by Joseph Pegna, Ram Goduguchinta, and Kirk Williams. Pegna has been active in additive manufacturing since the late 1980s, with particular emphasis on LCVD in leading research programs at the University of California, Irvine; Rensselear Polytechnic Institute; and the University of Montreal.[a–c] Goduguchinta (with Pegna as his advisor) and Williams both elucidated fundamental understanding of LCVD concepts in their doctoral theses.[d–h]

Initially locating FFF in Plattsburgh, N.Y., the three built off a rich history of R&D in academia, in particular at the Georgia Institute of Technology, University of Illinois at Champaign-Urbana, University of Texas at Austin, University of Connecticut, Uppsala University in Sweden, the Max-Planck-Institut für Biophysikalische Chemie in Göttingen, Germany, and Johannes-Kepler Universität, in Linz, Austria.[i–n]

Staying true to the adage that developing "hardware is hard," FFF focused on perfecting a range of specialized functions necessary for the commercial implementation of LCVD, such as the beam parallelization, precision gas feed and control, and mechanical system design to ensure fiber stability during growth. FFF's work has in part been supported by several government funding agencies, including the Department of the Army, DARPA, NASA, the National Science Foundation, New York State Energy Research and Development Agency, and the Department of Energy.

Today, FFF employs 11 members across a range of business and technical functions, and is finishing its first phase of commercialization, bringing online scaled production tools for high-volume manufacturing of fiber and powder products.

Compositional and end-use areas of particular focus

- Silicon carbide fiber reinforced ceramic composites for thermal management and thermal-mechanical performance in high-temperature aerospace propulsion, including combustion liners, shrouds, and blades.
- Silicon nitride fiber reinforced ceramic composites for electromagnetic transmission at high operational temperatures in hypersonic vehicles, such as apertures and antennas.
- Boron fiber reinforced polymer composites for replacement of carbon in aerostructure applications, including the large surface area of airframes. (The composite leverages the advantageous strength-to-weight ratio of a boron-only fiber, with no dissimilar heavy metal core.)
- Ultrahigh-temperature fiber materials as the reinforcement phase for multi-use composites in extreme temperature environments (greater than 2,000°C) at leading edges of hypersonic vehicles and spacecraft. (These fibers are transition metal based-chemistries, such as lanthanum, niobium, tantalum, and hafnium, in carbide, diboride, and nitride formulations.)
- High-purity silicon carbide powder for component fabrication in the power electronics industry.

Kirk Williams, company co-founder and senior manager of R&D, connects a fiber optic cable to one of the lasers in preparation for running the system to produce LCVD materials.

Credit: Free Form Fibers

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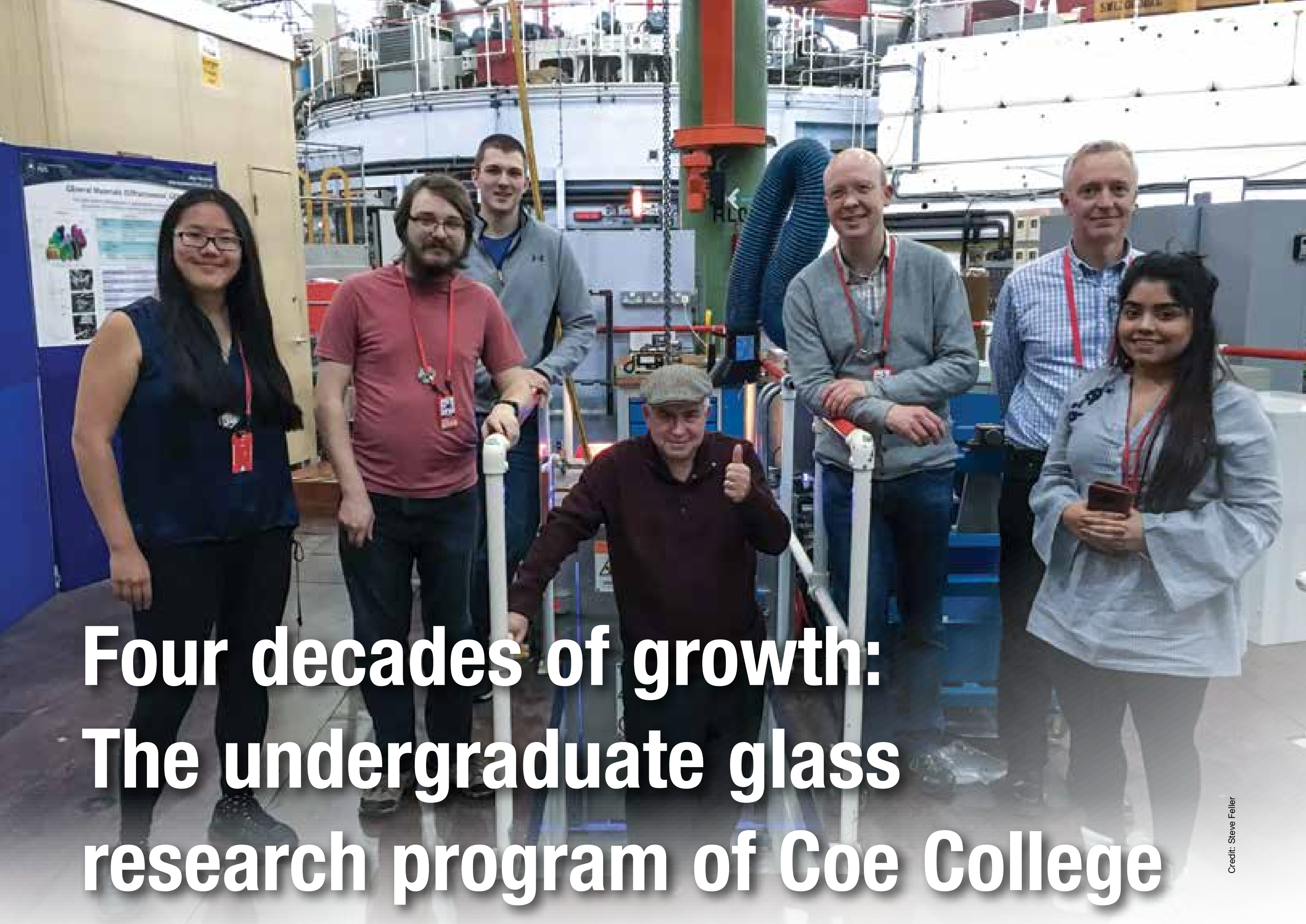
Four decades of growth: The undergraduate glass research program of Coe College



Credit: Steve Feller

Coe College collaborates on neutron scattering at the Rutherford Appleton Lab in England, with Sheffield Hallam University, U.K. Left to right: Hayley Austin, Greg Goukas, Michael Packard, Steve Feller, Paul Bingham, Martin Wilding, and Suchi Vaishnav.

By Steve Feller and Mario Affatigato

For more than 40 years, the glass research program of Coe College has worked with undergraduates exclusively, giving them a head start on their careers.

Since its inception in the 19th century, Coe College in Cedar Rapids, Iowa, has grown into a center of excellence in glass science, with hundreds of its students and several of its faculty doing a large amount of research in the field. What makes it distinctive is that its faculty works with undergraduates exclusively.

The origins of glass science at Coe College can be traced indirectly to the very beginning of Coe's history. Stephen Stookey was the first man to earn a degree from Coe in 1884. More than 50 years later, in 1936, a relative of Stephen's—S. Donald Stookey—graduated from Coe. Don Stookey went on to have an extraordinary 47-year career at Corning Glass Works, where he invented products such as CorningWare, Pyroceram, and photochromic eyeglass lenses. That fact alone is reason enough to put Coe College on the map in the world of glass and ceramics.

The modern program in glass science research at Coe College began in 1979, with the arrival of professor Steve Feller from Brown University. Feller had just finished his doctorate with Phil Bray, the pioneer who first used nuclear magnetic resonance (NMR) to study glass, and he swiftly moved to reestablish undergraduate research within the college's physics department. Knowing that obtaining an expensive, research-grade NMR spectrometer was unlikely at such a small school, Feller's initial efforts focused on measuring physical properties in glass systems, the compositional ranges of which were extended through the use of roller quenching for glass formation.

Just seven years after Feller's arrival, Mario Affatigato enrolled as an undergraduate student at Coe. Upon graduation with a physics degree, he went to Vanderbilt University to work in optical physics with professor Richard Haglund. While in graduate school, Coe students worked with him on several occasions. Affatigato returned to Coe in 1995 as a faculty member in physics and launched his research agenda in glass science. This work quickly led to research grants—including a PECASE award from the National Science Foundation—that supported a rapid advance of glass science at Coe.

The gestalt of Feller and Affatigato led to significant increases in students, projects, equipment, papers, talks, and participation in the ceramic and glass community.[1] The research-grade equipment—mainly obtained through NSF Major Research Instrumentation grants and operating support from the NSF Research in Undergraduate Institutions and Research Experiences for Undergraduates programs—led to a research program anchored in glass science that now sees more than 40 students every summer doing research. The physics department has grown and is now about 80 students in total; along with its growth has come a large increase in the number of women participants (about 30–35) as well as BIPOC students.

The husband-and-wife team of Ugur Akgun and Firdevs Duru arrived a few years ago, and their arrival gave students more opportunities to do research in high-energy physics, biophysics, and astrophysics. Drawing upon the glass science strength of the department has led both Akgun and Duru to investigate using glass in their research, including in the design of particle detectors and the use of glass for shielding in space transport.

The latest physics faculty member is materials engineer and glass scientist Caio Bragatto. Bragatto obtained his doctoral degree working on ionic conductivity in glass under professor Ana Candida Martins Rodrigues at the Federal University of São Carlos, Brazil. He did post-doctoral research with professor Lothar Wondraczek at the University of Jena, Germany, before coming to Coe College. Bragatto conducts undergraduate research on the relationship between ionic conductivity and atomic structure in glass.

Overall, Coe's faculty and students are publishing papers at a monthly rate, with well over 200 in the literature to date. Also, a complete renovation of Coe's Peterson Hall of Science in 2013 led to redesigned labs having modern infrastructure, a key step for the large number of students and a growing equipment base.

The department's collective total experience of working with undergraduate students to do research exceeds 85 years, the overwhelming majority in glass science. As a result, there are points of distinction for the Coe glass research program. The following is a brief listing.

1. About two-thirds of Coe physics majors go to graduate school, most in materials science. (The department graduates about 20 per year.)


Credit: Steve Feller

Coe College glass researcher Makyla Boyd explains her work at PhysCon 2019 (Providence, R.I.), the largest known gathering of undergraduate physics students in the United States.

2. Coe is an NSF Research Experiences for Undergraduates site, one of a handful at a small college in the country.

3. Job success is excellent among graduates of the Coe physics program. Coe alumni work at Corning, Inc., Medtronics, Georgia Tech, 3M, Indiana University, Argonne National Laboratory, Los Alamos National Lab, Tesla, Google, HP, Boeing, and numerous other companies and universities.

4. Many Coe alumni give back to the program by providing research experiences to current students. In recent years, Coe students averaged 10–15 internships per summer.

5. Coe physics faculty have numerous collaborations with glass colleagues. These collaborations include Steve Martin (Iowa State University), Cristina Siligardi (University of Modena and Reggio Emilia, Italy), Adrian Wright (emeritus, University of Reading, U.K.), Philip Bray (Brown University), John Mauro (Penn State), Tsuyoshi Honma and Takayuki Komatsu (Nagaoka University of Technology, Japan), Scott Kroeker (University of Manitoba, Canada), Alex Hannon (Rutherford Appleton Laboratory), Diane Holland (University of Warwick, U.K.), Efstratios Kamitsos (National Hellenic


Credit: Steve Feller

Part of the furnace collection at Coe College.

Credit: Steve Feller

The Coe College group at PhysCon 2019 (Providence, R.I.), the largest known gathering of undergraduate physics students in the United States. The Coe group was the largest group in attendance, of 200 physics departments in the nation.

Research Foundation, Greece), Emma Barney (University of Nottingham, U.K.), Ollie Alderman (Rutherford Appleton Laboratory), and Edgar Zanotto (Federal University of São Carlos, Brazil). Joint work on topics of mutual interest and need is preferred.

6. During the past year, the department was recognized by the American Physical Society's Award for Improving Undergraduate Physics Education.

7.Both Feller and Affatigato have contributed to the glass and physics communities through service. Affatigato has a lead role as editor-in-chief of the *International Journal of Applied Glass Science*, serves on the current ACerS Board of Directors, and is a past chair of the Glass & Optical Materials Division. Feller is a past chair of GOMD, a Centenary Fellow of the Society of Glass Technology, and has served in several American Institute of Physics leadership roles, including being a co-president of the national honor society in physics. Both are Fellows of ACerS and the Society of Glass Technology.

8. Coe students and faculty have organized several conferences within the field, including the annual Iowa Glass Conference, co-hosted with professor Steve Martin and Iowa State University students at alternating locations; the borate series of conferences (the 2002 meeting was at Coe); numerous ACerS meetings; and an NSF workshop on doing undergraduate research in glass science. Also, since 2008, Feller has organized the AIP (PhysCon) series of national undergraduate conferences in physics.

The future looks promising for the glass research program within the physics department of Coe College.

Acknowledgements

We are grateful for the support of NSF in the development and support of this program. The current grant NSF-DMR 1746230 specifically is thanked.

About the authors

Steve Feller is B.D. Silliman Professor of Physics and Mario Affatigato is Fran Allison and Francis Halpin Professor of Physics at Coe College in Cedar Rapids, Iowa. Contact Feller at sfeller@coe.edu or Affatigato at maffatig@coe.edu.

Learn more about Feller in the July episode of Ceramic Tech Chat at https://ceramictechchat.ceramics.org.

References

[1]S.A. Feller, "A four-year research plan for undergraduates," The Council on Undergraduate Research Quarterly (December 1998) pp. 92–94. 100

Alumni spotlight: Deborah Watson

When Coe College alumna Deborah Watson (2008–2012) started at Coe, glass research was not initially on her radar—she planned to pursue a career in the medical field after majoring in chemistry and minoring in physics. Yet when physics professor Steve "Doc" Feller, a fellow Brooklynite, invited Watson during her sophomore year to participate in the Coe glass research program, it set the foundation for a new pathway.

"My research on the structure and properties of borate glasses helped me to recognize the different applications of glass," Watson says, including applications in the medical field, such as the bioactive glass developed by Larry Hench.

After graduation, while preparing to take the MCAT exam, Watson received a call from Feller connecting her with Steve Martin, an Iowa State University materials science and engineering professor who specializes in glass. She ultimately attended Iowa State for her Ph.D., where she researched glassy solid electrolytes for solid-state sodium battery applications. Now she is a senior product development engineer at 3M (Saint Paul, Minn.), where she develops hollow glass microspheres for use as a filler material in a variety of applications.

Watson credits the Coe glass research program for not only giving her an edge in the job market—by learning how to make and characterize materials all at the undergraduate level—but also for building her confidence as a researcher.

"Doc and Mario made you feel like a part of the family," she says. 100

MCARE-EHS 2021 covered sustainable energy solutions on a global scale

By Rishabh Kundu and Alessandro De Zanet

The Materials Challenges in Alternative & Renewable Energy (MCARE 2021) combined with the 4th Annual Energy Harvesting Society Meeting (EHS 2021) took place virtually July 19–22, 2021, due to the COVID-19 pandemic. The four-day conference welcomed 208 attendees, including 69 students, from 21 countries and included 188 talks, 48 posters, and the new PowerPoint Karaoke event.

Day 1 started with a plenary talk by Taeghwan Hyeon, professor at Seoul National University and director of the Center for Nanoparticle Research at the Institute for Basic Science in South Korea. He talked about his research on nanomaterials for medical and energy applications, and during a "Meet and Greet" before the talk, he offered invaluable advice to young researchers and students on how to approach commercialization of their research and manage stress.

G. Jeffrey Snyder, professor of materials science and engineering at Northwestern University, gave the plenary talk on Day 2. He talked about thermoelectrics for distributed cooling and energy harvesting, which he says serves as a "wonderful supplement" to external charging capabilities.

Day 3's plenary speaker was Eva Unger, Young Investigator Group Leader at Helmholtz-Zentrum Berlin. During the Q&A after her talk on hybrid perovskites, she reminded attendees of the importance of engaging their community throughout the development process as it helps to estimate the impact their research may have on society.

The first edition of MCARE PowerPoint Karaoke took place on Day 3. This student-led event—which was organized by Anja Sutorius, Khan Le, Rishabh Kundu, and Alessandro De Zanet under the guidance of MCARE lead organizer Eva Hemmer—helped people improve their freestyle presentation skills by asking them to present a single slide prepared by someone else in 1–2 minutes. After all the presentations were delivered, attendees voted for the best presentations and slides. The list of winners can be found at https://ceramics.org/mcare-2021-ppt-karaoke.

Credit: Eva Hemmer

There were many happy faces following the first edition of the MCARE PowerPoint Karaoke at MCARE-EHS 2021. Organizers are indicated by green frames and winners by ribbons.

In the closing session, Hemmer highlighted the diverse participation at MCARE-EHS 2021 and noted that MCARE 2022 will take place in South Korea from Aug. 22–26, 2022. EHS organizing co-chair Shashank Priya reminded attendees that EHS 2022 is planned to be held in September 2022 in the Washington, D.C. area. MCARE organizing co-chair Sanjay Mathur closed the session, thanking all the organizers and participants.

All the abstracts of the presentations and posters are available on the MCARE-EHS 2021 official website at https://bit.ly/3fmFMhx. Also, recordings of all sessions will be available through the Bravura platform through Sept. 30, 2021.

A detailed account of the conference—including highlights from the diverse symposiums and poster presentations from all four days—can be read at https://ceramics.org/mcare-ehs-2021-wrapup01 and https://ceramics.org/mcare-ehs-2021-wrapup02. 100

SAVE THE DATE JAN. 23–28, 2022

46TH INTERNATIONAL CONFERENCE AND EXPOSITION ON ADVANCED CERAMICS AND COMPOSITES

The American Ceramic Society www.ceramics.org

Engineering Ceramics Division The American Ceramic Society

Organized by the Engineering Ceramics Division of The American Ceramic Society

Hilton Daytona Beach Resort and Ocean Center | Daytona Beach, Fla., USA

We are pleased to announce that the 46th International Conference & Exposition on Advanced Ceramics & Composites (ICACC 2022) will be held from Jan. 23–28, 2022, in Daytona Beach, Fla. This conference has a strong history of being the preeminent international meeting on advanced structural and functional ceramics, composites, and other emerging ceramic materials and technologies. The Engineering Ceramics Division (ECD) of The American Ceramic Society has organized this esteemed event since 1977. Due to the high quality of technical presentations and unique networking opportunities, this event has achieved tremendous worldwide interest and has attracted active participation from ceramic researchers and developers from the global technical community thanks to the dedication and support of our membership.

We look forward to seeing you in Daytona Beach, Fla., in January 2022!

Palani Balaya
Program Chair, ICACC 2022
National University of Singapore
mpepb@nus.edu.sg

HONORARY SYMPOSIUM AND FOCUSED SESSIONS

Emergent Materials and Sustainable Manufacturing Technologies in a Global Landscape: International Symposium in Honor of Dr. Tatsuki Ohji

Special Focused Session on Diversity, Entrepreneurship, and Commercialization

11th Global Young Investigator Forum

- FS1: **Bio-Inspired, Green Processing, and Related Technologies of Advanced Materials**
- FS2: **Materials for Thermoelectrics**
- FS3: **Molecular-level Processing and Chemical Engineering of Functional Materials**
- FS4: **Ceramic/Carbon Reinforced Polymers**
- FS5: **Current Challenges in Microstructural Evolution: From Fundamentals to Engineering Applications**

SYMPOSIA

- S1: **Mechanical Behavior and Performance of Ceramics and Composites**
- S2: **Advanced Ceramic Coatings for Structural, Environmental, and Functional Applications**
- S3: **19th International Symposium on Solid Oxide Cells (SOC): Materials Science and Technology**
- S4: **Armor Ceramics – Challenges and New Developments**
- S5: **Next Generation Bioceramics and Biocomposites**
- S6: **Advanced Materials and Technologies for Rechargeable Energy Storage**
- S7: **16th International Symposium on Functional Nanomaterials and Thin Films for Sustainable Energy Harvesting, Environmental and Health Applications**
- S8: **16th International Symposium on Advanced Processing and Manufacturing Technologies for Structural and Multifunctional Materials and Systems (APMT16)**
- S9: **Porous Ceramics: Novel Developments and Applications**
- S10: **Modeling and Design of Ceramics and Composites**
- S11: **Advanced Materials and Innovative Processing Ideas for Production Root Technologies**
- S12: **On the Design of Nanolaminated Ternary Transition Metal Carbides/Nitrides (MAX Phases) and Borides (MAB Phases), Solid Solutions thereof, and 2D Counterparts (MXenes, MBenes)**
- S13: **Development and Applications of Advanced Ceramics and Composites for Nuclear Fission and Fusion Energy Systems**
- S14: **Crystalline Materials for Electrical, Optical, and Medical Applications**
- S15: **6th International Symposium on Additive Manufacturing and 3D Printing Technologies**
- S16: **Geopolymers, Inorganic Polymers, and Sustainable Materials**
- S17: **Advanced Ceramic Materials and Processing for Photonics and Energy**
- S18: **Ultrahigh-temperature Ceramics**

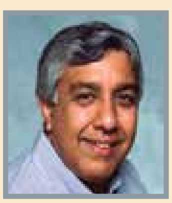
The Materials Science & Technology (MS&T) technical meeting and exhibition is the long-standing, recognized forum for fostering technical innovation at the intersection of materials science, engineering, and application.

The event's unmatched technical program addresses structure, properties, processing, and performance across the materials community. Its exhibition showcases a wide variety of equipment and services to the automotive, aerospace, instrumentation, medical, oilfield, and energy industries.

PLENARY SPEAKERS

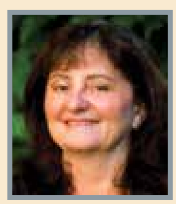
Visit the MS&T Plenary Session webpage to view the complete abstracts and biographies.
https://bit.ly/MST21-plenaries

AIST ADOLF MARTENS MEMORIAL STEEL LECTURE



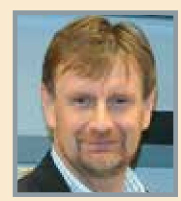
Anil K. Sachdev
Principal Technical Fellow and lab group manager at GM Global Research and Development

TMS PLENARY SPEAKER



Tresa Pollock
Alcoa Professor of Materials at the University of California, Santa Barbara

ACERS EDWARD ORTON JR. MEMORIAL LECTURE



Clive Randall
Director of Materials Research Institute at The Pennsylvania State University

ACERS LECTURES AND AWARDS

Visit the MS&T Special Events webpage to see all lectures and awards, including dates and times.

MONDAY, OCT. 18 8:10–8:55 A.M.

THE NAVROTSKY AWARD FOR EXPERIMENTAL THERMODYNAMICS OF SOLIDS

Xin Qian, Georgia Institute of Technology, USA

MONDAY, OCT. 18 9–10 A.M.

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

Elizabeth Opila, University of Virginia, USA

ACERS RICHARD M. FULRATH AWARD SESSION

Postponed to MS&T22 due to COVID-related travel restrictions.

Surojit Gupta, University of North Dakota, USA
Elizabeth Paisley, Sandia National Laboratory, USA
Tsuyoshi Honma, Nagaoka University of Technology, Japan
Kenichi Okazaki, Semiconductor Energy Laboratory, Japan
Hirokazu Sasaki, Shoei Chemical, Inc., Japan

TUESDAY, OCT. 19 1–2 P.M.

ACERS FRONTIERS OF SCIENCE AND SOCIETY — RUSTUM ROY LECTURE

Alexander Michaelis, Fraunhofer Institute for Ceramic Technologies & Systems IKTS, Germany
Advanced ceramics for energy and environmental technology

TUESDAY, OCT. 19 2–4:40 P.M.

ACERS GOMD ALFRED R. COOPER AWARD SESSION COOPER DISTINGUISHED LECTURE

Efstratios I. Kamitsos, National Hellenic Research Foundation, Greece

ACERS GOMD ALFRED R. COOPER YOUNG SCHOLAR AWARD PRESENTATION

Jacob M. Lovi, Iowa State University, USA
Graham Beckler, Coe College, USA
Lauren Y. Moghimi, Stanford University, USA

WEDNESDAY, OCT. 20 1–2 P.M.

ACERS BASIC SCIENCE DIVISION ROBERT B. SOSMAN LECTURE

Wayne Kaplan, Israel Institute of Technology, Israel
Combining atomistic and continuum approaches to interfaces

SPECIAL EVENTS

Visit the MS&T Special Events web page to see all special events, including dates and times.

SUNDAY, OCT. 17 3–5 P.M.

WIKIPEDIA EDIT-A-THON FOR DIVERSITY IN MATERIALS SCIENCE AND ENGINEERING

SUNDAY, OCT. 17 5–6 P.M.

MS&T WOMEN IN MATERIALS SCIENCE RECEPTION

MONDAY, OCT. 18 1–2 P.M.

ACerS 123RD ANNUAL MEMBERSHIP MEETING

MONDAY, OCT. 18 5–6 P.M.

WELCOME RECEPTION HOSTED BY THE MS&T PARTNERS

MONDAY, OCT. 18 7:30–10 P.M.

ACerS ANNUAL HONOR AND AWARDS BANQUET

MONDAY, OCT. 18–THURSDAY, OCT. 21
VARIOUS HOURS

ACerS BASIC SCIENCE DIVISION CERAMOGRAPHIC EXHIBIT & COMPETITION

TUESDAY, OCT. 19 VARIOUS HOURS

GENERAL POSTER SESSION WITH PRESENTERS

STUDENT ACTIVITIES

Visit the MS&T Student Activities webpage to see a complete description of all student events, including details for applying for Material Advantage chapter grants and individual travel grants. https://bit.ly/MST21-students

- **UNDERGRADUATE STUDENT POSTER CONTEST**
- **GRADUATE STUDENT POSTER CONTEST**
- **UNDERGRADUATE STUDENT SPEAKING CONTEST**
- **STUDENT NETWORKING MIXER**
- **ACerS STUDENT TOUR**
- **ACerS PCSA HUMANITARIAN PITCH COMPETITION**
- **CERAMIC MUG DROP CONTEST**
- **CERAMIC DISC GOLF CONTEST**
- **CAREER FAIR**
- **STUDENT AWARDS CEREMONY**
- **AIST STUDENT PLANT TOUR**
- **AIST STEEL TO STUDENTS RECRUITING RECEPTION**

HOTELS

Hotel reservation deadline: **Sept. 23, 2021**
For best availability and immediate confirmation, make your reservations online at matscitech.org/mst21.

U.S. Government Rate

Rooms are extremely limited; proof of federal government employment must be shown at check-in or higher rate will be charged. U.S. Government rate is the prevailing government rate.

Cancellation

Reservations cancelled less than 72 hours prior to Noon of scheduled arrival date will be charged one night's rate and tax.

HILTON COLUMBUS (ACerS Headquarters)
$210 USD + tax

HYATT REGENCY COLUMBUS
(AIST & TMS Headquarters)
$210 USD + tax

RED ROOF INN
$169 USD + tax

DRURY INN & SUITES CONVENTION CENTER
$179 USD + tax

Rates listed above are for single or double occupancy.

Calendar of events

August 2021

31–Sept 1 6th Ceramics Expo – Huntington Convention Center of Cleveland, Cleveland, Ohio; https://ceramics.org/event/6th-ceramics-expo

September 2021

5–8 ICG Annual Meeting 2021 – Songdo ConvensiA, Incheon, Korea; https://www.icg2021.org

15–16 ceramitec conference 2021 – Messe München, Munich, Germany; https://www.ceramitec.com/en/trade-fair/ceramitec-conference

20–22 Serbian Ceramic Society ACA IX conference – Serbian Academy of Sciences and Arts, Serbia, Belgrade; http://www.serbianceramicsociety.rs/index.htm

October 2021

12–15 ➨ International Research Conference on Structure and Thermodynamics of Oxides/carbides/nitrides/borides at High Temperature (STOHT) – Arizona State University, Ariz.; https://mccormacklab.engineering.ucdavis.edu/events/structure-and-thermodynamics-oxidescarbidesnitridesborides-high-temperatures-stoht2020

17–21 ACerS 123rd Annual Meeting with Materials Science & Technology 2021 – Greater Columbus Convention Center, Columbus, Ohio; https://ceramics.org/mst21

18–20 Flourine Forum 2021 – Pan Pacific Hanoi, Vietnam; http://imformed.com/get-imformed/forums/fluorine-forum-2020

25–27 China Refractory Minerals Forum 2021 – InterContinental, Dalian, China; http://imformed.com/get-imformed/forums/china-refractory-minerals-forum-2020

November 2021

1–4 ➨ 82nd Conference on Glass Problems – Greater Columbus Convention Center, Columbus, Ohio; http://glassproblemsconference.org

15–17 ➨ ACTSEA 2021 7th International Symposium on Advanced Ceramics and Technology for Sustainable Energy Applications toward a Low Carbon Society – National Taipei University of Technology, Taiwan; https://materweek2021.conf.tw

December 2021

12–17 14th Pacific Rim Conference on Ceramic and Glass Technology (PACRIM 14) – Hyatt Regency Vancouver, Vancouver, British Columbia, Canada; www.ceramics.org/PACRIM14

January 2022

18–21 Electronic Materials and Applications 2022 (EMA 2022) – DoubleTree by Hilton Orlando at Sea World Conference Hotel, Orlando, Fla.; https://ceramics.org/ema2022

23–28 46th International Conference and Expo on Advanced Ceramics and Composites (ICACC2022) – Hilton Daytona Beach Oceanfront Resort, Daytona Beach, Fla.; https://ceramics.org/icacc2022

March 2022

15–18 17th Biennial Worldwide Congress Unified International Technical Conference on Refractories – Hilton Chicago, Chicago, Ill.; https://ceramics.org/unitecr2021

May 2022

22–26 Glass & Optical Materials Division Annual Meeting (GOMD 2022) – Hyatt Regency Baltimore, Baltimore, Md.; https://bit.ly/3ftnJqI

June 2022

22–26 ACerS 2022 Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Omni Charlotte Hotel, Charlotte, N.C.; https://bit.ly/31zyfob

July 2022

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

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

October 2022

14–19 ACerS 124th Annual Meeting with Materials Science & Technology 2022 – David L. Lawrence Convention Center, Pittsburgh, Pa.; https://ceramics.org/event/acers-124th-annual-meeting-with-materials-science-technology-2022

July 2024

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

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

Entries in **BLUE** denote ACerS events.

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

denotes virtual meeting

Ceramic & Glass MANUFACTURING

SEPTEMBER 2021 • VOLUME 2 • ISSUE 3

www.ceramics.org/ceramicandglassmanufacturing

THE VALUE OF COLLABORATION: PARTNERSHIPS ARE A PATH TO SUCCESS

ABET ENSURES QUALITY IN UNIVERSITY ENGINEERING EDUCATION




CONTENTS

Ceramic & Glass MANUFACTURING

Vol. 2, No. 3

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INDUSTRY NEWS

SCHOTT BEGINS PRODUCTION IN CHINA

Specialty glass manufacturer SCHOTT opened a new factory in Jinyun, China, to manufacture high-quality borosilicate glass tubing to produce vials and syringes for COVID-19 vaccines. With an initial capacity of 20,000 tons of glass and room for further expansion, the plant is functioning as a production and supply hub in the region.


The Schott plant, in the eastern coastal region of China.


Berlin Packaging plans to expand its operations in the Balkans and the Mediterranean.

BERLIN PACKAGING ACQUIRES GLASS SUPPLIER IN GREECE

Berlin Packaging announced the acquisition of Elias Valavanis S.A., a supplier of glass packaging for the food and beverage industry. Based in Larissa, Greece, Elias Valavanis has locations in Bulgaria, Romania, and throughout Greece. This acquisition is the fifteenth that Berlin Packaging completed in Europe since 2016, and its fifth in Europe this year. The company says all employees and locations for this acquisition will be retained.

VERDER SCIENTIFIC ACQUIRES MAGER SCIENTIFIC

Verder Scientific Inc. agreed to acquire all shares of Mager Scientific Inc. Verder Scientific, based in Newtown, Pa., is a division of the Netherlands-based Verder Group, a family-owned group of companies that develops, manufactures, and distributes industrial equipment. Mager Scientific, based in Dexter, Mich., is a distributor of metallographic and hardness testing equipment in the U.S. and represents the QATM product lines. Verder Scientific president Georg Schick will become president of Mager Scientific, while Jarrad Lawlor, former owner of Mager Scientific, will lead the QATM business unit for the U.S. and Canada, as well as oversee its Nikon operations.

Georg Schick and Jarrad Lawlor


RHI Magnesita employs 12,000 people in 28 production sites around the world.

RHI MAGNESITA TESTING CARBON DIOXIDE SEPARATION TECHNOLOGY

RHI Magnesita executed a memorandum of understanding with Australian technology company Calix Limited. The agreement covers the development of a flash calciner for use in the production of refractory materials to enable carbon dioxide separation. The companies agreed to undertake studies up to and including engineering and design for a commercial-scale demonstration facility at an RHI Magnesita site.

CERANOVA CORP. MOVES, EXPANDS

CeraNova Corp. moved to a new location in Marlborough, Mass. CeraNova manufactures transparent and advanced ceramics for a range of applications. The new location provides nearly 50% more space for manufacturing, research and development, and office support. "Our government contract work continues to expand, and our commercial sales for 2020 more than doubled from the previous year," says John Gannon, president and CEO.

FIRST SOLAR INVESTS IN THIRD PANEL PLANT IN OHIO

First Solar, Inc. says it will invest $680 million to expand its U.S. domestic photovoltaic (PV) solar manufacturing capacity by 3.3 gigawatts annually, constructing its third U.S. manufacturing facility in Lake Township, Ohio. The facility is expected to begin operating in the first half of 2023. Tempe, Ariz.-based First Solar produces ultralow carbon, thin film PV modules using a fully integrated, continuous process under one roof. In addition to its Ohio manufacturing facilities, First Solar also operates factories in Vietnam and Malaysia.


First Solar expects to produce an average of one PV module every 2.75 seconds across its three-factory Ohio footprint.


The sample chamber with sample holders.

CERAMTEC SAMPLE CONTAINERS HEADED TO SPACE

The CeramTec Group produced ceramic sample containers for a space experiment facility on the International Space Station. The silicon nitride sample holders are used in the electromagnetic levitator, a multipurpose research facility for experiments on board the ISS. The facility enables precision measurements of thermophysical properties of metals, alloys, and semiconductors that are not possible on earth, making it feasible to analyze the formation of material structures and to expand the understanding of transition processes, atomic structures, and material properties. The sample containers started their journey into space with the SpaceX-22 in June 2021.

ENCIRC COMMITS TO DECARBONIZATION

Glass manufacturer Encirc announced its commitment to decarbonizing by the middle of this decade, using hydrogen in its furnaces to create billions of ultralow-carbon glass bottles. The availability of hydrogen will enable the further expansion of Encirc's Elton facility in the United Kingdom. Encirc employs more than 1,000 people at its Elton facility. It will use the supply from the U.K.'s proposed HyNet North West regional decarbonization project in its furnaces. The HyNet North West program is bidding to be one of at least two chosen by the government to produce, store, and distribute hydrogen, as well as capture and store carbon from industry in the northwest of England and North Wales.


Encirc also completed a fuel-switching initiative this year at a plant in Northern Ireland.

THE VALUE OF COLLABORATION: PARTNERSHIPS ARE A PATH TO SUCCESS

By David Holthaus

Michael Jordan may be the greatest basketball player ever, but he knew he couldn't win on his own.

"Talent wins games, but teamwork and intelligence win championships," Jordan is quoted as saying. That was true of his Chicago Bulls. It wasn't until a visionary coach built a team around Jordan that the once-forlorn Bulls won six championship titles.

This advice is true in business too. Ground-breaking ideas need the fertile soil provided by partners in business, government, and academia so the concepts can germinate and grow.

A network of partnerships helped propel a small business called SpheroFill LLC to research and develop innovative medical applications for a cutting-edge technology. While serving as a senior scientist at Savannah River National Laboratory in South Carolina, George Wicks invented porous wall hollow glass microspheres, originally for strategic purposes.

Wicks was convinced there were other uses for the technology, and the laboratory put out a request for proposals for new uses. As Paul Weinberger tells it, he and a colleague, William Hill, both submitted proposals, both of them for regenerative medicine. Weinberger's was for regrowing tracheas, while Hill's was for regrowing bone.

The spheres, one-third the size of a human hair, about 20–40 microns, contain channels or pores through which liquids, gases, or solids could pass into the hollow void of the sphere. "That gave us the idea to use it as a carrier for molecules," Weinberger says.

Both of their ideas received funding, and as the two of them began collaborating with Wicks, a partnership gelled.

"By the second or third meeting, we came to the realization that we really got along well together, and regardless of what happened to our individual projects, we'd be friends, and we started to work on this together long-term," Weinberger says.

A three-dimensional sound field created by Materials Development Inc. enables levitation of 25 styrofoam spheres. The process allows for measurements using neutron methods to study how liquids change into glass and to investigate extreme temperature processes. *Credit: Materials Development Inc.*

The three brainstormed further possibilities for the technology, including the possibility of developing it as a soft-tissue surgical filler. After reviewing the literature, they determined that that such an application had not yet been developed. "We realized if we didn't do it, nobody would," Weinberger says.

In 2015, they formed SpheroFill and were awarded patents from several countries, including the United States, Japan, and the European Union. A partnership with the Applied Research Center (ARC) helped build the technology. ARC is a not-for-profit economic development agency located in Aiken County, S.C., at the county-owned Savannah

River Research Campus. SpheroFill set up shop there with seed funding, lab space, access to an electron microscope and analysis equipment, and expert consultants.

Other than the seed grant, the partners bootstrapped the new company using funds from their retirement savings, Weinberger says. Earlier this year, their work received a big boost when the National Science Foundation (NSF) awarded the team a $256,000 grant to continue their research.

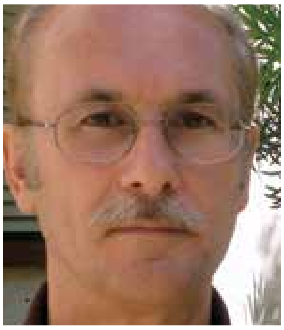
"The NSF's stamp of approval is huge," Weinberger says. "They have a huge infrastructure for picking up companies and carrying them across the finish line and showing them what it takes to bridge the gap commercially."

With an annual budget of $8.5 billion, the NSF is the funding source for about 25% of all federally supported basic research conducted by U.S. colleges and universities.

The Advanced Photon Source at Argonne National Laboratory in Lemont, Ill.
Credit: Argonne National Laboratory

The grant process was difficult, Weinberger says. With an application that ran to more than 200 pages, the SpheroFill team had help from the South Carolina Research Authority, a public, not-for-profit corporation, as well as from a former university dean of research and development turned consultant.

"Those were things we had no experience with," Weinberger says. "We relied on our newfound partners and collaborators. It was a humbling but very strong learning experience."



Rick Weber

The grant came from the NSF's Small Business Technology Transfer Program, designed to help small businesses transform ideas into marketable products. After completing the 12-month Phase I award, the company will be eligible for a second round of investment from NSF.

The government funding is critical to a small company, such as SpheroFill, engaged in long-term research into leading-edge technology, Weinberger says.

"We could have languished and floundered and not gone anywhere," he says. "It takes so much to de-risk new biomedical technologies. It's so much expense, and no investor will touch a company that was at the stage we were at a year ago."

Small businesses such as SpheroFill work on problems that are big and complex. That's why they need help from government and other partners, says Rick Weber. Weber in 2006 founded Materials Development Inc., or MDI. MDI has developed an instrument to process and study materials in extreme conditions.

Weber had worked with a company developing advanced instruments for NASA flight experiments and realized that the noncontact processing tools he was helping to develop could be used for processing advanced glasses. Studying materials in extreme temperatures is confounded by the container. A perfectly inert container does not exist in nature, so experiments can be contaminated.

Weber's solution was to eliminate the container and use acoustic and aerodynamic forces to levitate materials so they float at temperatures as high as 3,500°C. The materials can then be probed with neutron or X-ray beams to investigate their structure and reactions to such extreme conditions. The process is useful for creating high-performance optical and laser glasses, defect-free crystals for the semiconductor industry, aerospace alloys, and, at lower temperatures, development of amorphous pharmaceuticals.

Weber and his small team collaborated with scientists at the Argonne National Laboratory (ANL) Advanced Photon Source, a high-power, radiation light-source research facility owned by the U.S. Department of Energy.

The work was partially funded by a Phase II Department of Energy Small Business Innovation Research award that was completed in 2015, and it resulted in MDI's development of a sample aerodynamic levitation system.

The government support benefits both parties, Weber says. "It's very good funding for this type of work," he explains. "It helps the agency get creative talent from the industry. And it helps us commercialize the technology."

MDI's work was continued at the Spallation Neutron Source at Oak Ridge National Laboratory (ORNL), which provides intense neutron beams for research.

These one-of-a-kind facilities have been integral to MDI's development of instruments to study materials in extreme environments, Weber says.

CACT photo: Alfred University's Center for Advanced Ceramic Technology provides short-term analytical programs, sponsored research, internships, and workforce development programs for New York State companies. *Credit: Alfred University*

"Small business can be very fast-moving and innovative," he says. "But government labs have resources that are unique and specialized, so there's a natural synergy there, in some cases."

The company's access to the high-tech infrastructure at ANL and ORNL was precipitated by networking at professional conferences. Weber recommends that small-business owners and researchers develop relationships with people at agencies that are relevant to their work.

"It's really important to understand what their goals are and to get to know some of the people involved in the program," he says. "Talk to them and learn about where you fit in."

Small businesses are not the only companies that benefit from partnerships and collaborations.

Corning Inc., an $11 billion global concern, holds the Corning Glass Summit every two years to foster collaboration with academicians studying and teaching materials science.

"It's an opportunity to establish closer relationships with professors at various universities in the U.S. and abroad," says Tim Gross, a research fellow at the Corning, N.Y.-based company.

The first Glass Summit took place in 2014 and addressed problems facing the glass science and technology community, identifying research areas of interest to Corning and the industry. In 2016, the Summit explored emerging glass applications, and in 2018, organizers added a poster session focusing on academic research. Post-doctoral researchers, undergraduates, and graduate students presented on glass and materials science topics, creating opportunities for Corning employees to interact with promising researchers early in their careers.

The pandemic canceled the 2020 event, and it was held virtually in 2021, which opened it up to a broader audience overseas.

The Summit helps connect Corning, which employs about 50,000 people worldwide, with students and professors interested in glass science. "The main motivation is to make sure we have a strong talent pipeline," Gross says. "We want to hire people who have a strong foundation in the things we care about."

Fifty universities, government agencies, and professional organizations were represented at the 2018 event.

Corning also sponsors a sabbatical program that offers professors the opportunity to work with Corning scientists on research topics. The Gordon S. Fulcher Sabbatical Program (named for a famed Corning glass scientist) selects one outside researcher per year to participate


Tim Gross

in the program at the company's Sullivan Park research lab. The sabbatical can last from six to 12 months.

New York is also home to a partnership among the state government, industry, and academia. The state funds 15 Centers for Advanced Technology to promote collaboration among private industry and universities. Alfred University's Center for Advanced Ceramic Technology (CACT) was one of the first, having been established in 1987.

"Our mission is to support the growth of industry in New York State," says David Gottfried, the CACT's deputy director of business development. "We offer applied research to help solve short-term or intermediate-term industrial challenges."

The research can range from conducting material analysis to working on multiyear projects to assist in bringing new technologies to the market. "We try to cover the whole spectrum from short-term analytical to long-term sponsored research," Gottfried says.


David Gottfried

The Center typically works with 35 to 40 companies a year, on 100 to 120 projects.

The Center also assists with workforce development, sponsoring student internships, and covering half of the cost of their pay and overhead. It also partners with companies seeking to apply for federal Small Business Innovation Research grants.

The results for business include savings in personnel and equipment costs, and new revenue from commercializing new products. The benefits for the state include the creation and retention of jobs, new capital investment, and additional tax revenue.

A state report found the economic impact of the overall CAT program from 2017 to 2019 to be $25.7 billion, providing an annual return on investment of up to 45 to 1.

That's something Michael Jordan would undoubtedly admire.

How to participate in DARPA's small-business technology and innovation programs

The Defense Advanced Research Projects Agency (DARPA) is an arm of the U.S. Department of Defense responsible for developing emerging technologies for the military. Its mission is "to make pivotal investments in breakthrough technologies for national security." This article was originally published on DARPA's website, https://www.darpa.mil/work-with-us/for-small-businesses/participate-sbir-sttr-program.

PROGRAM HISTORY

Congress established the Small Business Innovation Research (SBIR) Program in 1982 to provide opportunities for small businesses to participate in federal government-sponsored research and development.

The goals of the program are to stimulate technological innovation; use small business to meet federal R&D needs; foster and encourage participation by socially and economically disadvantaged small-business concerns (SBCs), and by SBCs that are at least 51% owned and controlled by women; and increase private-sector commercialization of innovations derived from federal R&D, thereby increasing competition, productivity, and economic growth.

Congress established the Small Business Technology Transfer (STTR) pilot program in 1992 to stimulate a partnership of ideas and technologies between innovative SBCs and research institutions through federally funded research or research and development. The STTR program is a vehicle for moving ideas from our nation's research institutions to the market, where they can benefit both private-sector and military customers.

THREE PHASES OF SBIR AND STTR

The SBIR and STTR programs are composed of the following three phases.

Phase I involves a Department of Defense (DoD) program announcement that seeks contract proposals to conduct feasibility-related experimental or theoretical research and development projects related to the agency's mission. These projects, as defined by agency topics contained in a program announcement, may be general or narrow in scope, depending on the needs of the agency. The object of this phase is to determine the scientific and technical merit and feasibility of the proposed effort and the quality of performance of the SBC with a relatively small agency investment before consideration of further support in Phase II.

Several different proposed solutions to a given problem may be funded. Proposals will be evaluated on a competitive basis using the criteria published in the DoD program announcement. Considerations may also include program balance with respect to market or technological risk, or critical agency requirements.

Phase II continues the research/research and development effort from the completed Phase I. The DoD does not issue separate SBIR or STTR program announcements for Phase II. All Phase I awardees for a given topic will receive notice of when to submit a Phase II proposal. The agency must base its decision on the results of work performed under the Phase I award and the scientific and technical merit, and the commercial potential of the Phase II proposal. Phase II awards may not necessarily complete the total research and development that may be required to satisfy commercial or agency needs beyond the SBIR or STTR programs. The government is not obligated to fund any specific Phase II proposal.

Phase III refers to work that derives from, extends, or completes an effort made under prior SBIR or STTR funding agreements, but it is funded by sources other than the SBIR or STTR programs. Phase III work is typically oriented toward commercialization of SBIR- or STTR-funded research or technology.

HOW TO PARTICIPATE

DARPA issues SBIR and STTR funding opportunities on a "just-in-time" basis, outside of the three predetermined announcements issued at the DoD level.

Step 1: Determine eligibility. Review complete eligibility requirements at https://www.sbir.gov/about#sbir-policy-directive – Chapter 6: Eligibility and Application (Proposal) Requirements.

For SBA's Guide to SBIR/STTR program eligibility, please search for SBIR Eligibility at https://www.sbir.gov/ (You must use the search function on the top right-hand side of the page.)

Step 2: Find a topic. Review the current and past announcements at https://www.dodsbirsttr.mil/submissions/login to identify topics of interest. On the announcement page, you will find the announcement instructions and topics for each DoD component. Click on the DARPA tab to find the topics and instructions. Be sure to review both the DoD Announcement Instructions and the DARPA-specific Instructions.

Step 3: Ask questions. During the announcement period, communication between small businesses concerns and topic authors is highly encouraged. During the prerelease period, you may have direct communication with a topic author to ask technical questions about their topic. For your convenience, contact information is provided within each topic.

To ensure competitive fairness, direct communication between proposers and topic authors is not allowed once a topic enters the open period (when SBCs are able to submit proposals to DoD). However, during the open period, proposers may submit written questions about open topics via the DARPA SBIR/STTR BAA email address listed in the topic instructions. All questions and answers generated from emails are posted in Q&A documents and published under the topic listing at https://www.darpa.mil/work-with-us/opportunities and at https://www.darpa.mil/work-with-us/for-small-businesses/proposers-day.

All proposers are advised to monitor these pages during the open announcement period for questions and answers and other significant information relevant to their SBIR/STTR topics of interest.

Step 4: Prepare your proposal. All proposals are initially screened to determine responsiveness with submission requirements published in the DoD SBIR/STTR Program Announcement and supplemental DARPA instructions. Proposals that do not comply with the requirements are considered nonresponsive and are not evaluated. Proposals that do comply with the requirements are evaluated by engineers and/or scientists to determine the most promising technical and scientific approaches.

Step 5: Submit proposal. All SBIR/STTR proposals must be prepared and submitted electronically through the DoD SBIR/STTR Electronic Submission website at https://www.dodsbirsttr.mil/submissions and in accordance with the program announcement. Once you begin a proposal cover sheet, you may edit the cover sheet and proposal volumes at any time until the BAA close (or due date for the Phase II proposal). When you have completed your proposal and reviewed it, you must click "Submit Proposal." If the proposal status is "In Progress," it will not be considered submitted upon the announcement close.

TYPES OF FUNDING AGREEMENTS

DARPA administers all SBIR and STTR projects as firm-fixed price, cost plus fixed-fee contracts, and on a case-by-case basis, other transactions (OTs) for prototype.

OTs are instruments other than contracts, grants, and cooperative agreements that are used to stimulate, support, or acquire research or prototype projects.

Intellectual property (IP)

See https://www.acquisition.gov/browse/index/far, reference clause 52.227-11.

And https://www.acq.osd.mil/dpap/dars/dfarspgi/current/, reference clauses: 252.227-7013, 252.227-7014, 252.227-7015, 252.227-7038.

For OTs, the parties are allowed flexibility to negotiate IP because Bayh-Dole does not apply. DARPA normally does not acquire IP rights that will impede commercialization of technology.

A soil scrubber to clean chemical warfare agents, left, was developed for DARPA by the Southwest Research Institute, San Antonio, Texas. *Credit: DARPA*

EXPORT CONTROL

The following will apply to all projects with military or dual-use applications that develop beyond fundamental research (basic and applied research ordinarily published and shared broadly within the scientific community):

–The contractor shall comply with all US export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of this contract. In the absence of available license exemptions/exceptions, the contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports of (including deemed exports) hardware, technical data, and software, or for the provision of technical assistance.

–The contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed onsite at any government installation (whether in or outside the United States), where the foreign person will have access to export-controlled technologies, including technical data or software.

¬–The contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.

–The contractor shall be responsible for ensuring that the provisions of this clause apply to its subcontractors.

Please visit http://www.pmddtc.state.gov/regulations_laws/itar.html for more detailed information regarding ITAR/EAR requirements.

ABET ENSURES QUALITY IN UNIVERSITY ENGINEERING EDUCATION

By Eileen De Guire

Suppose you are an employer seeking a materials scientist for an entry-level position. You advertise the position, and soon you have a short list of qualified candidates from reputable schools to interview.

As an employer, you have made some assumptions about "qualified candidates" and "reputable schools." How do you know a candidate's education makes them qualified, and what makes an educational institution reputable?

Education quality in the United States is assessed through accreditation processes, and there are several accrediting organizations that serve specific segments of the higher education system. ABET, previously known as the Accreditation Board for Engineering and Technology, accredits "college and university programs in the disciplines of applied and natural science, computing, engineering and engineering technology at the associate, bachelor's and master's degree levels," according to its website (www.abet.org). Through a rigorous process of self-assessment and external review, ABET accreditation ensures college and university programs meet set standards for quality. "With ABET accreditation, students, employers and the society we serve can be confident that a program meets the quality standards that produce graduates prepared to enter a global workforce," according to the website.

ABET depends on professional societies and their volunteers. Societies provide input, but in addition, all decisions are made by representatives from member societies. The criteria are developed and approved by ABET's Commissions and the Area Delegations, comprising volunteers from the member societies.

ACerS has a long tradition of participating in ABET. In an interview with *Bulletin* editor Eileen De Guire, Darryl Butt, FACerS and dean of the College of Mines and Earth Sciences at the University of Utah, talks about his work as an ABET volunteer.

A working session from the 2016 ABET annual meeting. Janet Callahan (third from left) was ACerS's ABET commissioner at the time. *Credit: Janet Callahan*

Q: ***What is your involvement in ABET?***

A: I'm not an employee or representative of ABET, but I volunteer as an ABET program evaluator. I volunteer through ACerS to help ABET review ceramic engineering programs. I've also been a beneficiary of ABET in that I've hired many students over the years from ABET-accredited engineering programs, not just ceramic engineering students but also materials science, mechanical engineering, electrical engineering students, and more.

Q: ***Why does ABET-accreditation matter not only to programs and students, but also to the employers who hire degreed students?***

A: First of all, it really helps engineering degree programs by setting up a framework for continuous improvement. There's a bunch of different parts to the ABET accreditation review related to faculty, facilities, student outcomes, and more; and there are certain things that ABET expects of universities in terms of curriculum. Math and science, obviously, engineering courses, and more. But the process also sets up a framework for how you decide what you're training students to be able to do and who you should be consulting with related to the program's constituencies. Engineering programs engage with a variety of constituencies, which may include industry, employers, and their alumni. A program's constituencies are unique to where you are in most cases, and so it looks at things from many different angles, internally as well as externally. It basically sets up this framework or helps you set up a framework for continuous improvement in your program and staying relevant.

ABET accredited programs provide students with the all the right tools so that when they go out into industry or to a national lab or to graduate school, they're going to have the skills that they need to be successful. For example, for professional licensure, students must have earned a degree from an ABET-accredited program.

I am a big fan of continuous improvement and what ABET embodies. I have to tell you, what I've learned over the years is if you make continuous improvement part of your corporate or university culture, and you use it in the spirit that it's intended, it really facilitates conversations between the faculty, between the students, and the constituencies in a way that can be fun. It also is a way to set up a process for facilitating discussions about teaching pedagogy. It keeps you at the forefront of education.

Q: ***How often does an engineering program go through the accreditation process?***

A: The typical process is every six years. I should point out that ABET accredits not just U.S. engineering degree programs but also international ones.

Q: ***How would you say ABET is relevant in our industry, especially in light of the diminished number of ceramic engineering programs?***

A: I think this is a really important question. There are three ABET-accredited ceramic engineering programs left in the U.S. And obviously, there are other ones internationally that we, in effect, support. But ceramics is deeply embedded in most materials science and engineering programs. So, if you're an ABET evaluator for ceramic engineering, based on ACerS requirements, you've also completed training as an evaluator for materials science programs. Our evaluators are embedded across the country, contributing to engineering excellence. And the ceramics industry doesn't only hire ceramic engineering students. They hire mechanical engineers, electrical engineers. ABET supports the ceramic industry by accrediting engineers from all different disciplines that support our industries as well as national labs. We don't want to look at our Society as being just these three programs. Our Society is interdisciplinary. It's much broader than that.

Another thing—accreditation of engineering programs isn't just about looking at science and math. It's also to some degree about assuring that engineering students get a broad education, which means that they learn the higher order skills of leadership and appreciating diversity and inclusion. In the future, I suspect there's going to be some requirements for cyber security. There are all sorts of things that we should be paying attention so that students coming out of accredited universities have lots of skills.

Q: ***Just to clarify, you are connected with the team that evaluates materials science and engineering?***

A: Yes. So when you petition to join as an ACerS evaluator, we decided a while ago, and partly because there are so few ceramics programs that we also accredit, to collaborate with TMS. So ACerS-approved evaluators are also approved by TMS to evaluate ceramics programs. Approved ACerS program evaluators thus potentially contribute to the materials engineering programs as well as ceramic engineering programs.

Q: ***It sounds like the professional societies are critical to the ABET accreditation process?***

A: Absolutely. Their participation is vital.

Q: ***Would it be fair to say that the societies are representing the needs of their industries through the volunteers that they support to ABET?***

A: Through their members, volunteers provide feedback to programs on how they can improve their programs. We have folks in The American Ceramic Society who are involved in ABET at a whole bunch of different levels, from people like me (evaluators) to people who are commissioners. When ABET makes a change in their expectations, the professional societies have a voice in that. And because they do stay in touch with their constituencies, then ABET gets feedback from constituencies in effect through the volunteers of the societies.

Q: ***Why would you say ABET is important to the societies that support it?***

A: It's an outside organization that keeps us honest and assures quality. The last thing we would want in our industry is for us to have catastrophic problems in the field of ceramics. Ceramics are used for all sorts of things that life depends on, right? Human implants and as lining of gigantic furnaces and critical parts and in aerospace systems. If we didn't have this outside entity assuring that our graduates have certain standards in terms of ethics, certain skills in terms of math and physics and in engineering talents, we can have serious problems in the industry. Having this sort of independent body helps assure our quality and keeps us honest, which helps the whole industry to be more competent and credible. That's great.

Q: ***Do you have to be an academic to be an evaluator?***

A: A lot of folks from all sorts of different fields or areas help with ABET. People from industry are very important, people from national labs get involved. It's really quite a mix. And you know, it's interesting, the visits. The evaluators are typically not academics. There are always some academics in the mix, but oftentimes it's folks from industry. We really appreciate the industrial members.

Q: ***If somebody wants to get involved with ABET, how would they do that?***

A: If you go to www.abet.org, there's a wealth of information there. In fact, there's a button you can click on that says "About ABET," and you can learn a ton. And in fact, I think there's some information there on why ABET is valuable.

Also, on the ACerS webpage, you can click on the "About" link and click on "Committee Roster" under "Governance," and you'll find a list of the people in ACerS that are ABET representatives, and it's a wonderful group of folks. Any one of them will be more than happy to talk your head off about ABET because they're all big advocates and are very enthused about it.

Q: ***Is there anything else that is important for our audience to be aware of?***

A: I think the one message that I would like to have resonated is that if, as a university, you embrace the principles of continuous improvement, over time what you discover is that it gets easier and easier and becomes part of your culture. Eventually, what happens is continuous improvement actually becomes kind of fun. And it really is just a way to facilitate conversations between your students, your faculty, your constituents. There's work that goes along with it—writing, documentation, etc. You should be doing that anyway, and once you get used to thinking in a sustainable way about how to improve your organization, the accreditation process becomes unintimidating and really can be kind of fun and what we should be doing anyway.

And I do think we need the support of the Society. We need everyone to understand why we need to support ABET accreditation of our programs. And everyone in the Society should understand what ABET is because it does impact everybody. We need more involvement, too. No question.

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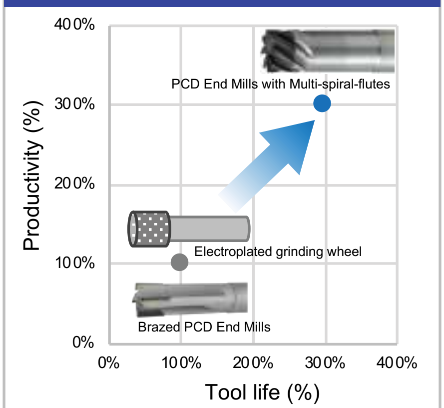

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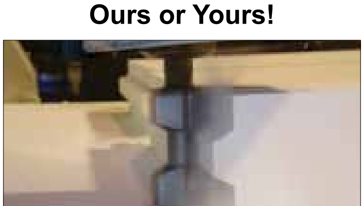

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Kah Leng
Guest columnist

Ceramics for next-generation thermal barrier coatings

In the early 1950s to 1960s, efficiency improvements in turbine engines was largely due to increases in turbine entry temperature, i.e., the temperature of the combustion chamber exhaust gases as they enter the turbine unit. Even today, higher entry temperatures are sought to further increase engine efficiency.

As the operating temperature increases, the durability of high-temperature components in the engine must increase as well to survive in such harsh environments. An insulation layer called the thermal barrier coating (TBC) is one way to improve durability.

TBCs have been used in civilian aircraft since the early 1980s.[1] TBCs are applied to components to create a thermal gradient on the surface, thereby extending the components' life cycle and durability. There is a significant reduction in the coated components' surface temperature, generally in the range 100–300°C.[2]

TBCs usually are deposited on top of substrates, a process that consists of four layers. The first layer is the substrate, commonly nickel- or cobalt-based superalloy. These superalloys are mainly used to manufacture critical parts (i.e., high-pressure turbine blades) in turbine engines due to their superior characteristics at elevated temperature, including creep and oxidation resistance.

The second layer is the bond-coat, which serves to minimize thermal expansion mismatch between the metallic substrate and ceramic topcoat. Alloys of platinum/nickel-rich aluminide or MCrAlY (where M represents nickel, cobalt+nickel, or iron) are the industries' primary bond-coat materials.

Beyond 700°C, the bond-coat will act as a reservoir where aluminum diffuses out to form a protective thermally grown oxide (TGO) layer between the bond-coat and ceramic topcoat. The TGO layer is known as the third layer in TBCs. The selected composition of TGO–α-Al_2O_3– is the slowest growing oxide at high temperatures, with excellent mechanical integrity and low oxygen diffusivity, protecting the bond-coat from further oxidation.[3]

The last layer is the ceramic topcoat, which provides thermal insulation for the substrate component. Zirconia-based ceramics, particularly yttria-stabilized zirconia, are widely used as the ceramic topcoat for turbine blades due to a low thermal conductivity and a high coefficient of thermal expansion.

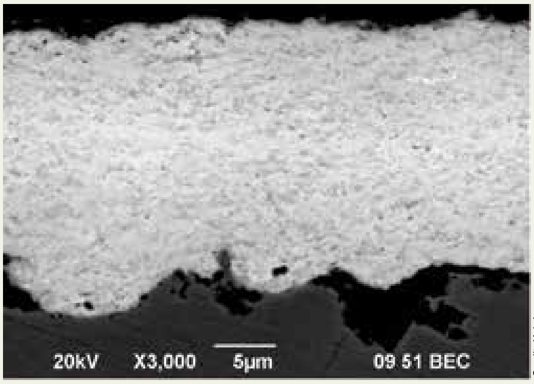
Multiple techniques are available for depositing TBCs. The main group of techniques is thermal spraying, which includes plasma spraying, electron beam physical vapor deposition (EBPVD), and high-velocity oxy-fuel (HVOF).

Plasma-spraying techniques create the coating using a stream of hot plasma jets to deposit the material feedstock (in either powder, solution, or suspension form) on the substrate. The jets are produced through either an electrical source or a radio frequency discharge.

EBPVD deposition relies on evaporation of materials from a melt inside a vacuum chamber. A high-energy electron beam heats the material ingots into a vapor cloud that condenses onto the substrate to form a coating.

HVOF deposition uses a high-velocity gas, made by combusting a mixture of oxygen and fuel and focused through a nozzle, to carry the material feedstock (in either powder, solution, or suspension form) to the substrate.

The current challenge for TBCs is the phenomenon of spallation, or the ejection of fragments from a material, which occurs beyond 1,200°C. When spallation occurs, it leaves components bare to the unacceptably high-temperature environment and the components undergo rapid degradation, leading to catastrophic failure. The presence of calcia-magnesia-alumina-silica in the air intake of turbine engines increases the spallation speed of TBCs.[4]



Credit: Kah Leng

Figure 1. SEM micrograph of a gadolinium zirconate coating created using an HVOF technique through liquid feedstock on a stainless-steel substrate (SS 304). The thickness of the coating is ~20 μm.

Gadolinium zirconate (GZO), believed to be the next-generation TBC, is the focus of my research using HVOF techniques (Figure 1). Optimization of spray parameters is required before reviewing the performance of the as-sprayed HVOF GZO coating.

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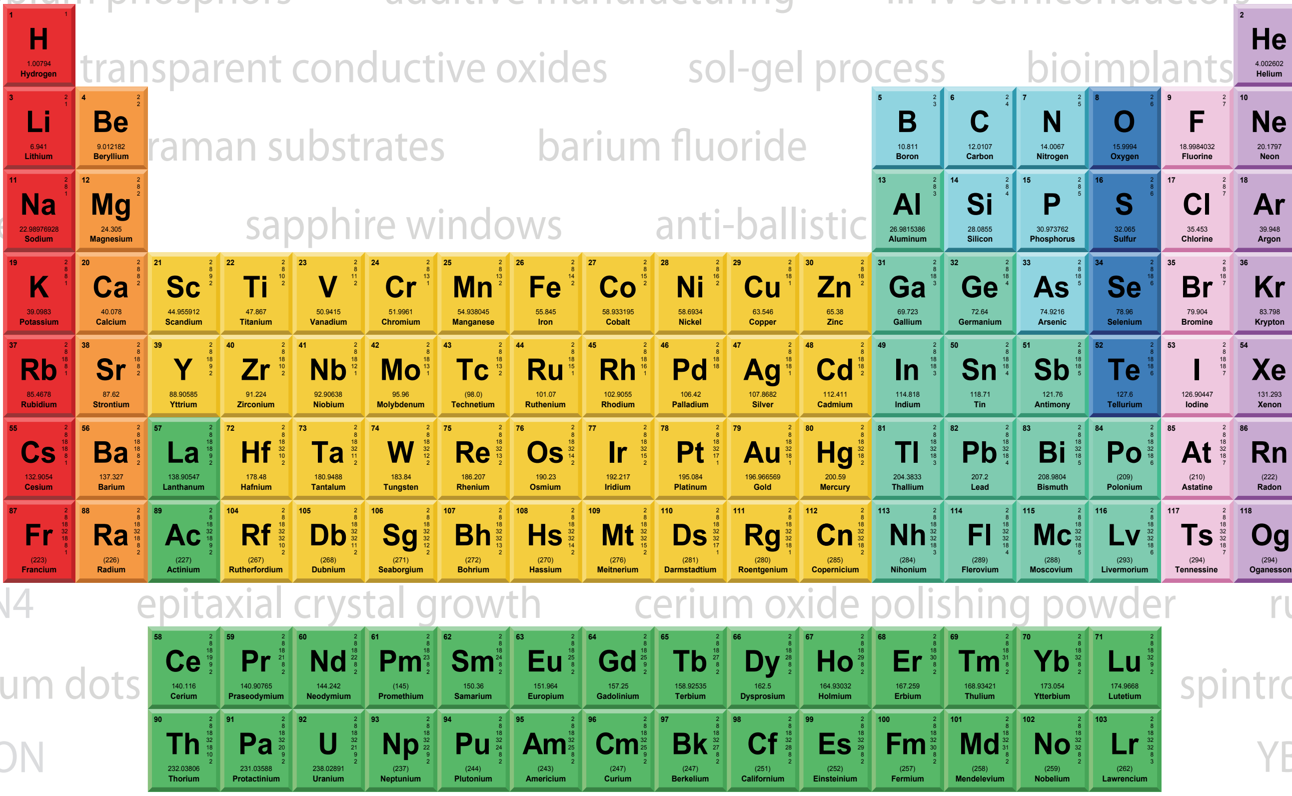
Kah Leng is a second-year Ph.D. student at University of Nottingham, England. Apart from his Ph.D., he enjoys cooking, traveling, and hitting the gym.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