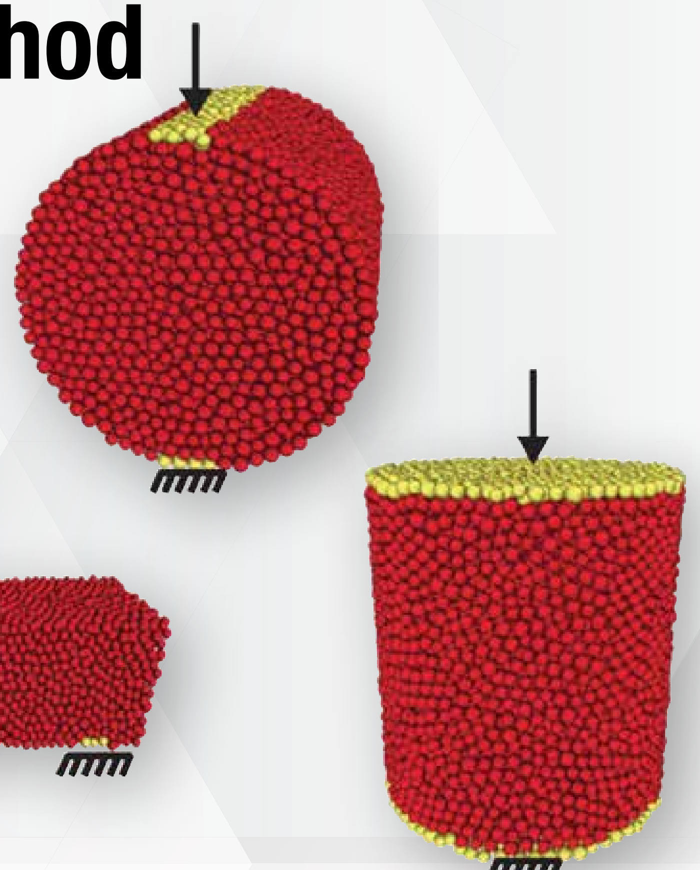
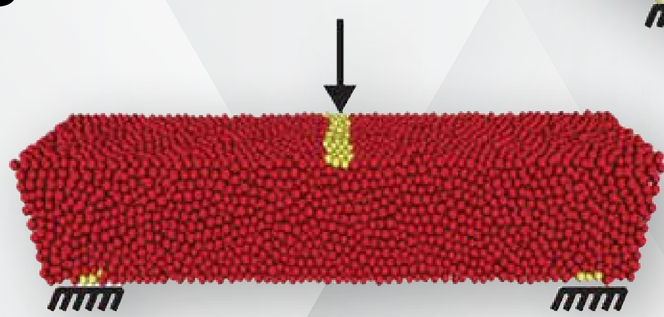
AMERICAN CERAMIC SOCIETY
bulletin
emerging ceramics & glass technology
MARCH 2020

Discrete element modeling— A promising method for refractory microstructure design





ceramics expo

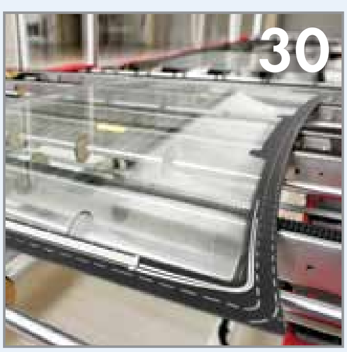
Special show issue
May 5–6, 2020
Cleveland, Ohio

Ceramics Expo: Empowering a greener future | Curved glass manufacturing | PCSA 2020-2021

contents

March 2020 • Vol. 99 No.2

feature articles



department

columns

meetings

resources

online
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March 2020 • Vol. 99 No. 2

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As seen on *Ceramic Tech Today*...

Credit: ACerS

Quantifying potential—researchers close in on hafnia-based nonvolatile memory

Hafnium oxide-based ferroelectrics are promising materials for nonvolatile memory devices, as they are compatible with modern semiconductor technologies. Researchers led by the Moscow Institute of Physics and Technology came up with a unique method to better characterize these materials.

Read more at www.ceramics.org/hafniamemory

Also see our ACerS journals...

Engineering resilience with precast monolithic refractory articles
By D. Goski and M. Lambert
International Journal of Ceramic Engineering & Science

Review of corrosion of refractory in gaseous environment
By M. K. Mahapatra
International Journal of Applied Ceramci Technology

Corrosion modeling of magnesia aggregates in contact with CaO–MgO–SiO_2 slags
By W. Zhang, A. Huang, Y. Zou, et al.
Journal of the American Ceramic Society

Also be sure to check out the Topical Collection "Properties, Processing and Structure of Refractory Ceramics," available on ACerS Publication Central at https://ceramics.onlinelibrary.wiley.com/hub/topical_collections

Applied Ceramic TECHNOLOGY | Applied Glass SCIENCE | Ceramic Engineering & Science | Journal

Read more at www.ceramics.org/journals

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ACSBA7, Vol. 99, No. 2, pp 1– 48. All feature articles are covered in Current Contents.

news & trends

From space to deep sea—Search for critical materials intensifies

Battery manufacturers, if they wish to keep pace with the growing demand for batteries driven by renewable energy technologies and electric vehicle adoption, must have access to cobalt and other critical materials. But obtaining these materials while respecting labor and environmental regulations has driven some manufacturers to explore some previously unfathomable locations.

Lucrative lunar

Over fifty years ago, NASA astronauts made history when they first stepped onto the moon. Fast forward to today, and instead of government-funded missions fueled by discovery and national pride, a crop of private companies are emerging with missions of returning to the moon to exploit its resources with the hopes of planet-sized profits.


Credit: Nigel Howe, Flickr (CC BY-NC 2.0)

The U.S. Commercial Space Launch Competitiveness Act of 2015 makes it legal for companies to own and sell resources they extract from space, including the moon and asteroids.

The United States passed the U.S. Commercial Space Launch Competitiveness Act in 2015, making it legal for companies to own and sell resources they extract from space, including the moon and asteroids. And a U.S. presidential memorandum signed into policy in 2017, Space Policy Directive 1, established that "the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations..."

A whole slate of startup companies now seem eager to make that directive a reality by raising millions of dollars in funding to support their space missions. For example, a company called Moon Express raised more than $65 million from big-time investors to support its mission "to redefine possible by returning to the Moon and unlocking its mysteries and resources for the benefit of humanity." Jeff Bezo's company Blue Origin reportedly secured $13 million in funding to build lunar landers that can deliver 6.5 metric tons of payload to the moon's surface "to save earth." And Japanese company ispace now has more than $90 million to "begin the development of [a] lunar lander to establish a flexible and regular lunar transportation system, and lead the exploration and development of lunar surface through micro-robotic systems," according to the company's founder Takeshi Hakamada.

Plus, "Two startups called Planetary Resources and Deep Space Industries raised $50.3 and $3.5m for space mining before they were acquired by large companies (although they were focused more on asteroid mining than moon mining)," according to an article on *The Hustle*.

Despite all this activity and investment, the moon's small, local deposits of rare earth elements were concentrated by different processes than what took place on earth. That may mean the methods developed on earth to mine, separate, extract, and purify rare earth elements may not work on the moon.

Even if mining the lunar landscape is feasible, another remaining challenge will be how to transport the resources back to earth. One of the biggest challenges and most expensive parts of space travel is transportation, explains Angel Abbud-Madrid, Director of the Center for Space Resources at the Colorado School of Mines, in a *Wired* video. So work needs to be done to make such transportation economically viable.

Deep sea mining

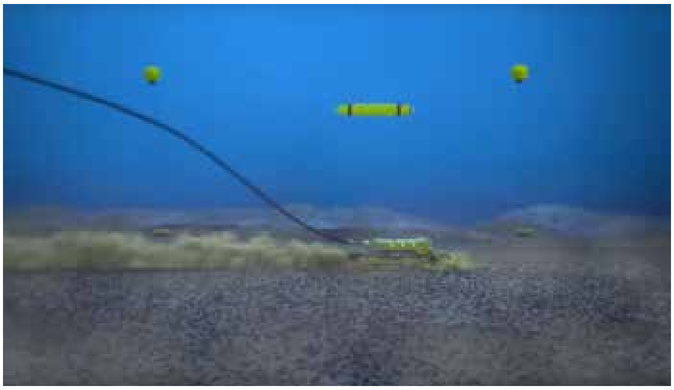
Deep sea mining refers to mineral retrieval processes that take place on the ocean floor. The term generally applies to extraction of three distinct types of ore deposits found in the deep sea:

- Seafloor massive sulfides (hydrothermal vents)
- Ferromanganese (polymetallic) nodules
- Cobalt crusts

Of these three, most deep sea mining research and exploration focuses on the first two.

Interest in deep sea mining initially picked up in the 1960s with the publication of a 1965 book that claimed nearly limitless supplies of critical materials could be found throughout the planet's oceans. The possibility was explored and then abandoned by the 1980s, but interest in the topic has grown again in the 2000s—and now is poised to become a serious venture.

"In 2018, [De Beers Group] ships extracted 1.4 million carats [of diamonds] from the coastal waters of Namibia; in 2019, De Beers commissioned a new ship that will scrape the bottom twice as quickly as any other vessel," according to an article from *The Atlantic* on the consequences of deep sea mining.



Credit: Massachusetts Institute of Technology (MIT), YouTube

One aspect of deep sea mining many researchers are investigating is sediment plumes, i.e., collections of sand, dirt, and rocks stirred up when mining technologies dredge the ocean floor. It is unknown how far plumes can travel or their effects on the marine environment.

"Another company, Nautilus Minerals, is working in the territorial waters of Papua New Guinea to shatter a field of underwater hot springs lined with precious metals, while Japan and South Korea have embarked on national projects to exploit their own offshore deposits."

All these underwater mining programs currently take place just offshore or in waters designated as a country's national territory. Mining in international waters—waters that transcend national boundaries—is not allowed.

However, that could soon change. The International Seabed Authority (ISA), an autonomous international organization established by the United Nations to govern resources of the deep seabed, has granted "exploratory" permits around the world in international waters and is writing an underwater Mining Code to regulate commercial mining. *The Atlantic* article reports that officials hope the code will be ratified for implementation this year.

With commercial deep sea mining so close to becoming reality, people may assume that scientists know what the environmental impact of such mining would be and how to limit it. Unfortunately, that is far from the case.

Until recently, it was assumed the deep sea hosted minimal life because the traditional model of life relies on photosynthesis. But when a pair of oceanographers discovered an intricate web of life around hydrothermal vents in 1977, marine biologists realized chemosynthesis could also support life and began to realize the deep sea actually supports incredibly diversity.

To date, knowledge of deep sea ecosystems is limited, and knowledge of the environmental impacts of deep sea mining is even scarcer. Thus, researchers strongly caution mining companies from pursuing deep sea mining too quickly when so much is still unknown.

On the plus side, researchers now have a better idea of how mining affects the environment thanks to new access to ISA data. In July 2019, the ISA launched its newly developed ISA Deep Data repository, which holds centralized data of public and private information on marine mineral resources acquired from various institutions worldwide. A *National Geographic* article from last year explains this database, which contains all environmental data reported by miners since 2001, is the first time "scientists will be able to analyze the quantity and quality of that information and determine if mining contractors have complied with ISA rules." ■

Corporate partner news

NSL Analytical Services acquired by May River Capital

Larry Somrack | Ron Wesel | Carey Lewis | Andy Housley

NSL Analytical Services, an independent commercial materials testing laboratory, announced the company was acquired by May River Capital, a Chicago-based private equity investment firm. NSL president Larry Somrack will continue with NSL Analytical as president emeritus. Joining the executive team with Somrack will be Ron Wesel, Carey Lewis, and Andy Housley. ■

Business news

PLANTS, CENTERS, AND FACILITIES

Strategic Materials triples crushed glass abrasives production with new US facility
North American glass recycler Strategic Materials opened a new crushed glass abrasives production facility in Houston, Texas. The over 30,000 ft^2 facility began production in early December 2019 with improved bagging technology and production line capabilities, with plans for further expansion in 2021. https://www.strategicmaterials.com

New additive manufacturing center opens in Sweden
Manufacturer and distributor GE Healthcare Life Sciences introduced a new additive manufacturing center in Umea, Sweden, to accelerate biopharma manufacturers' access to the latest available technology. This center, which was a two-million USD investment, will aim to integrate 3D printed parts into the production of manufacturing equipment. https://www.medicalplasticsnews.com

World's largest floating wind turbine now online
One of the three platforms that will make up the WindFloat Atlantic wind farm off the coast of Portugal was connected to the grid via a 20-kilometre (12.4-mile) long cable on New Year's Eve. Once the other two platforms come online, WindFloat will be able to provide enough clean energy for around 60,000 homes. https://www.sciencealert.com

ACQUISITIONS AND COLLABORATIONS

Allied Glass acquired by investment firm
A Sun European Partners affiliate completed the acquisition of Allied Glass for an undisclosed sum. Allied Glass is one of the largest U.K.-based manufacturers of glass packaging containers for the premium spirits and food and drinks markets. https://www.glass-international.com/news

Kyocera and 24M develop world's first SemiSolid lithium-ion battery system
Kyocera Corporation and 24M announced that Kyocera has formally launched its residential energy storage system, Enerezza, the world's first system built using 24M's novel SemiSolid electrode manufacturing process. https://www.businesswire.com/portal/site/home/news

Mkango subsidiary buys into UK magnet recycling firm HyProMag
Mkango Resources announced that its subsidiary Maginito completed the acquisition of an initial 25% interest in HyProMag, a private U.K.-based company focused on rare-earth magnet recycling. https://www.sharecast.com/sharecast/index.html

Grupo Mess named Buehler distributor for metallographic, hardness equipment in Mexico
Buehler announced a partnership with Grupo Mess, a leading Mexico supplier of scientific equipment and services specializing in metrology, to provide Buehler Mexico customers local support for all their metallographic product and service needs involved in product inspection or quality control laboratories. https://www.buehler.com/buehler-press-releases.phpl

MARKET TRENDS

Three fiber cement markets driving global demand
A study from The Freedonia Group examines how a number of developments in India, the United States, and China will affect the ebb and flow of the global fiber cement market through 2023 and beyond. https://www.freedoniagroup.com

Global additive manufacturing market 2019 worth over $10 billion
SmarTech Analysis' fourth annual additive manufacturing market summary report sees the global AM market 2019 growing to over $10.4B, crossing the pivotal double-digit billion threshold for the first time in its nearly 40 year history. SmarTech goes on to forecast the AM market will grow into an almost $55 billion yearly business by 2029. https://www.3dprintingmedia.network

Most glass and glazing materials prices see year-over-year increases
According to the latest Producer Price Index from the U.S. Bureau of Labor Statistics, the not seasonally adjusted prices for materials used in glass and glazing manufacturing were a mixed bag in December 2019, but the trend of year-over-year increases continued. https://www.usglassmag.com

Etch process to reach $8.8 billion by 2024
A report by BCC Research says the global market for etching processes should grow from $6.9 billion in 2019 to $8.8 billion by 2024 at a compound annual growth rate of 4.9%. The processes are expected to grow because of the increase in demand of a large array of semiconductors and power devices. https://www.bccresearch.com/market-research ■

Adhesives and sealants: Innovations, equipment, applications, and extreme applications

By Srinivasa Rajaram

The global markets for adhesives and sealants are estimated to be valued at $48.780 million and $21.745 million, respectively, in 2020 and projected to expand at a compound annual growth rate (CAGR) of 5.3% and 5.1%, respectively, through the next five years.

Increased demand for adhesives and sealants is driven by the emergence of new market applications that have resulted from evolving and improving assembly processes. In particular, a shift from major forms of industrial joining, such as welding and mechanical fastening, to adhesive bonding in major industries, such as automobiles, brought about growth opportunities. Similarly, miniaturization of components in the electronics industries enabled the use of adhesives to replace soldering and brazing in these industries.

The adhesives and sealants industry is made up of two chemically similar but functionally different groups of formulated products. Adhesive products are used to create a bond between two different or similar materials. Sealants are used to create an impenetrable barrier to gas or moisture.

Classification of adhesives by curing technology include

- **Physically hardening**, the market for which is expected to grow by a CAGR of 5.2% to $27,005 million by 2025,
- **Chemically curing**, the market for which is expected to grow by a CAGR of 4.9% to $26,175 million by 2025, and
- **Pressure sensitive**, the market for which is expected to grow by a CAGR of 6.7% to $9,975 million by 2025.

Classification of sealants by technology include

- **One-component sealants**, the market for which is expected to grow by a CAGR of 5.1% to $11,410 million by 2025,
- **Two-component sealants**, the market for which is expected to grow by a CAGR of 4.9% to $8,850 million by 2025, and
- **Sealant tapes**, the market for which is expected to grow by a CAGR of 5.3% to $7,625 million by 2025.

Paper, board, and packaging applications will have the greatest value and will also be the fastest-growing market in the coming years for the global adhesives market, growing by a CAGR of 5.8% to $23,180 million by 2025. Civil engineering applications follow in second place with an expected CAGR of 5.5% to $12,835 million, followed by various assembly applications with an expected CAGR of 5.4% to $7,675 million.

In terms of the global sealant market, construction applications are expected to lead the market in value terms with $14,760 million by 2025, though industrial assembly applications are expected to have the higher growth rate of 5.2% to $5,050 million.

The Far East represents the highest growth region for adhesive and sealant products. Four countries are highlighted as representing opportunities for significant growth—China, South Korea, Taiwan, and Vietnam. A smaller regional market, Eastern Europe, has three major markets: Poland, Hungary, and Russia, showing demand growth above 4%. With growing investment in its industrial base, India has also become a major growth area in the Asian region and has the potential to develop into a significant market for adhesive and sealant products.

Growth in most other countries is sporadic due to the small size of the total demand. The effect of one large new order, or the loss of another, can swing the growth rate from positive to negative.

In terms of market size, the major industrialized adhesive and sealant producers and consumers remain the United States, Japan, Germany, Italy, the United Kingdom, and France. The development of new products and technologies will flow from these countries for at least the next few years.

Table 1. Global market for adhesives, sealants, and application equipment, by product type, through 2025 ($ millions)

Product Type	2018	2019	2020	2025	CAGR% 2020–2025
Hot-melt, acrylic, and pressure-sensitive adhesives	18.955	19,965	21,750	29,020	5.9
Adhesive and sealant application equipment	17,140	17,840	18,570	22,720	4.1
Silicone, PUR, and acrylic sealants	14,475	15,205	15,990	20,505	5.1
Cyanoacrylic, anaerobic, and miscellaneous adhesives	13,030	13,725	14,045	17,690	4.7
Epoxy, PUR, and polyvinyl adhesives	12,010	12,635	12,985	16,445	4.8
Butyl, polysulfide, SMP, and miscellaneous sealants	5,210	5,485	5,755	7,380	5.1
Total	80,820	84,855	89,095	113,760	5.0

About the author

Srinivasa Rajaram is a research analyst for BCC Research. Contact Rajaramat analysts@bccresearch.com.

Resource

S. Rajaram, “Adhesives and sealants: Innovations, equipment, applications and extreme applications” BCC Research Report CHM100A, January 2020. www.bccresearch.com.

SOCIETY, DIVISION, SECTION, AND CHAPTER NEWS

Corporate Partner news

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

Our newest Corporate Partners are:

- **California Nanotechnologies Inc.**
- **Fiven**
- **RHI Magnesita**
- **Iwatani Corporation of America**
- **Pacific Ceramics**

The ACerS Corporate Partnership Program offers member companies the benefits of individual membership, marketing, advertising, recruiting, and cost-saving. Please contact membership director Kevin Thompson at kthompson@ceramics.org with questions. ■

The American Ceramic Society announces new Energy Materials and Systems Division

The American Ceramic Society announced the establishment of the new Energy Materials and Systems Division.

The ACerS Board of Directors approved the Division's creation and rules at their December 2019 meeting.

"The Division will address a wide variety of materials related to energy, keeping the primary focus on ceramic and glass materials and emphasizing importance of system-related research," ACerS president Tatsuki Ohji says. "The Division will foster collaboration, innovation, education, and networking among members with interest in ceramics and glass for energy-related applications."

Starting this year, the EMS Division will be the home of the Materials Challenges in Alternate & Renewable Energy (MCARE) meetings and the Energy Harvesting meetings. The Energy Harvesting meeting will be a combined meeting with MCARE in even years and a standalone meeting in odd years.

Next steps include working with the Nuclear & Environmental Technology Division members to combine that Division with the EMS Division. Also, it will be proposed that the NETD's awards (D.T. Rankin, Outstanding Student Researcher and NETD Student Stipends) will continue under the EMS Division.

Officers:

Chair: **Armin Feldhoff**, Leibniz University Hannover
Vice chair: **Kyle Brinkman**, Clemson University
Secretary: **Krista Carlson**, University of Utah
Program Committee Chair: **Eva Hemmer**, University of Ottawa ■

Credit: ACerS

ACerS and The European Ceramic Society established new collaborations with the signing of a Memorandum of Understanding during ICACC in January. From left: Mark Mecklenborg (ACerS executive director) looks on as Tatsuki Ohji (ACerS president) and Jon Binner (ECerS president) sign. Pavol Sajgalik (right, ECerS secretary) also observes.

American and European ceramic societies sign collaboration agreement

Leaders of The European Ceramic Society and The American Ceramic Society signed a Memorandum of Understanding when officials from both organizations met recently at the International Conference on Advanced Ceramics and Composites in Daytona Beach, Fla. ACerS president Tatsuki Ohji signed on behalf of ACerS, and ECerS president Jon Binner represented ECerS.

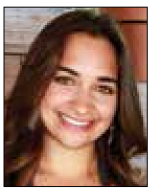
The societies agreed to establish a joint award to recognize people who foster international collaboration between ACerS and ECerS. In addition, the societies will establish a joint ECerS-ACerS symposium at each other's meetings to promote international exchange of ideas. The symposium will alternate each year between ACerS Annual Meeting at MS&T and ECerS' biennial conference. The MOU formalizes existing collaborations on activities for students, including ECerS Summer School and ACerS Winter Workshop.

"This agreement provides a strong foundation for growing our relationship in the future," says Tatsuki Ohji, ACerS president.

The European Ceramic Society, established in 1987, is a nongovernmental, nonprofit federation of 28 member national ceramic societies and two associated national ceramic societies serving academic and industry ceramists. The agreement calls for ACerS International Chapters to work closely with the national societies in their respective countries to complement each other's activities, promote mutual membership, and advance ceramic and glass science and industry across Europe.

"We have many members in common. This agreement provides a framework for communication and exchange of ideas," says Jon Binner, ECerS president. ■

Volunteer Spotlight



Christensen

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

This month ACerS turns its Volunteer Spotlight on **Victoria Christensen**.

Christensen is a second year Ph.D. student at the University of California, Santa Barbara, working in the Frank Zok group on oxidation behavior of ceramic matrix composites.

She began volunteering with ACerS during her senior year at The Pennsylvania State University as an ACerS President's Council of Student Advisors (PCSA) delegate on the External Partnerships Committee (EPC). Becoming EPC chair the following year, Christensen established a mentoring program and a humanitarian project pitch competition for students at ACerS Annual Meeting at MS&T 2019. This year, she is the council chair of the PCSA and will help the delegates organize ACerS' first student-run symposia on humanitarian engineering at ACerS Annual Meeting at MS&T 2020.

Christensen also served on the Winter Workshop planning committee for the past three years and helped organize the Global Young Investigators Forum held at ACerS Annual Meeting at MS&T 2019. Her favorite activity at conferences is getting to know her peers and colleagues within ACerS, so you will often find her networking at ACerS Annual Meeting at MS&T and ICACC. Do not hesitate to say hi if you see her!

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

ACerS Associate Membership and Young Professionals Network

The American Ceramic Society offers one year of Associate Membership at no charge for recent graduates who have completed their final degree. To receive the benefits of membership in the world's premier membership organization for ceramics and glass professionals, visit www.ceramics.org/associate.

Also, consider joining ACerS Young Professionals Network (YPN) once you are an ACerS member. YPN gives young ceramic and glass scientists between 25–40 years old access to invaluable connections and opportunities. Visit www.ceramics.org/ypn for more information, or contact Yolanda Natividad at ynatividad@ceramics.org. ■

In memoriam

Manfred Kahn
R. James Kirkpatrick
Richard Robinson
John Drew
Robert Hopper
Charles Packer

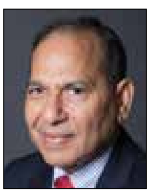
Some detailed obituaries can also be found at www.ceramics.org/in-memoriam.

Society, Division, Section, and Chapter news (cont)

Names in the news


Bordia

Rajendra Bordia, Clemson professor and scientific director of MADE in S.C., was named George J. Bishop, III Chair in Ceramic and Materials Engineering at Clemson University.


Singhal

Subhash Singhal received the Electrochemical Society's inaugural Subhash Singhal Award for his research work on solid oxide fuel cells and electrolyzers.

Additionally, he received an Honorary Doctorate degree in Science and Technology by the University of Tartu, Estonia, in recognition of work to develop renewable energy. An ACerS Fellow, he is also a member of the National Academy of Engineering.


Tabor

Jon K. Tabor, chairman emeritus of Allied Mineral Products, will retire March 31, 2020, after a 50-year career with Allied. Tabor has served as sales manager, vice president of sales, president, CEO, chairman, and most recently chairman emeritus. ■

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

St. Louis Section/RCD 56th Annual Symposium: March 25–26, 2020

The St. Louis Section and the Refractory Ceramics Division of The American Ceramic Society will sponsor the 56th Annual Symposium on Refractories on the theme "Properties and Performance of Refractory Ceramics—A Tribute to Richard C. Bradt" on March 25–26, with a kickoff event on Tuesday, March 24. The meeting will be held in St. Louis, Mo., at the Hilton St. Louis Airport Hotel.

Program cochairs are Kelley Wilkerson and Jeff Smith of Missouri University of Science and Technology.

A sample of the talks include *Increased usage of scientific methodology for the advancement of refractory technology* by Charles E. Semler; *Thermal shock of refractories: A comprehensive review* by Joseph Homeny; *Reflections on the thermal shock fundamentals and their parameters* by Vânia R. Salvini; *Derivation of thermal stress parameters through dimensional analysis* by Jay J. Tu; *Sample preparation, thermal expansion, and Hasselman's thermal shock parameters of self-flow refractory castables* by William L. Headrick, Jr.; and *Let's make a castable with almost no water–and no cement. Use of particle packing principles to minimize water addition to castables* by Bjørn Myhre.

The Tabletop Expo on Wednesday evening will include a "Meet and Greet" for the attendees prior to the dinner buffet.

A block of rooms is set aside at the Hilton (314-426-5500). To receive the $115 rate, mention the group code "SAC" when making your reservation.

For further information, visit https://ceramics.org/event/56th-annual-st-louis-section or contact Patty Smith at 573-341-6265 or psmith@mst.edu. ■


St. Louis/RCD annual symposium

Credit: ACerS

AWARDS AND DEADLINES

Credit: ACerS

Electronics Division names best student posters and oral presentation of EMA 2020

The Electronics Division presented awards for outstanding student work during the January 2020 Conference on Electronic Materials and Applications in Orlando, Fla. Congratulations to these students:

Poster Competition EMA 2020

First place

Design of novel molecular ferroelectrics using first-principles based and machine learning approaches, **Ayana Ghosh**, University of Connecticut

Second place

Improving the electrical and ferroelectric properties of lead iron niobite by decreasing calcination temperature, **Nicole Bartek**, University of Duisburg-Essen

Third place

Oxide ion conduction mechanisms in sodium bismuth titanate ($Na_{0.5}Bi_{0.5}TiO_3$), **Charles McLouth Culbertson**, Oregon State University

Oral Presentation Competition EMA 2020

First place

Robust in-plane ferroelectricity in ultrathin epitaxial Aurivillius films, **Elzbieta Gradauskaite**, ETH Zurich

Second place

Effects of electrode composition and potential on moisture incorporation and degradation of dielectrics and piezoelectrics, **John McGarrahan**, North Carolina State University

Third place

Phase exchange during wake-up and fatigue in ferroelectric $Hf_{0.58}Zr_{0.42}O_2$ *films*, **Shelby Fields**, University of Virginia ■

Awards and deadlines (cont)

New for 2020: Rishi Raj Medal for Innovation and Commercialization Nominations Deadline: April 15, 2020

This new award annually recognizes one individual whose innovation lies at the cusp of commercialization in a field related, at least in part, to ceramics and glass. The award consists of a medal, $2,500 award, and registration waiver to attend ACerS Annual Meeting at MS&T. The award is presented at the ACerS Annual Meeting Awards Banquet. Nominations should consist of a concise description of the achievement (200 word maximum) that outlines its significance in terms of past, ongoing, or the potential for societal benefit through science and technology. Supplementary documents that would aid in the evaluation process also are requested. Membership in the Society is not required. More information may be found at https://ceramics.org/awards/rishi-raj-medal-for-innovation-and-commercialization. ■

Take note of three awards with a May 15 deadline

While January 15 was the deadline for most award nominations to be submitted, there are three prestigious Division awards that have a **May 15, 2020,** deadline. Award eligibility for each can be found at www.ceramics.org/awards.

Glass & Optical Materials: Alfred R. Cooper Scholars Award

This award recognizes undergraduate students who have demonstrated excellence in research, engineering, and/or study in glass science or technology. The recipient will receive a plaque, a check for $500, and a complimentary registration to ACerS Annual Meeting at MS&T.

Electronics: Edward C. Henry Award

This annual award recognizes an outstanding paper reporting original work in the *Journal of the American Ceramic Society* or the *Bulletin* during the previous calendar year on a subject related to electronic ceramics. The author(s) will be presented with a plaque and $500 (split among authors).

Electronics: Lewis C. Hoffman Scholarship

The purpose of this $2,000 tuition award is to encourage academic interest and excellence among undergraduate students in the area of ceramics/materials science and engineering. The 2020 essay topic is "Reflecting on the last 100 years of ferroelectricity, predict where the field may be in 50 years."

Additional information and nomination forms for these awards can be found at ceramics.org/awards. Contact Erica Zimmerman at ezimmerman@ceramics.org with questions. ■

Credit: ACerS

Winners of the 2020 SIFT competition.

Credit: ACerS

SIFT competition winners at ICACC 2020

Mahesh Banda, Rohan Parai, and Sashanka Akurati, all from Old Dominion University in Virginia, won the 3rd Student Industry Failure Trial (SIFT) competition held at ICACC20 and hosted by the ACerS President's Council of Student Advisors. Four teams, made up of a total of 15 individuals competed in this year's SIFT competition. Materials data was collected for previously failed ceramic parts provided from industry, which participants analyzed to determine the material and how they failed. Students then suggested possibilities for material improvement.

Shot Glass competition winners at ICACC 2020

The Shot Glass competition at the ICACC conference each year always draws a crowd. The competition involves engineering a container using only pipe cleaners to protect a shot glass dropped from increasing heights.

This year 38 participants made up 12 total teams. The winning team from the University of North Dakota included Chandler Borillo, Maharshi Dey, Dustin Gerard, and Annie Miles. Their shot glass won the competition with a drop from a motorized lift at 122 inches—and then topped off the night by surviving a drop from over 31 feet.

Deadline for eligibility for the Basic Science GEMS Award is March 15

Sponsored by ACerS Basic Science Division, the annual Graduate Excellence in Materials Science Awards recognize the outstanding achievements of graduate students in materials science and engineering. The award is open to graduate students making oral presentations in any symposium at MS&T20. In order to be eligible for these awards, submit your abstracts to MS&T20 by **March 15, 2020.**

Winners of the 2020 Shot Glass competition.

Credit: ACerS

ACerS GGRN—Graduate student membership for ceramic and glass students

Build an international network of peers and contacts within the ceramic and glass community with ACerS Global Graduate Researcher Network. GGRN membership in ACerS addresses the professional and career development needs of graduate-level research students who have a primary interest in ceramics and glass.

GGRN members receive all ACerS individual member benefits plus special events at meetings and free webinars on targeted topics relevant to the ceramic and glass graduate student community.

ACerS GGRN membership is only $30 per year. Visit www.ceramics.org/ggrn to learn what GGRN can do for you.

Credit: ACerS

CERAMICANDGLASSINDUSTRY FOUNDATION

Winter Workshop 2020 hosts top ceramics students


Students, lecturers, and guests of Winter Workshop 2020

Credit all images: ACerS

The Ceramic and Glass Industry Foundation welcomed U.S. and international students to the 2020 Winter Workshop, which took place January 24–28 at the Hilton Daytona Beach Oceanfront Resort in Daytona Beach, Fla.

The workshop provided a combination of technical and professional development sessions, outstanding networking opportunities, and included a tour of the Kennedy Space Center. The annual event is designed for ceramic and glass students and young professionals from around the world. This year, the European Ceramic Society provided 16 travel grants for European students, and a total of 43 students participated in the event. Francis Cambier and Anne Leriche of the European Ceramic Society were special guests and on hand to welcome the students.

The Saturday morning sessions of Winter Workshop featured various experts who delivered the following lectures:

Jared Weaver, GE Global Research: "CMCs and EBCs at GE: From laboratory experiments to industrialization,"

Giorgia Franchin, University of Padova: "Additive manufacturing of ceramics: Strategies, technologies and applications,"

William Fahrenholtz, Missouri S&T University: "Ultra-high temperature ceramics for extreme environments,"

Romain Gaume, University of Central Florida: "Crystal-field engineering for materials scientists: an important tool in the design of phosphors, lasers, and scintillators,"

Geoff Brennecka, Colorado School of Mines: "Fund yourself! Strategies for proposal writing for gaduate fellowships and beyond,"

Theresa Davey, Tohoku University: "Professional skills for navigating global environments," and

Jessica Krogstad, University of Illinois at Urbana-Champaign: "The value of being yourself: How embracing diversity can benefit creativity, productivity and culture in the scientific community."

Following the lectures, students engaged lecturers during roundtable sessions, which produced interesting discussions and allowed students one-on-one time to ask questions.

Next year's Winter Workshop will take place in Daytona Beach, Fla., Jan. 22–26, 2021, in conjunction with the 45th International Conference and Expo on Advanced Ceramics and Composites (ICACC2021). ■

Winter Workshop students enjoying the Kennedy Space Center

advances in nanomaterials

Graphene "melting" is really sublimation

In a recent paper, two researchers from Russia explored melting of graphite and graphene and confirmed some previous hypotheses—and revealed graphene "melting" is in fact sublimation.

Researchers have struggled to create an accurate phase diagram of carbon for more than 100 years. The melting curve of the phase diagram in particular drives contention. Experiments give very different melting temperatures for graphite—ranging from about 4,000 K (6,740°F) to 5,000 K (8,540°F)—and some studies confirm while others deny the presence of a maximum on the melting curve.

These contentions present considerable opportunities for researchers to investigate, and that opportunity was embraced by Yu D. Fomin (researcher at the Moscow Institute of Physics) and Vadim V. Brazhkin (researcher at the Institute of High Pressure Physics Russian Academy of Sciences).

They compared their results from empirical AIREBO model and ab initio simulations to prior experimental and theoretical data and came to several main conclusions.

Existing models are highly inaccurate

Some empirical models (AIREBO, Tersoff potential, Brenner potential) are fitted to experimental data on carbon and hydrocarbons at low temperatures. Thus, "These models fail to reproduce the structure of liquid carbon above the melting line" and "do not describe the melting line of graphite properly."

A melting curve maximum should exist—and it is caused by a smooth structural crossover

While their results show a maximum should exist, the researchers say is not caused by a liquid-liquid phase transition. Rather, a smooth structural crossover occurs and causes the maximum. Unlike "real" LLPT, smooth crossover does not include a density jump but rather smoothly changes from one structure to another.

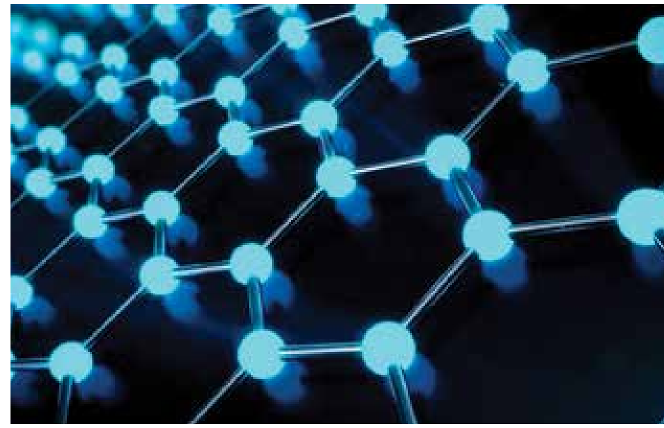
Graphene "melting" is actually sublimation

Data from previous computer modeling studies showed a "collapse" of graphene into a phase composed of linear chains at high temperatures (4,500–4,900 K). The researchers state that this collapse is due to sublimation rather than melting.

However, the researchers say the suggested temperatures for sublimation do not make sense.

"Since the melting temperatures of [carbon] systems do not depend on the pressure, one should conclude that the temperature of the triple point should be the same as the melting temperature of graphite (T_t = 3640 K for AIREBO and T_t = 4250 K for LCBOPII)," the researchers write. "The 'melting' (sublimation) points of graphene are T_m = 4900 K for AIREBO and T_m = 4510 K for LCBOPII. These sublimation temperatures are above the temperatures of the triple point of graphite, which does not make sense."

The researchers ran a simulation of graphene melting in an argon atmosphere and found the melting temperature obtained in their simulation agreed with the melting temperature of graphite obtained with the same model. However, because of graphene's two-dimensional nature and the fact that carbon-argon interactions can affect decomposition, "the temperature obtained in our simulations is not an exact melting temperature of pure graphene."



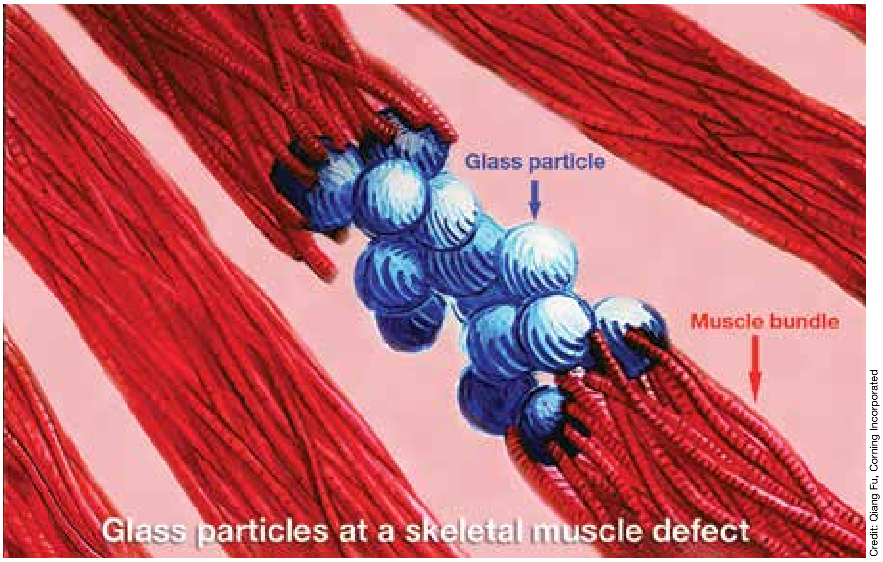
Credit: Moscow Institute of Physics and Technology

Sophisticated analysis of simulation data is required to make any conclusions on the melting or sublimation temperature of graphite or graphene, two researchers from Russia conclude in a recent study.

"Some further corrections are required to obtain the genuine melting temperature of graphene," they conclude.

The paper, published in *Carbon*, is "Comparative study of melting of graphite and graphene" (DOI: 10.1016/j.carbon.2019.10.065). ■

Bioactive glasses show promise in muscle regeneration



Glass powder can be directly applied to a defect site during operation, which is a big benefit in addition to its low cost.

A new study by researchers at Corning, The Pennsylvania State University, and Shanghai Jiaotong University Affiliated Sixth People's Hospital (China) evaluates the ability of bioactive glasses to stimulate muscle regeneration.

Bioactive glass is routinely used to regenerate and repair bone and hard tissues, and research on using bioactive glass to heal soft tissues continues to grow as well. Yet using bioactive glass to regenerate muscle, specifically skeletal muscle, is rarely studied.

Skeletal muscle, one of three major muscle types in the body, can self-repair small wounds. However, critical-size injuries or volumetric muscle loss (VML) overwhelms muscle repair mechanisms and requires external help.

Current treatment options for VML, including physical therapy, removal of scar tissue, and muscle transposition, show limited success repairing damaged skeletal muscle. So researchers are actively searching for more effective methods to treat VML.

Biomaterials can stimulate bone and tissue regeneration. Yet soft materials such as hydrogel and decellularized extracellular matrix, materials known for their biocompatibility and easily controlled shape, are incapable of stimulating muscle regeneration when stem cells and/or growth factors are not incorporated in the soft materials.

It is possible to create soft materials containing stem cells and growth factors, but "the use of stem cells usually requires extra time/cost to culture them in vitro before transplantation and the growth factors are very expensive," Qiang Fu, research associate at Corning Incorporated, explains in an email. "Furthermore, the process to deliver cells or growth factors is complicated and not well controlled."

In contrast to soft materials, bioactive glasses are widely reported to stimulate growth of blood vessels and tissues without the need for stem cells or growth factors. However, few studies to date focus on muscle regeneration using bioactive glasses due to glass rigidity or brittleness and the lack of flexibility in shaping a glass scaffold.

In the new study, Fu and his colleagues demonstrate that synthetic biomedical materials based on bioactive glasses can be used to treat VML without using growth factors or stem cells.

The researchers evaluated three bioactive glass compositions (silicate 45S5, borate 13-93B3, and aluminoborate 8A3B) for skeletal muscle regeneration in two situations:

1. **In vitro**—they observed how the glass compositions affected mouse muscle myoblast cells in solution.
2. **In vivo**—they injected the glass compositions into live rats.

In solution, aluminoborate 8A3B demonstrated the highest potential of the three compositions. Specifically, "8A3B demonstrates a comparable weight loss to 45S5 while having the least impact on the pH of the soaking solution" and "8A3B glass with moderate boron release shows the most effectiveness in supporting in vitro angiogenesis [development of new blood vessels]."

In the rat model, aluminoborate 8A3B was again the leading contender. Rats injected with 8A3B formed the highest number of new blood vessels and the largest new muscle fibers (about 20 μm compared to 5–10 μm with 13-93B3).

"The better ability of 8A3B composition than the rest suggests a desired boron release profile is important in promoting the formation of angiogenesis and stem cells, which agrees with literature studies on borate glasses," the researchers conclude.

Fu and Weitao Jia from the Sixth People's Hospital plan to investigate long-term (up to six months) effects of bioactive glasses to restore functionality of regenerated muscle, and they also plan to investigate the glasses' efficacy in a large animal model, such as rabbits or mini pigs.

Penn State professor John Mauro adds that future studies will continue to develop understanding of which aspects of glass composition govern muscle regeneration performance. "With such understanding, further optimization of the glass composition can be achieved to accelerate the regeneration of muscle tissue," he says in an email.

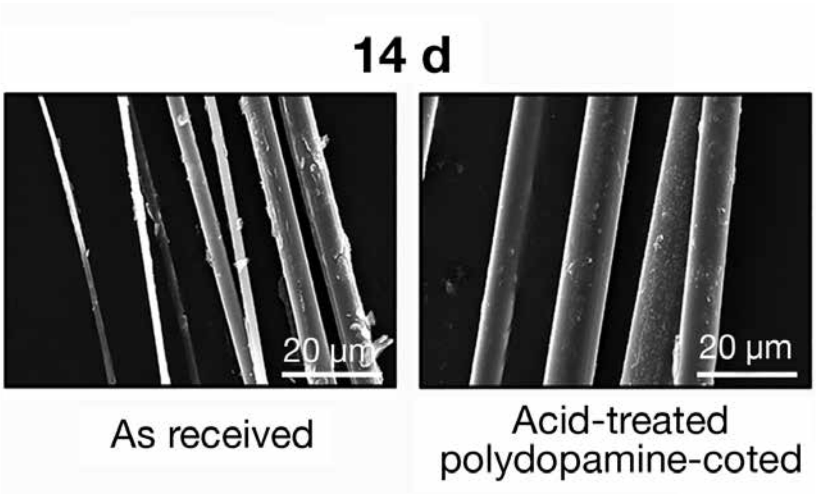
The paper, published in *Acta Biomaterialia*, is "Glass-activated regeneration of volumetric muscle loss" (DOI: 10.1016/j.actbio.2019.12.007). ■

Strong and long-lasting treated phosphate glass for bone-replacement therapies

Researchers have yet to develop a material that can act as a temporary bone in the short-term, promote growth of natural bone to replace it, and be absorbed by the body as the natural bone grows. However, research on composites of multiple materials looks promising, and a recent study focuses on improving one such composite with the use of bioglass phosphate fibers.

Phosphate glass fibers have good initial strength and are bioabsorbable. Unfortunately, the processes that lead to bioabsorption reduce the fiber diameter and the strength of the fibers very rapidly, leading to premature fiber pull-out and breakage. Methods such as annealing fibers stabilize the mechanical properties, though with reductions in initial strength.

In the recent study, researchers from the University of Nottingham (U.K.) and Mansoura University (Egypt) explored methods for stabilizing the fiber surface after annealing to take advantage of the long-term benefits while minimizing the issues that lead to reduced initial strength. In their work, they acid etched the annealed fibers to expose pristine glass surfaces and coated the surface with polydopamine, a promising biomaterial know to adhere well to inorganic materials and form nanoscale coating thicknesses.



Credit: Parsons et al., *International Journal of Applied Glass Science* (CC BY 4.0)

An optimized combination of acid treatment and polydopamine coating was able to recover approximately 85% of a phosphate glass fiber's initial strength.

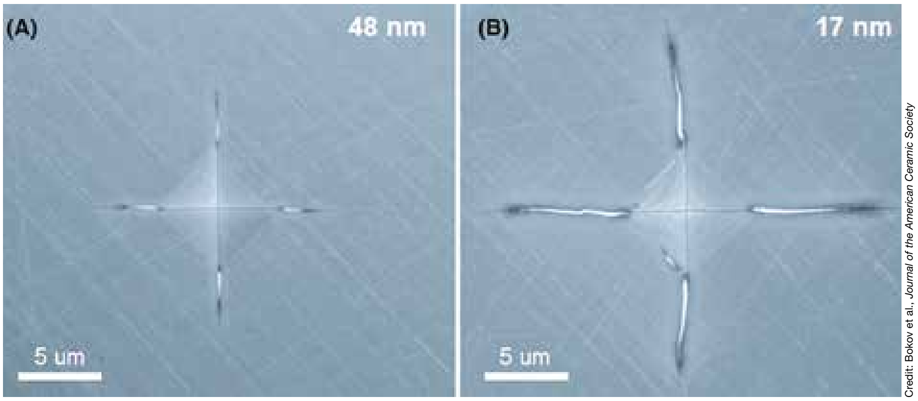
For their best combination of processing parameters, the median initial strength of the processed fibers was 15–20% lower than the as-received fibers (compated to the initial strength of annealed fibers, which was 50% lower). Their processed fibers were both shelf-stable and stable with immersion in water for up to two weeks (the diameter and strength remained relatively constant under these conditions).

The researchers also discussed the scalability of various aspects of their process. Their annealing, cooling, acid etching, washing, and coating processes can all be performed continuously. Furthermore, they etched the phosphate glass fibers in relatively mild hydrochloric acid, which is significantly less hazardous and more environmentally friendly than hydrofluoric acid needed to etch silicate glass.

While this study shows the results of early stage research, the results show promise for commercialization of fiber reinforcements for larger-sized bone replacement composites.

The open-access paper, published in *International Journal of Applied Glass Science*, is "Improved phosphate-based glass fiber performance achieved through acid etch/polydopamine treatment" (DOI: 10.1111/ijag.13672). ■

Size-induced grain boundary affects hardness of ceramics



For relatively large grains (48 nm), corner cracks are fairly short (about 4.5 μm), whereas their sizes roughly double up to 8 μm for small grains (17 nm).

When grain sizes in ceramics become critically small, ceramics can appear to soften. Researchers from the University of California, Davis, the Federal University of Santa Catarina (Brazil), and Sun Yat-sen University (China) show this false impression is due to an extensive network of nanocracks caused by increased grain boundary energy.

Cracks often form and propagate at grain boundaries, which can lead to material failure. However, grain boundaries also can absorb defects in the material by stopping short cracks from advancing further. If grain sizes are small enough—meaning there are a lot of boundaries—the ceramic gets harder and stronger.

Typically, ceramics grow harder as grain sizes decrease, a relationship called Hall-Petch. However, once grain sizes reach a critical size, hardness begins to decrease instead.

The mechanisms behind this inverse Hall-Petch relationship in ceramics are still under debate, and understanding these mechanisms are what the researchers of the recent paper looked to achieve.

They explain that while grain boundary sliding appears to be the mechanism behind inverse Hall-Petch in metal alloys, the mechanism behind inverse Hall-Petch in ceramics appears to be cracking caused by "the activation of new energy dissipation modes."

"When the grain size in a dense material is reduced to the nanoscale, geometrical constrains may significantly affect the structural nature of the grain-grain interfaces due to a large population of triple junctions and high density of kinks—all potentially increasing the excess energy of the grain boundary," they write. "Therefore, as the grain size is reduced, the value of the specific grain boundary energy may be increased ... which could translate into reduced strength (or toughness, or stability), since the strength of boundaries has been directly related to its energy in previous works."

To better understand how grain size affects grain boundary energy at the nanoscale (and therefore likelihood of cracking), the researchers used yttria-stabilized cubic zirconia (10YSZ) as a model ceramic system. They found grain boundary energy values do not significantly change for relatively large grains, with an average value of 0.56 J/m^2 for grains larger than 36 nm. Yet the situation changes for grain sizes smaller than 36 nm, at which point a big increase in grain boundary energy is observed (up to 0.84 ± 0.4 J/m^2 at 16 nm).

"This phenomenon can be attributed to a change in the grain boundary area and volume, with higher energy boundaries being more favorable to accommodate the geometry of such small grain sizes," the authors write.

They note that another possible explanation for the observed grain boundary

Research News

Isotopically enriched cubic boron nitride reveals high thermal conductivity

An international team of physicists, materials scientists, and mechanical engineers confirmed the high thermal conductivity predicted in isotopically enriched cubic boron nitride (c-BN). Theoreticians had predicted that isotopically pure c-BN should have extremely high thermal conductivity. However, c-BN is challenging to make and it is difficult to measure the thermal conductivity accurately when the value is high. The team overcame these challenges, and the measured thermal conductivity values for the c-BN samples were quite close to the ones calculated. The team also studied the related compounds, boron phosphide and boron arsenide. For more information, visit https://www.eurekalert.org.

Physicists prove that 2D and 3D liquids are fundamentally different

Researchers led by Nanyang Technological University in Singapore proved that 2D liquids have fundamentally different dynamical properties to 3D liquids. Researchers routinely use 2D experiments and simulations to represent 3D liquids, simply because studies in 2D are easier to do. However, the new study shows differences between 2D and 3D liquids, including a subtle collective motion of the atoms in 2D liquids not seen in 3D. To extract relevant information on the dynamics of 3D liquids from the 2D investigations, researchers need to develop a way to selectively filter-out the effect of the observed collective particle oscillations. For more information, visit https://media.ntu.edu.sg/NewsReleases.

energy increase is the increase of triple joints and density of kinks, "assuming those increase the excess energy of the system." However, they quickly discount this idea. "The fraction of triple junction is increased to 0.34% at 36 nm, and 1.62% at 16 nm. Despite the onset coincidence, the actual fraction of triple junctions is very small," they explain.

They offer a final alternative explanation that the energy change could be attributed to a size-induced complexion transition, but "This is, of course, highly speculative at this point as it can also be related to impurities."

How this increased grain boundary energy relates to hardness is discussed in the final part of their results and discussion section.

"As grain sizes decrease, hardness increases and reaches a maximum of 18.41 ± 0.26 GPa at the grain size of ~27 nm," they write. "Below this critical size, ... hardness decreases down to 16.36 ± 0.32 GPa at ~17 nm."

When observed on the macroscale, the increased number of nanocracks can give the impression that the ceramic is softening. "But softening in a lay language would mean that the [ceramic] is actually more mobile at the atomic level," Ricardo Castro, professor at UC Davis, explains in an email, "and our data doesn't show that." Instead, "we notice the [ceramic] is always cracking underneath the indentation, be it with large grains or small ones."

Now that the researchers established that cracking appears to be the mechanism behind inverse Hall-Petch in ceramics, Castro says the next step is to define a strategy to control cracking and thereby avoid the inverse Hall-Petch relation.

The paper, published in *Journal of the American Ceramic Society*, is "Size-induced grain boundary energy increase may cause softening of nanocrystalline yttria-stabilized zirconia" (DOI: 10.1111/jace.16886). ■

Glass sphere is cooled to its motional quantum ground state

Physicists from the University of Vienna, the Austrian Academy of Sciences, and the Massachusetts Institute of Technology successfully cooled a glass nanoparticle containing about 100 million atoms to its motional ground state. In recent decades, researchers achieved great success in cooling large ensembles of atoms to create exotic systems, for example, the Bose-Einstein condensate. Physicists want to take this concept further by cooling solids that comprise much greater numbers of atoms that interact very strongly. The researchers of this study cooled their nanoparticle using a scheme called cavity cooling by coherent scattering. For more information, visit https://physicsworld.com. ■

Templating gives control over eutectic material structure

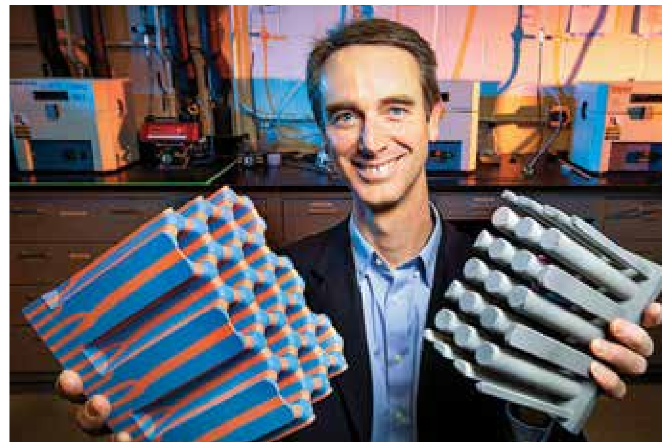
In a recent study, researchers from the University of Illinois at Urbana-Champaign and the University of Michigan investigated guiding the self-assembly of eutectic materials by templating.

A eutectic system is a homogeneous mixture of substances that melts or solidifies at a temperature lower than the melting point of the constituent elements. For example, water typically freezes at 0°C (32°F) but will freeze at –16°C (2°F) in a 20% salt solution.

When eutectic liquids do solidify, they demonstrate a unique ability—individual components of the mixture self-assemble to form a cohesive structure. This ability is highly desirable in the production of many modern technologies.

"Instead of depositing layers of material individually, we start with a liquid that self-assembles as it solidifies," Paul Braun, professor of materials science and engineering and director of the Materials Research Lab at the University of Illinois at Urbana-Champaign, says in a university press release. "This can speed up production and allows us to make larger volumes at one time."

Many common solder alloys used in electronics are eutectic materials, such as tin-lead alloys. Also, directionally solidified turbine blades comprised of eutectic alloys are in regular service in both commercial and military jet engines.



Credit: Fred Zwicky, University of Illinois

University of Illinois professor Paul Braun holds a model showing how a simple layered material, depicted in orange and blue, transforms into a complex Archimedean-structured composite when it freezes around a template, depicted in gray.

However, natural self-assembly can be limiting.

"Decades of research on solidification of binary and ternary eutectic systems indicate that only a limited set of regular mesostructures emerge, even over a broad range of processing conditions," Braun and coauthors explain in a recent paper. "By engineering the heat removal, for example, the microstructure could be modified … however, the resulting microstructures are still quite similar to those found in the native eutectic."

In their study, the researchers decided to see if new microstructures could be created by templating, a synthesis technique that uses a template to control material formation and is one of the most important techniques for controlled synthesis of nanostructured materials.

"Templating is a common practice used in organic polymers processing," Ashish Kulkarni, first author and graduate student, says in the press release. "However, it is not something that has been explored in inorganic materials processing because inorganic microstructures are more rigid and harder to control."

To investigate templating inorganic eutectic materials, the researchers studied silver chloride–potassium chloride (AgCl–KCl). "The silver chloride-potassium chloride system was largely selected as a model system due to it forming a simple lamellar eutectic [material with layered structure] with a low (318°C) melting point," Braun and Kulkarni explain in an email. "This system is also interesting because it is optically transparent, and readily forms microstructures with characteristic length scales on the order of the wavelength of visible light. Finally, this system has a low surface tension, and thus flows easily into the template."

The researchers poured an AgCl–KCl melt in a template containing tiny posts arranged in hexagonal shapes. As the AgCl–KCl melt solidified, the posts disrupted layer formation and caused a composite to form with an array of different square, triangular, and honeycomb-shaped microstructures.

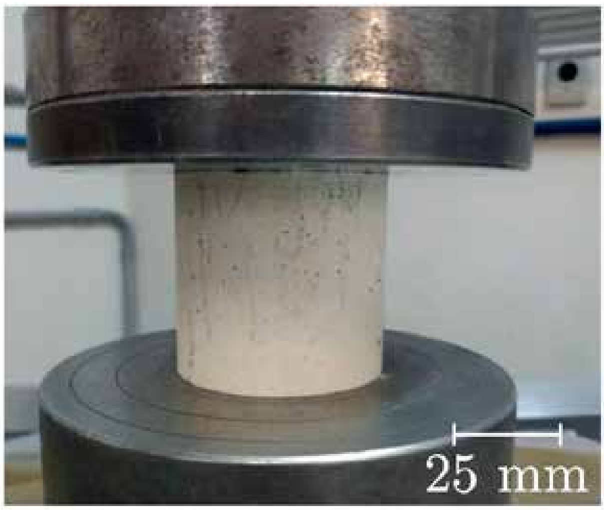
The fact the researchers achieved new microstructures was not the only exciting finding—they also found the template reduced the number of defects in the material.

"When eutectics are forced to solidify through a template, the template both modifies and regulates the kinetics of the solidification and increases the energetic cost of defect formation," Braun and Kulkarni explain. "The net effect is that if the template has a near-perfect repeating pattern (like in our case), the eutectic solidifying through it will closely follow the order of the template and thus have reduced number of defects."

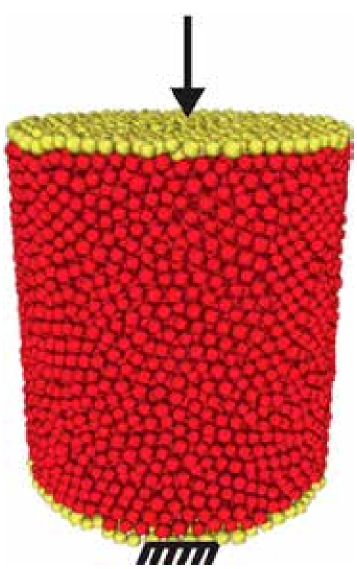
Braun and Kulkarni say they are now working on fabricating such Archimedean patterns out of metal-dielectric eutectics for use as optical metamaterials (in contrast to the all-dielectric system used in this study). They are also looking at the possibility of designing templates that could lead to eutectic microstructures with quasicrystalline patterns.

The paper, published in *Nature*, is "Archimedean lattices emerge in template directed eutectic solidification" (DOI: 10.1038/s41586-019-1893-9). ■

Discrete element modeling—A promising method for refractory microstructure design



Credit: Moreira et al.



By M. H. Moreira, T. M. Cunha, M. G. G. Campos, M. F. Santos, T. Santos Jr., D. André, and V. C. Pandolfelli

Discrete element modeling is a tool with great potential for modeling refractory materials—if challenges to applying DEM for continuous problems are overcome.

Refractory materials are required to keep their structural stability when subjected to extreme mechanical and chemical environments. Thermal shock spalling, corrosion, creep, and other complex phenomena may take place while using them. Therefore, mechanical behavior of refractory materials is of great interest.

In recent years, researchers reported various technical problems and industrial challenges concerning refractory materials that are not easily solved using conventional experimental methods. Thus, numerical computational tools emerged to better understand the physical problems and to analyze such complex conditions.

The finite element method (FEM) is one of the most popular approaches for studying thermomechanical problems. It is a numerical method that subdivides a large system into smaller, simpler parts for easier analysis through the use of a mesh, i.e., a geometrical representation of the domain of interest that comprises all elements to be analyzed.

This technique is suitable to solve elliptic and parabolic problems, and it is not restricted to linear or isotropic cases. The mesh makes it geometrically flexible and able to model complex domains. Additionally, this technique is easily implemented as computer codes and is also robust because most mathematical problems can be stated as a variational problem where FEM can be applied. However, one of the main disadvantages to FEM is the difficulty of analyzing microscopic situations and material discontinuities, as the equations associated with the problem are derived based on a continuous materials assumption.[1]

Trying to overcome this issue, researchers developed the FEM remeshing technique, which solves complex problems by updating the mesh to consider discontinuities, but this procedure can affect its performance.[2] Möes et al.[3] developed the extended finite element method (XFEM) to model fracture and interfacial problems, using discontinuous basis functions on the nodes where cracks may occur. The advantage of this procedure is that it is not necessary to update the mesh. Nevertheless, this method also has a high computational cost and the study of complex features, e.g., crack initiation at multiple locations, is still an ongoing research.[1]

In contrast to FEM, meshfree methods have been studied, developed, and proposed as an alternative approach. Some examples are the smoothed-particle hydrodynamics (SPH) and

Capsule summary

MODELING DISCONTINUITIES

Discrete element modeling, which models interactions of discrete particles, can model microstructures with a large number of discontinuities, such as refractory materials.

CHALLENGES TO DEM

DEM faces two challenges modeling continuous problems: choosing a contact model between particles and finding corresponding microscopic parameters that describe a material's macroscopic behavior.

A MANUAL FIX

A manual calibration using Brazilian and uniaxial compression tests results in a DEM model capable of reproducing the mechanical behavior of a continuous problem.

its modified approach (corrective SPH and discontinuous SPH),[4] the moving least square (MLS),[5] and the element-free Galerkin method (EFGM).[6] These techniques aim to study a problem with a random distribution of nodes without a mesh or connection between them. Nevertheless, they are very time-consuming and may undergo several numerical issues, such as low accuracy near the boundaries and difficulties to impose Dirichlet boundary conditions.[1]

Another approach to modeling discontinuous problems is through discrete methods, such as molecular dynamics (MD)[7] and the discrete element method (DEM).[8] These methods differ from FEM because the body is not represented by a continuous mesh where constitutive laws are obeyed but rather by a set of discrete bodies or particles that interact with its neighbors following contact or distant interaction laws at the microscale.

Such interactions create emergent properties that can be measured on a macroscale as an apparent property that results from the multiple interactions at the microscale. This possibility enables DEM to be a tool with great potential for modelling cracks and representing microstructures that have a large number of discontinuities, such as inclusions, cracks, debonding, and porosity, which is the case of refractory materials. In addition, the major advantage of DEM is the likelihood of investigating both crack initiation and propagation, as well as the phenomena of coalescence and bifurcation, which can be used to understand and simulate the macroscopic behavior of the materials[9] (Figure 1).

Various studies used DEM for ceramics applications (continuous problems), regarding problems related to compression tests,[10] crack initiation and propagation in alumina,[11] and the effect of average grain size on the toughness of alumina ceramics.[12] André et al.[13] studied the Young's Modulus of a borosilicate glass matrix with alumina inclusion affected by microcracks. Wang[14] analyzed the fracture propagation in concrete to evaluate the difference in strength due to aggregates and aggregate/mortar interfacial transition zone (ITZ), yielding insights concerning the effect of the microstructure on its mechanical behavior.

Nevertheless, DEM has not been extensively applied to model commercial refractory materials, although it can improve the link between the material's microstructure (which has a large number of discontinuities) with their macroscopic properties during application.[13] Such approach can optimize the processing and applications of refractory materials, increase their performance, and save time, effort, and resources in the industry.

There are two major challenges to applying DEM for continuous problems: the choice of the contact model between the particles and how to find the corresponding microscopic parameters that describe the macroscopic behavior of the material (the calibration step). The present work is based on previous research that proposed a straightforward approach to overcome such challenges.[9]

The aim of this study was to explore the possibilities of applying discrete element modeling as a tool for analyzing mechanical tests of refractories. The results attained can lead to models that in the future could help global key players to overcome, for example, the challenges of evaluating the mechanical and thermal damage in steel plant installations, which are not easily developed experimentally.

Thus, an alumina castable considering Alfred's grain size distribution was studied

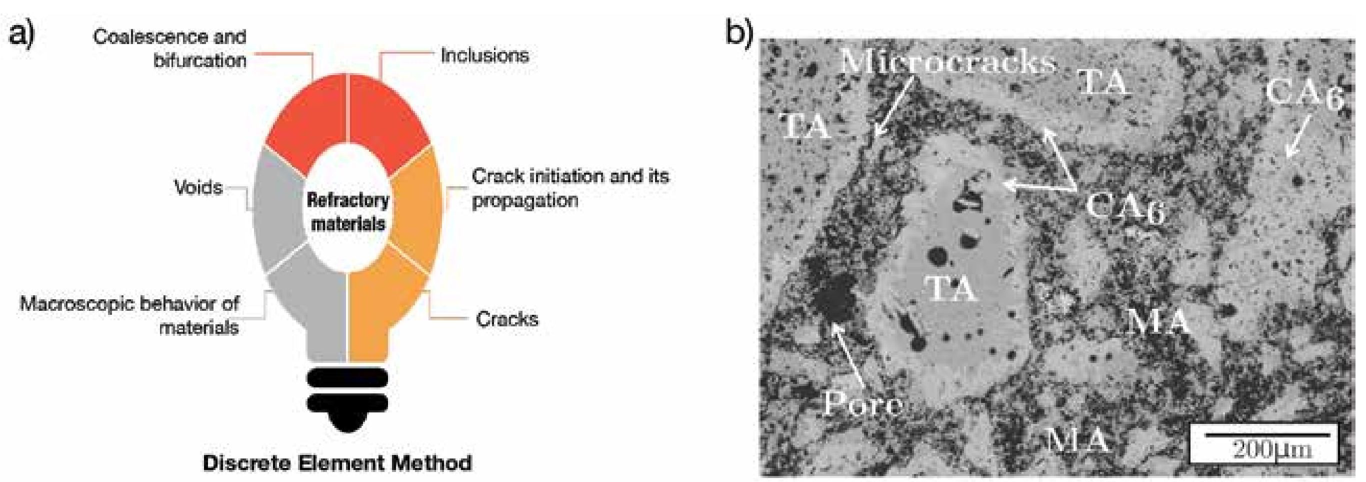


Figure 1. (a) Schematic representation of features of a refractory material and its connection with DEM, (b) SEM micrograph of a spinel containing alumina castable refractory showing all multiple phases, pores, and microcracks. (TA: tabular alumina; CA_6: $CaO.12Al_2O_3$; MA: $MgAl_2O_4$)

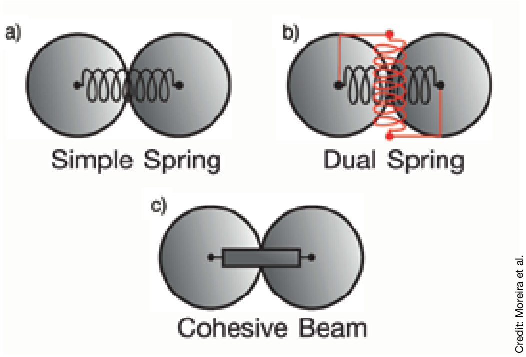


Figure 2. Schematic representation of the most common cohesive bond models. Recreated from Reference 1.

with GranOO, an opensource discrete element workbench.[15] The calibration process was carried out by an automatic algorithm developed by Andreá et al.[9] and by a manual calibration accomplished using the Brazilian and uniaxial compression tests. The three-point bending test was used in a further validation step.

Materials and methods

Discrete element method (DEM)

DEM is fundamentally different from continuum methods, such as FEM. Instead of considering the regions of interest as a continuum media, where known constitutive laws describe its behavior in a grid (the domain's mesh in FEM), in DEM the domain of interest is expressed by a set of rigid spherical bodies that interact following specific laws.[1]

For the representation of mechanical phenomena, DEM, which originated as a tool for simulating naturally discrete problems such as granular flow, powder compaction, and related problems, can be of great benefit when specifying laws of bonding between elements.[16]

The bond between particles can be based on distinct models. The most common ones are the contact bond (simple spring) model, the dual spring model, the parallel bond and flat joint models,[16] and the recently developed cohesive beam model.[9] Figure 2 presents a schematic representation of some common bond models.

Each bond model is characterized by a set of variables, which are commonly referenced as micro (or local) parameters. Because the mechanical behavior of the whole structure is an emergent property that arises from the interaction of each element, two distinct scales are separately considered: the macroscopic (the scale of the material sample that will be simulated and is represented in the model) and the microscopic (the discrete element scale), as seen in Figure 3a.

The physical features of the whole sample are referenced as macroscopic properties, whereas the quantities related to the bonds and individual elements are the already mentioned microparameters. Although studies were conducted in order to propose analytical relationships between the set of micro- and macroparameters,[17,18] there are no direct laws that correlate the set of microparameters and the experimentally measured properties of the material.[17]

Thus, a calibration step is commonly needed to find the set of microvalues that best represent the mechanical behavior (Figure 3c). Usually, experimental tests with a homogeneous stress state, such as uniaxial compression, are used for the calibration step, whereas an experimental one with a nonhomogeneous stress state is applied to validate the model obtained with the optimal set of microparameters.[18]

GranOO workbench

The Granular Object-Oriented workbench (GranOO) was used for the DEM simulations. GranOO is not a software but rather a set of C++ libraries that was originally developed to study tribological problems,[19] and it was redesigned in order to be generalized and used in multiple DEM simulations. Based on the open source nature of this project, any contact bond model can be implemented; however,

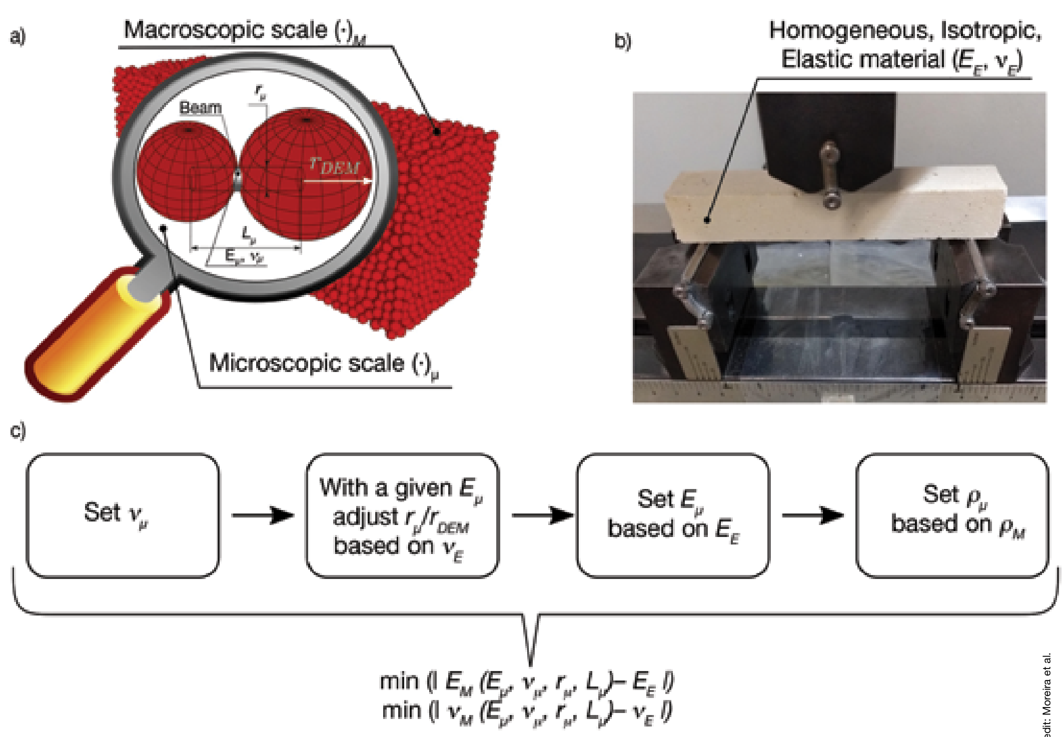


Figure 3. Common procedure for a DEM simulation. a) Describes both scales and the cohesive beam model and its properties, including the beam's length (L_μ), its radius (r_μ), the Young's Modulus (E_μ), and the Poisson ratio (ν_μ). b) Shows the actual sample and the assumptions made (an elastic material described by its Young's Modulus (E_E) and the Poisson ratio (ν_E). c) Presents the automatic calibration algorithm used and its mathematical meaning, the minimization of the difference between simulated macro properties and the experimental ones (adapted from Reference 1).

a default cohesive beam model is available, which is described by the beam's properties: L_μ, r_μ, E_μ, and ν_μ (Figure3a). The fundamental idea is to use the Euler-Bernoulli theory of beams to express their mechanical behavior.

GranOO workbench also has an algorithm solution for the creation of the DEM domain. This step is important as there are three properties for the geometric representation of the domain that should be assessed in order to have DEM models for continuous materials: the homogeneity, the isotropy, and the fineness. Further details can be found in André et al.[19]

Next, GranOO also presents an algorithm for the automatic calibration of the microparameters. This algorithm is based on a number of quasistatic tests carried out in a model material and is fully described by André et al.[9] This algorithm minimizes the difference between the macro properties that arises from the DEM model and the experimental properties, as described in Figure 3c.

The last step is a dynamic calibration of the density of the discrete elements to ensure that the overall mass of the DEM domain equals the continuous body density, compensating the virtual porosity due to the spherical shape of the DEM elements.[9] Finally, a failure criterion needs to be set for the DEM model to define the bond breakage, thus the approach used on the GranOO workbench and the manual calibration procedure.

Table 1. Calcium aluminate cement (CAC) alumina castable composition characterized in the present work.

Raw Material		Supplier	wt.%
Tabular alumina 6–3		Almatis	25
Tabular alumina 3–1		Almatis	10
Tabular alumina 1–0.5		Almatis	21
Tabular alumina 0.6–0.2		Almatis	7
Tabular alumina 0.2–0		Almatis	18
Tabular alumina < 45 μm		Almatis	6
Reactive alumina	CT3000	Almatis	2
	A1000SG	Almatis	5
CAC	Secar 71	Imerys	6
Dispersant castament FS60		BASF	0.2
Water			4

Failure criteria and manual calibration

The discrete nature of DEM makes it a good candidate for modeling the failure of materials. However, a failure model needs to be defined in order to have a qualitative comparison with the experimental results.[1] There are two major classes of approaches to model a fracture within the DEM framework: a local description (in the cohesive beam) and a nonlocal one.

Both methodologies were compared, and the nonlocal description was found to better represent the behavior of the failure of brittle materials, both at a micro- and macroscale. This approach consists of using the virial stress and converts it into the equivalent Cauchy stress tensor for each discrete element, taking into account its interaction with each neighbor.[1] Finally, any of the common failure criteria, e.g., hydrostatic, von Mises, Tresca, Rankine, or Griffith, can be considered using the Cauchy stress tensor of each discrete element.

The present work uses the Rankine criterion for the results obtained via GranOO's automatic calibration algorithm. In addition, another approach was applied in the current work using an asymmetric Rankine criterion in both tension and compression defined as $\sigma_1 > \sigma_{\mu,t}$ or $\sigma_3 < -\sigma_{\mu,c}$ (considering the three principal stress $\sigma_1 > \sigma_2 > \sigma_3$). However, as already described, both limits of microstress in tension ($\sigma_{\mu,t}$) and compression ($\sigma_{\mu,c}$) need to be calibrated, leading to a second group of results. Such limits were obtained by applying a fixed set of microparameter values and a manual calibration of $\sigma_{\mu,t}$ and $\sigma_{\mu,c}$ using the Brazilian and the uniaxial compression results, validated by a three-point bending test. All three experiments are commonly used for mechanical characterization of refractories.

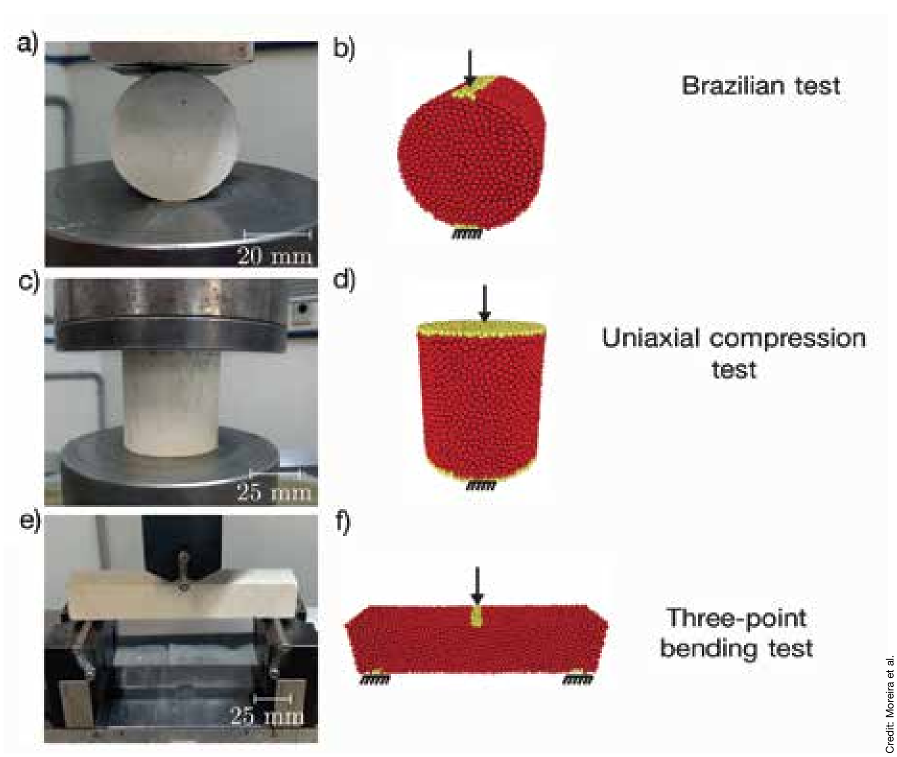


Figure 4. Experimental setup (a), (c), and (e), and DEM representation, (b), (d), and (f). The yellow discrete elements represent the set that will be displaced (black arrows) or clamped (black fixed support).

Experimental procedure and modeling assumptions

A 6 wt.% of calcium aluminate cement alumina castable (Table 1) was developed to assess DEM, following Alfred's Packing Model (q = 0.26). The samples were molded as cylinders (40 mm in diameter and 40 mm in height) for the Brazilian test, cylinders (50 mm × 50 mm) for the uniaxial compression test, and as bars (25 × 25 × 150 mm³) for the three-point bending test.

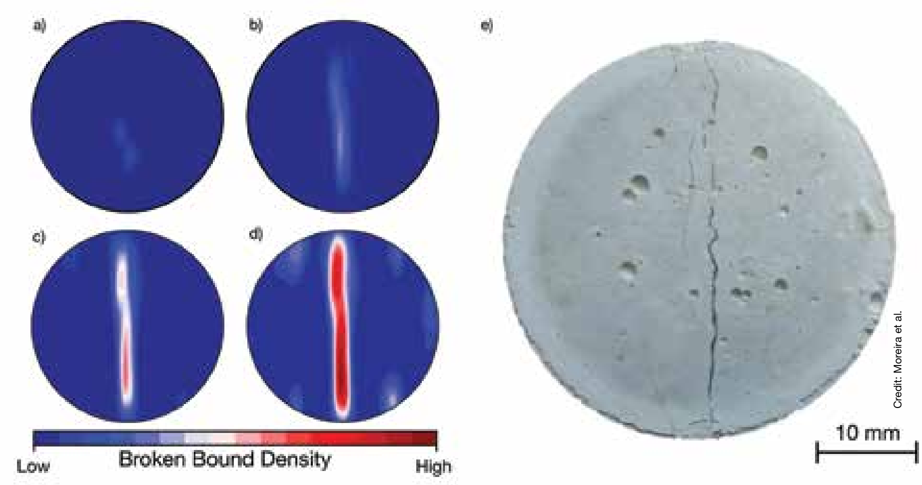


Figure 5. (a-d) Results for the Brazilian test broken bounds density progress and (e) photograph of the tested sample failure.

The experiments were conducted following ASTM C133 for the three-point bending test and the uniaxial compression measurements, using universal testing systems MTS (MTS810, MTS Systems Corp) or Instron 5500R, respectively. The Brazilian test was carried out with a fixed displacement of 1.3 mm/min and parallel plates as supports. All samples were evaluated after curing for 24 hours in a climate chamber with 80% of relative humidity and dried at 110°C for another 24 hours.

To reproduce the mechanical tests, constant displacements were fixed on positions of the DEM domain in a manner to simulate the experimental conditions (Figure 4). The explicit dynamic algorithm of GranOO automatically computes an optimal time step and the displacements are defined per increment. For the current work, the displacement used was 2×10^{-9} m/iteration.

The material is considered homogeneous, isotropic, perfectly elastic, and brittle on the simulations. Such assumptions are considered reasonable when considering the experimental results of the mechanical tests.

Automatic calibration results

Each experimental test was reproduced in discrete element domains of the same dimensions of the real samples. The macroparameters used were: Young's modulus of 62.04 GPa measured with an optical extensometer (Instron AVE 2663-821) on a uniaxial compression test equipment (Instron 5500R), Poisson ratio of 0.25 measured by impulse excitation technique (Sonelastic), and tensile failure strength of 9.06 MPa (measured by the Brazilian test).

Brazilian test

This test yields a tensile stress state in the samples that generates cracks from the middle of the cross section to the loading contact of the machine.[20] There are also shear failures in the regions close to the loading area. Figure 5 shows the crack propagation evolution and a picture of the experimental sample failure after the Brazilian test.

The crack propagation in the numerical model (Figure 5a-d) agrees qualitatively with the proposed description of the tensile and shear failure mechanisms. In Figure 5e, the photograph shows the failure of an experimental sample that presented the expected crack pattern.

Three-point bending test

The three-point bending test results can be analyzed in Figure 6. In (a-d), the crack originates between the lower loading rods, in the region where the tensile stress is the highest. This qualitative benchmark is important as it agrees with the results observed experimentally.

In Figure 6e, the comparison of the numerical and experimental force-displacement curves shows a good agreement between the macro Young's modulus for the linear regime of the experimental curves. The experimental results considered a correction factor due to the loading device deformation,

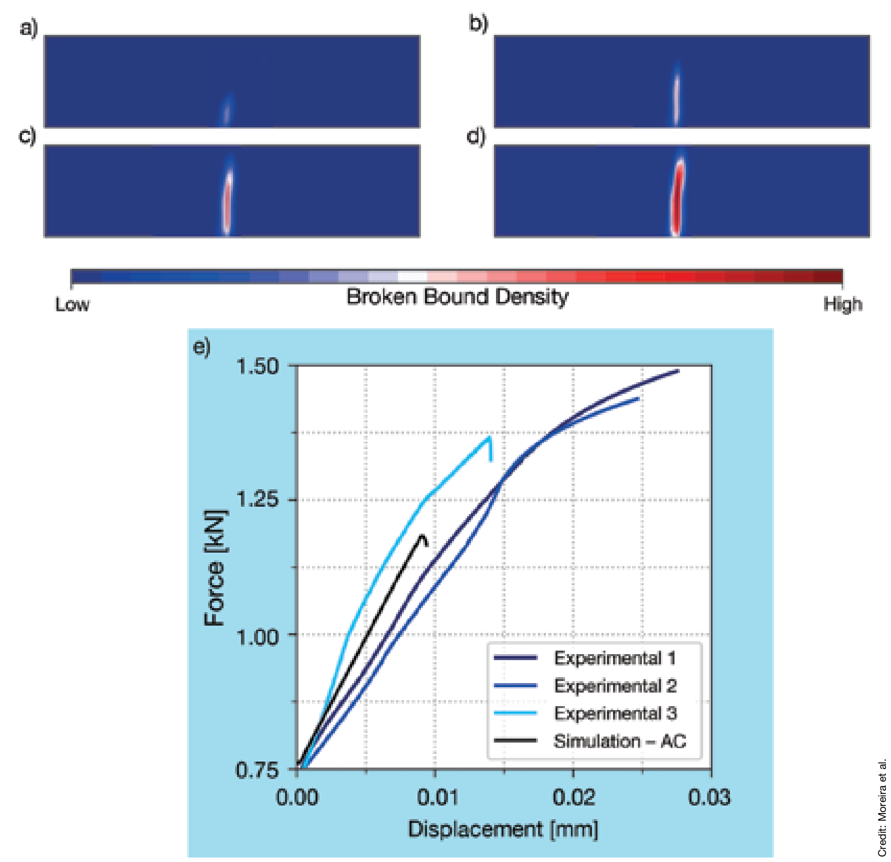


Figure 6. (a-d) Results for the three-point bending test broken bound density progress and (e) force-displacement curve for the simulation and the experiments.

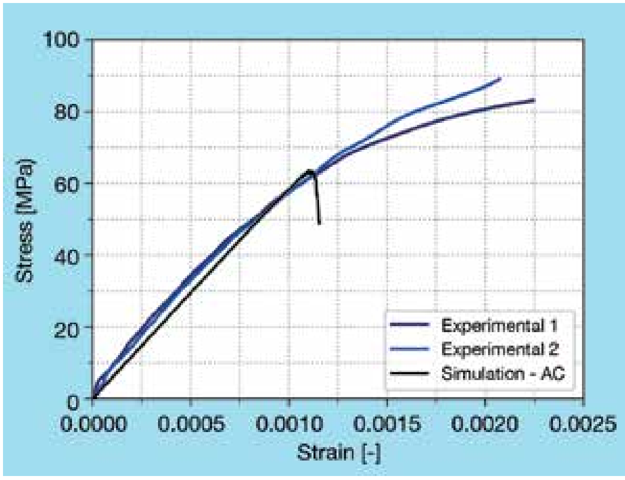


Figure 7. Stress-strain curve for the simulation using the automatic calibration (AC) and the experiments.

model crack propagation pattern did not yield insightful analyses, thus Figure 7 only presents the stress-strain curve that was assessed with the aid of an optical extensometer.

The comparison between numerical and experimental results show a good agreement for the Young's modulus, but the macrostress at failure is 29.0% lower for the DEM simulation. This finding could be related to the model assumptions, the shear effects not captured on the model, or the Rankine criterion used to define the breakage of the cohesive beams.

Manual calibration results

The user defined criterion is defined by two distinct conditions, one for the maximum principal tensile stress, $\sigma_1 > \sigma_{\mu,t}$, and another for the maximum compressive stress, $\sigma_3 < -\sigma_{\mu,c}$. The limit values were calibrated using the Brazilian test, which yield a good agreement, and the uniaxial compression one, which showed the largest difference in the experimental results. The calibrated criterion is validated with the three-point bending test. All the other microparameters were set equal to the values of the automatic calibration for the Brazilian test.

Calibration process of failure criterion

In order to calibrate this user defined criterion, multiple simulations with values of $\sigma_{\mu,t} \in$ [7 MPa, 14 MPa] and $\sigma_{\mu,c} \in$ [40 MPa, 210MPa] were carried out. The calibrated values were $\sigma_{\mu,t}$ = 13.5 MPa and $\sigma_{\mu,c}$ = –200 MPa. Using them for the user defined criterion resulted in a macro failure load which was within an error of 9.7% for the Brazilian test and 6.3% for the uniaxial compression one.

Three-point bending validation

The three-point bending DEM simulation using the calibrated values for the limits of the failure criteria can be found in Figure 8b. The values for the automatic calibration are also presented, highlighting that the new failure criterion still describes the mechanical behavior in a similar way to DEM simulation obtained from the automatic calibration, with the advantage of reproducing the uniaxial compression results. The difference between the experimental value of failure load is 2.27%, which is lower than the result for the automatic calibration, 16.2%.

however, the precision of such experiment could be improved with the aid of digital image correlation (DIC), which could provide a more accurate description of the actual behavior of the material. Nevertheless, there is a difference of 16.2% regarding the loading failure, which could be related to the Rankine failure criterion used for the automatic calibrated simulations.

Uniaxial compression test

For this test, a homogeneous compression stress state that can yield two main types of failures was assumed: shear failure or columnar vertical failure. The

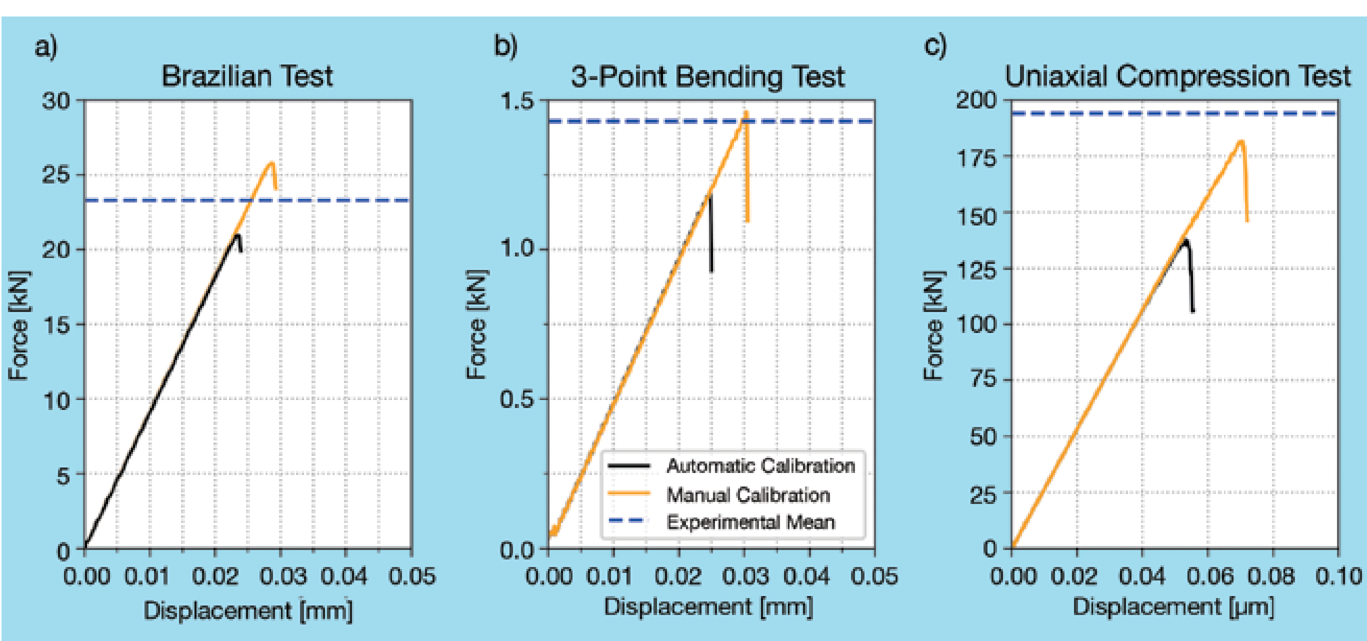


Figure 8. Results for the automatic and manual calibration and the average of the experimental results for the (a) Brazilian, (b) three-point bending, and (c) compression tests.

Conclusions

In the present work, a first "plug and play" approach using GranOO and its automatic calibration algorithm for the microparameters yielded promising results, when considering the crack patterns and the Young's modulus. However, the failure load errors were between 15–30%.

To address such inconsistency, a user defined failure criterion was investigated, and a manual calibration using the Brazilian and uniaxial compression test resulted in a model capable of reproducing the mechanical behavior of the three-point bending test both qualitatively (crack path) and quantitively (Young's modulus and load at failure).

The simulations were carried out on a regular desktop with a third generation Intel i5 – 3570, which shows the feasibility of such models for more complex geometries. It should be noted that more advanced experimental setups, such as using strain gages for the other tests besides uniaxial compression and digital image correlation, could be of great interest in order to have more reliable data for the comparison with the numerical results.

Using DEM highlighted important challenges that should be overcome to make it a reality. Namely, the crack propagation behavior for the compression test, the displacement values, and an approach to have a good match between the micro and macro properties only based on quantities with physical meanings.

Above all, the present work showed the potential of this tool to aid in materials design by modelling real microstructures of refractories (considering pores, particle size distribution, morphology of the grains, different phases, and more). This modeling can lead to the assessment of the local strength of the material, especially when considering complex geometries and phenomena, such as the drying of monolithic refractories, thermal shock, creep, and even bioinspired microstructures.

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Example production of a curved automotive windshield.

Integrated PFMEA-DOE approach for reliability analysis in the manufacturing of curved glass

By Ariel Gandelman, Carla Estorilio, Elisiane Maria Berton, Yukyhiro Oikava, and Lígia de Oliveira Franzosi Bessa

Identifying and fixing early-stage failure modes leads to cost savings down the road. Determining optimal initial and final molding furnace temperatures for curved glass is one such step.

Curved, laminated glasses traditionally are used in automotive applications. However, they are becoming more prominent in commercial construction as "anti-vandalism" and "shielded" glass, with the purpose of adding security to physical environments and people.[1,2]

The manufacturing process for curved glass is complex. Without tight process control, significant amounts of flaws and breakage can occur, resulting in costly rework or scrap. This situation was the case in a medium-sized curved glass manufacturing plant in Curitiba, a city in southern Brazil, where 20% of pieces had to be scrapped.

There are many methodologies to control production of curved glass. Among the most common is Six Sigma, applied through the define, measure, analyze, improve, and control (DMAIC) method. This study focuses on the "analyze" and "improve" phases. We used the Process Failure Mode and Effects Analysis (PFMEA) method to identify potential failures in the Curitiba curved glass manufacturing factory. PFMEA is required by the ISO TS16.949 standard,[3,4] which is a technical specification based on ISO 9001[5,6] but specific to the automotive industry.

Through this study, we identified critical control temperature setpoints for glass molding. Using minimal experimentation dictated by design of experiments (DOE) analysis, we defined furnace parameters that reduced a glass factory's failure rate to 3% and generated an annual savings of $150,000.

Production of curved, laminated glass

Laminated glasses, which have superior mechanical properties to flat glass, consist of two or more glass layers separated and joined by one or more layers of polyvinyl butyral (PVB) or resin.[7]

The starting material for creating curved, laminated glass is standard float glass. Critical parameters include clarity, color, thickness, adherence to aluminum, mechanical strength, integrity, crack resistance, chemical resistance, easy handling, and low cost.

Float glass is lapped to a desired thickness and then cut and drilled to a desired shape and function. Cut pieces are cleaned to remove all fine particulates, which can lead to scratching.

To create curvature, glass is placed on a template and heated in a furnace above the glass transition temperature (T_g), nominally 615°C. Softened glass assumes the mold shape through the action of gravity, and curved glass is subsequently tempered via slow cooling.

Molding time depends on the size, thickness, and curvature radius of the glass. Controlling this time is critical—if plates remain in the furnace for even 2 minutes more than required, the glass takes on a bluish coloring and physical structure, specifically thickness uniformity, is affected.

The final steps are application of resin between glass layers and curing of the resin. Finished pieces are then packed for shipment to the end user.

Analysis of failures

Failure can occur at any stage in this manufacturing process. As one might imagine, the further along in the process, the more valuable the piece and thus the more costly the failure. For the factory studied, Figure 1 shows accumulated cost by step, considering costs of raw materials, labor, and energy. Clearly, identifying and fixing early-stage failure modes is particularly important from a cost standpoint.

When analyzing in detail variables in the molding (and annealing) phase, we found numerous controllable and uncontrollable factors both prior to and during this stage. Considering the glass manufacturing process and in accordance with the Brazilian Association of Flat Glass Distributors and Processors, formation of deep cracks in cutting, lapping, drilling, and other factory process operations can contribute to failure of the glass as it passes through the furnace.

The most critical uncontrollable factors are ambient temperature and humidity, which impact the molding time and require close operator monitoring. Solutions to many of these failure modes were readily attained through adjustments to processing parameters and relatively low-cost additional equipment (Table 1).

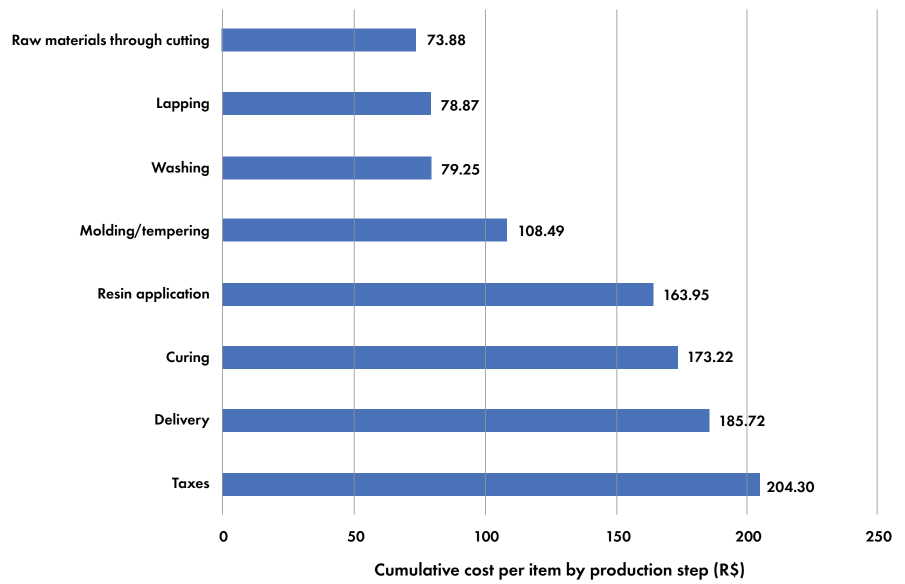

Figure 1. Cumulative cost after each production step for a curved glass manufacturing factory in Brazil.

Assessment of controllable furnace variables

Relationships between breakage and controllable variables in the furnace—initial (T_i) and final (T_f) molding furnace temperatures—were more difficult to identify. A skilled operator at the company reported that T_i had a range of 275–325°C, while the T_f range was 625–665°C (Table 2).

Considering that the objective was to identify the best combination of temperatures, aiming for a molding process without breakage, the study carried out some practical experiments with temperature variation. According to DOE methodology, nine experimental conditions using low, middle, and high

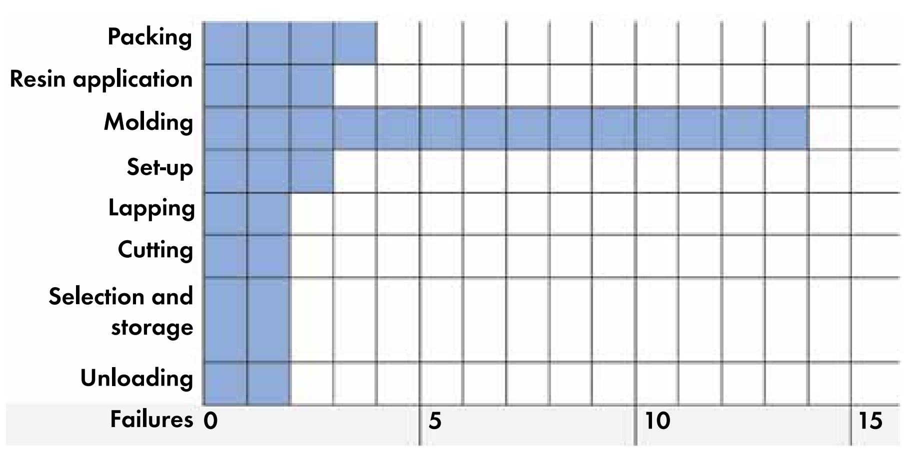

Figure 2. Failure rate at each processing step for a curved glass manufacturing factory in Brazil.

Table 1. Modes of failure affecting in-furnace breakage prior to and during molding and tempering

Failure mode	Cause	Action taken
Cracks and chipping prior to molding	Worn cutting tools and inappropriate processes in lapping and cutting phases	More frequent tool sharpening or replacement; operator training
Scratches	Dirt	Improve cleaning procedures and inspection
Fusion (sticking) of glass plates	Poor distribution of talc (anti-stick agent)	Operator training
Coloration and thickness variation (after molding)	Process time too long	In-furnace cameras for operator monitoring
In-furnace shattering	Incorrect orientation of tin-face of the float glass sheet	Labeling of tin-face
	Heating or cooling too quickly	Programmable temperature controllers
	Nonuniform temperature distribution	Improve reconditioning of furnace elements

Table 2. Temperature of the furnace during curved glass manufacturing

Level	Initial temperature, T_i (°C)	Final temperature, T_f (°C)
Low	275	625
Middle	300	645
High	325	665

values for T_i and T_f provide sufficient reliability of results.

The nine combinations and their results are shown in Table 3. T_f had the most significant effect on failure rate, while T_i had a lesser role. From this study, the operator limited upper temperature of the molding furnace to about 645°C.

Combinations with a T_f very close to the T_g cause overheating and lead to increased fragility and, consequently, increased glass breakage during the curvature process. Combinations that presented the least number of failures were those with lower T_f values (625°C and 645°C). However, it is still necessary to carry out an in-depth study of these temperatures to identify which would be most favorable, striving for zero breakages during glass curvature. Further, it is noteworthy that other tests could be performed, simulating variability of time in the furnace, in parallel with temperature regulation.

Cost savings realized

Despite limitations of the study, such as a lack of time to explore more test variations, identification of the best heating combinations resulted in reducing scrap rates (glass breakage in the furnace) from 20% to 3%. Mapping of costs and processes as well as implementation of corrective actions benefited the company, including greater control over the process itself.

Cost reduction, considering the impact of reduced furnace scrap, generated savings of about 45,000 Brazilian reals (R$) per month, or annual savings of R$500,000 (US$150,000). To achieve greater scrap reduction, more tests are needed to refine the temperature combinations, including variability of time in the furnace, with a goal of getting as close as possible to minimum scrap. Based on the professional experience of one of this article's authors, who had other experiences of process improvement in glass factories, this problem seems to be something recurring in this process profile. Therefore, it would be interesting to repeat this study in other plants.

Table 3. Failures at various combinations of initial and final molding temperatures

Combination	1	2	3	4	5	6	7	8	9
Initial temperature, T_i (°C)	275	275	275	300	300	300	325	325	325
Final temperature, T_f (°C)	625	645	665	625	645	665	625	645	665
Number of failures	4	4	24	4	4	17	4	4	15

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CERAMIC MANUFACTURING SOLUTIONS CONFERENCE

www.ceramics.org/CMSC

REGISTER TODAY

MAY 6-7, 2020
I-X CENTER
CLEVELAND, OHIO

The American Ceramic Society
www.ceramics.org

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Join industry experts for a deeper dive into ceramic and glass manufacturing challenges and practical advice on testing and process solutions.

The inaugural Ceramic Manufacturing Solutions Conference (CMSC) will feature practical programming covering solutions to critical aspects faced by the ceramic manufacturing community. CMSC 2020 will be held at Cleveland's I-X Center Ballroom in conjunction with Ceramics Expo.

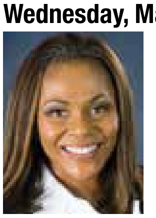
The 2020 CMSC program will focus on three important areas:

Session 1. Testing, Quality, and Health & Safety | Session 2. Ceramic Processing | Session 3. Raw Materials

Conference registration includes 1.5 days of technical programming, a networking reception on Wednesday evening, and a networking lunch on Thursday. All events occur in the Ballroom at the I-X Center in Cleveland, Ohio.

TECHNICAL PROGRAM

Wednesday, May 6 - IX Center Ballroom



Matthews

1 – 2 p.m. **Plenary Speaker:** Karen Matthews, Corning Incorporated
Industry 4.0: How "smart factories" could change the foundation of how we manufacture

2 – 5 p.m. **Testing, Quality, and Health & Safety**

– **J. Douglas Jeter**, Harrop Industries
OSHA's top 10 citations in 2019 and how you can avoid them in 2020

– **Mary Ann Keon**, Acme Brick
Ergonomics in a heavy manufacturing environment

– **William Walker**, Tenneco Powertrain
Making sense of failure modes and effects analysis

– **Beau Billet**, Edward Orton Jr. Ceramic Foundation
Non-destructive techniques to determine Young's Modulus for ceramics

5 – 7 p.m. **Networking Reception**

Thursday, May 7 - IX Center Ballroom

Freitag

9 – 10 a.m. **Plenary Speaker:** Douglas Freitag, United States Advanced Ceramics Association (USACA)
The state of manufacturing advanced ceramics and what gaps remain

10 a.m. – Noon **Ceramic Processing**

– **Cathleen Hoel**, G.E. Research
Practical considerations for ceramic additive manufacturing from conception to production

– **Bill Carty**, Alfred University
A comprehensive approach to ceramic forming using specific volume diagrams: Examples with extrusion

– **David O'Brien**, SINTX
Key steps in successfully manufacturing silicon nitride

Noon – 1 p.m. **Networking Lunch**

1 – 2:45 p.m. **Ceramic Processing: (continued)**

– **Frank Handle/Torsten Seidel**, ECT-KEMA GmbH
Old basics and new perspectives about extrusion in ceramics

– **Marc Bradburry**, Triangle Brick
3D printing: The tool you're missing

– **John Sanders/Mike Walker**, Clemson's National Brick Research Center
Overview of firing of structural clay ceramics

2:45 – 4 p.m. **Raw Materials**

– **Matt Creedon**, Washington Mills
Electrofusion of mullite ceramics

– **Charles Compson**, Almatis
Alumina: A raw material that is (almost) always behind the scenes

Ceramics Expo

Founding partner

The American Ceramic Society
www.ceramics.org

May 5–6, 2020 • I-X Center • Cleveland, Ohio, USA

http://www.ceramicsexpousa.com/

Empowering a greener future with ceramics at the center

Ceramics Expo returns to Cleveland on May 5–6, 2020, for its sixth annual technology showcase. It will emphasize the tremendous influence that ceramics continue to exert on our key industries and on our lives, as evidenced by this year's theme: "Enabling a Clean, Efficient & Electrified Future."

More than 300 suppliers and manufacturers from 25 countries will combine to deliver the largest and most diverse display to date. More than 3,000 visitors are expected at the show, which again will kick off with a VIP networking reception the evening before the expo. There will also be a dedicated space for the B2B Meetings initiative, located on the exhibit floor, bringing all avenues of dialogue together in a seamless presentation.

"It's a core aim every year to introduce added value for all exhibitors, visitors and conference delegates," says event director Danny Scott. "The two-day duration with pre-show networking received overwhelmingly positive reaction when introduced last year and so is clearly the favored format. However, we've continued with our policy of coming up with innovative, enhanced elements, and I'm pleased this year we'll be featuring our new Start-Up and Academia Pavilion. Ceramics Expo is the ideal forum at which to maximize all the exciting opportunities for furthering discussion and cross-fertilization, and for widening perspective."

Additionally, Ceramics Expo will feature more international groups, among them pavilions from China, Germany, South Korea, and the European Cluster of Ceramics. Below is a flavor of the products and concepts lined up by the exhibit groups.

MATERIALS MATTERS

Reliable feedstocks remain vitally important, enhanced R&D being a crucial commitment toward meeting the needs of industries at the forefront of innovating for a cleaner, more energy-efficient world.

Visitors will see a relatively new name—though one that actually has more than a century's experience. Fiven is the result of a recent corporate carve-out of Saint-Gobain's Silicon Carbide business by OpenGate Capital and is a pioneer in the business of silicon carbide grains and powders. While the company in recent years has streamlined and improved its processes to better serve customers in applications such as metallurgy, refractories, and abrasives, crucially it launched new products such as SIKA TECH for emerging applications in the field of electronics (e.g., process components for the semiconductor industry), and energy-efficient or emissions-control technologies. Fiven also offers ready-to-press granules based on fine powders with specific surface areas typically ranging from 10 m^2/g to 15 m^2/g, sintering additives, and temporary binders.

Working at the nanoscale continues to become increasingly important, though it is understood that there are many complexities surrounding the technology and its effective implementation. A leading exponent, Cerion Nanomaterials, is another first-time exhibitor. It has proved itself an expert in designing, scaling, and manufacturing metal, metal oxide, and ceramic nanomaterials for companies developing products or systems, and it provides access to this expertise through all phases of the product lifecycle including research, development, scale-up, and manufacturing.

Cerion's manufacturing processes are centered on a robust plant design that supports a variety of product families through lean manufacturing principles. Additionally, Cerion employs a "Design for Manufacture" methodology, where its development team works side-by-side with its scientists during all phases of research, ensuring near 100% translation from the lab to the manufacturing plant.

FINE FINISH

While a variety of technical ceramics are employed in the manufacture of systems central to energy storage, transportation, electronics, and electrification, other products in the ceramic family help to ensure that all sorts of materials get the finish that makes them fit for purpose. Here, we find another exhibitor clocking over 100 years experience: Günter Effgen, the system supplier for grinding and dressing tools, showing alongside cutting machine tool

Conference agenda at-a-glance

DAY 1, MAY 5, 2020

TRACK 1: INDUSTRY TRENDS & APPLICATIONS

9:20 – 9:30 a.m.	Plenary Opening Keynote
9:30 – 10:30a.m.	Plenary Panel: Fulfilling Market Requirements by Enabling a Clean, Efficient and Electrified Future
10:30 – 10:45 a.m.	Morning break
10:45 a.m. – 12 p.m.	Maximizing Advanced Ceramic Materials as the Disruptive Technology for Electronic Packaging and Assembly
12 – 1 p.m.	Lunch break
1 – 2 p.m.	Panel Discussion: Understanding the Global Roadmap of Regulatory Updates for Emission Control Technology and its Implications for Catalytic Conversion Technology
2 – 2:15 p.m.	Afternoon break
2:15 – 4:30 p.m.	Unlocking the Potential of Glass in Applications Varying from Consumer Electronic Displays to Solar Power

TRACK 2: MATERIALS & MANUFACTURING

9:20 – 9:30 a.m.	Session Taking Place on Track 1
9:30 – 10:30 a.m.	Session Taking Place on Track 1
10:30 – 10:45 a.m.	Morning break
10:45 a.m. – 12 p.m.	Planning for the Future: Economic and Logistical Strategy to Help Secure a Consistent Raw Material Supply
12 – 1 p.m.	Lunch break
1 – 2 p.m.	Innovation Spotlight: Strides Forward in Machining and Process Improvement
2 – 2:15 p.m.	Afternoon break
2:15 – 3:30 p.m	Standardizing the Accuracy and Efficiency of Quality Analysis and Testing of Ceramics Materials
3:30 – 4:30 p.m.	Innovation Spotlight: Breakthroughs in the Field of Raw Materials and Powders

DAY 2 - MAY 6 2020

TRACK 1: INDUSTRY TRENDS & APPLICATIONS

9:20 – 10:30 a.m.	Guiding the Next Generation of Mobility and Communication Forward Using Ceramic Sensors
10:30 – 10:45 a.m.	Morning Break
10:45 a.m. – 12 p.m.	Powering a Mobile Future: The Role of Ceramics in Taking Solid State Batteries from Theory to Practice and Improving Lithium Ion Models
12 – 1 p.m.	Lunch break
1 – 2:30 p.m.	Ironing out the Wrinkles: Addressing the Challenges of Integrating Ceramic Matrix Composites (CMCs)
2:30 – 3:30 p.m.	NASA - Special Project

TRACK 2: MATERIALS & MANUFACTURING

9:20 – 10 a.m.	Presentations: Understanding the Current Challenges of Integrating Additive Manufacturing into Technical Ceramics Production
10 – 10:30 a.m.	Panel Discussion: Further Integrating Additive Manufacturing into the Production of Technical Ceramics
10:30 – 10:45 a.m.	Morning break
10:45 a.m. – 12 p.m.	Achieving Commercialization: From Interpreting Noisy Data to Material Characterization
12 – 1 p.m.	Lunch break
1 – 2:30 p.m.	Actualizing Commercialization: From Material Characterization to Mass Production
2:30 – 3:30 p.m.	Session on Track 1

producer, DMG Mori. Diamond is used for high-performance grinding of glass, carbide, ceramics, and more. Due to their affinity for carbon, ferrous materials are poorly suited to the processing with diamond. For these tasks, cubic boron nitride (CBN) is an ideal grain material. CBN is suitable for machining a wide variety of materials, including high speed steels, steels for hot and cold working, stainless and heat resistant steels, and chromium and titanium alloys—all important for components in advanced manufacturing.

Also leading the line in vitrified CBN technology is Noritake Abrasives, which makes the point that CBN grains are the second hardest material in the world. CBN has an outstanding resistance to heat, and its sharp structure provides remarkable cutting ability. Noritake CBN wheels were developed for difficult-to-process metals, such as special steels and alloys with problematic configurations. They are manufactured with high efficiency, high precision, and long life. CBN tooling is technologically advanced, making it suitable for use in industries such as aerospace, automobile, bearings, and others.

HARNESSING AND HARVESTING ENERGY

A long-time supporter of Ceramics Expo is NASA Glenn Research Center, renowned for its development work in ceramics, ceramic matrix composites (CMCs), and ceramic coatings. This year, discussion will be opened right out with "NASA – Special Project" being a featured session at the conference (Day 2, Track 1, 2:30 p.m.). Visitors will hear how NASA's work positively affects the industry in a wider context and how this work locks into the expo's leading 2020 manufacturing and technology themes. NASA's special project is a session dedicated solely to the advancements and requirements of the space agency in the world of advanced ceramics. NASA is not only heavily involved in the production of CMCs but also a range of advanced coatings for corrosion and heat resistance and in energy harvesting and storage. These materials are expected to meet crucial performance requirements in the future.

EFFICIENT COMMINUTION

Wherever we encounter the myriad of raw materials that ultimately result in the masses, granulates, powders, and slips required by this industry, these materials need to be broken down accurately, speedily, and efficiently. First-time exhibitor General Kinematics delivers unique solutions incorporating vibratory equipment, rotary equipment, and process systems. The company's TWO-WAY feeders, for instance, open up a wide range of process possibilities. The TWO-WAY unit's bidirectional conveyance allows the user to alternate material flow for multidirectional product processing, for rejection of bad product, or any other process that may require multidirectional conveyance from a single unit. The unit's completely horizontal stroke shuffles material with no impact and a significant reduction in noise. These units are available in straight and all new bidirectional curved designs.

General Kinematics' VIBRA-DRUM grinding mills are proven in dozens of milling applications. Grinding processors are said to be achieving impressive energy savings (35%–50%) thanks to a unique rotational material motion that is more efficient than conventional ball or rotary mills. Exceptional grinding performance and energy savings result from what is known as the unit's "natural frequency" design. A sub-resonant, two-mass drive and spring system alternately stores and releases grinding power. Once in motion, energy is only needed to move the grinding media as a fluid mass and to overcome frictional losses.

PLANNING PERFORMANCE

Hand in hand with materials preparation goes testing and analysis, fundamental to achieving fit-for-purpose production and something that has been a strong feature of the expo since its inception. Stable Micro Systems, alongside its exclusive North American distributor of texture analyzers Texture Technologies Corp, will show—with the inclusion of live demos during the show—how goals in this area can be met.

The TA.XT*plusC* is Stable Micro Systems' flagship texture analysis instrument, capable of measuring virtually any physical product characteristic, such as hardness, fracturability, adhesiveness, gel strength, extensibility, and so on. It is commonly employed to measure and quantify fundamental, empirical, and imitative tests in both compression and tension, covering those relating to

texture analysis, materials properties, and effects of rheology of solid, semi-solid, viscous liquid, powder, and granulate materials. It presents a small portable solution for texture analysis testing measuring up to 50 kg in force.

There is also the TA.HD*plusC*, offering a maximum force capacity of 750 kg (7.5 kN), and a family of intelligent, factory-calibrated load cells down to 0.5 kg. It can perform precision testing to a few grams without compromising accuracy while also providing the required rigidity to accommodate measurements of considerably higher force for heavy duty applications. The greater testing bed area and height range offer the ability to test much larger samples within a twin-column frame. The team also offers the TA.XT*ExpressC*, an entry-level and QC-based texture analysis option offering cost effective portable analysis for a wide range of low force (up to 10 kg) applications.

CONFERENCE OFFERS MUTUAL BENEFITS

The Ceramics Expo 2020 Conference is once again a free-to-attend event—the only one of such standing in North America—and already there are confirmed top-level speakers from leading organizations including Tesla, Argonne National Laboratory, Moog Aerospace, DuPont, GE Aviation, Toshiba Electronics, ASTM, Kent State University, Saint-Gobain, Alfred University, and Honeywell Aerospace. It is a unique opportunity for all stakeholders to thoroughly consider mainstream ceramic issues; however, by also addressing the new imperatives, the whole ethos and approach will capture the imagination of all this year's delegates by exploring, for example, electronic packaging and assembly, energy storage and harvesting, and technical and industrial coatings.

These wider topics will be at the center of the opening keynote speech and plenary panel—it kicks off promptly at 9:20 a.m. on May 5! Responding to the plenary theme—*Fulfilling Market Requirements by Enabling a Clean, Electrified and Efficient Future*—we will see how advanced ceramics are a key material in this transition. The latest in solar power harvesting, solid state batteries and energy storage, emission control, efficient sensors, and the miniaturization of electronics are all innovations that rely on advanced ceramic components. In this context, the plenary panel will examine the latest trends and challenges facing the ceramics supply chain and how as an industry we can best prepare for the transition to greener technology.

Matching the production and technical demands of a multibillion dollar industry is something that will be reviewed in *Maximising Advanced Ceramic Materials as the Disruptive Technology for Electronic Packaging and Assembly* (Day 1, Track 1, 10:45 a.m.). Electronic circuitry is an excellent growth area for technical ceramics, though there are challenges in expanding their production. Advanced ceramic materials are still relatively expensive when compared to their nonceramic counterparts and take more time and expertise to produce. Speakers will address the versatility of ceramic materials and outline ideas for maximizing their usage in electronic circuitry. This approach will also allow electronic packaging manufacturers already using ceramics in their products to outline the benefits for those who have not yet begun integration. Ceramic substrates are relatively new materials in printed circuit boards, yet there are several application areas including memory modules, receiving/transmission modules and multilayer interconnect boards. The benefits of ceramic components in these applications include a low coefficient of thermal expansion, thermal conductivity management, good mechanical intensity, and resistance to chemical erosion.

Great interest will attend *Powering a Mobile Future: The Role of Ceramics in Taking Solid State Batteries from Theory to Practice and Improving Lithium Ion Models* (Day 2, Track 1, 10:45 a.m.). Speakers will examine prospective applications for solid state batteries and the benefits that accompany their integration, such as improved safety standards and higher energy density. Also examined will be the biggest challenges facing solid state battery manufacture—cost, testing, and material supply. Speakers will discuss key challenges in the testing, characterization, and development of advanced ceramics and glass in solid-state batteries, scope for energy density improvements, thermal management, and addressing possible fragility of ceramic and glass cathodes.

This preview is just a snapshot of what both the exhibit hall and conference tracks have to offer everyone in 2020, but the bigger picture is sure to be as exciting as ever. "The Ceramics Expo brand has been boosted by engagement from a number of modern powerhouse manufacturing industries," Scott comments. "These are industries that are innovating at a tremendous pace and on which the more traditional sectors increasingly rely. We will draw all these strands together in Cleveland to present a cohesive, forward-looking forum for all our valued attendees. ■

2020 GLASS & OPTICAL MATERIALS DIVISION ANNUAL MEETING

www.ceramics.org/GOMD2020

Join ACerS' Glass & Optical Materials Division for GOMD 2020, May 17–21, 2020, in New Orleans, La., for a program featuring four symposia: Fundamentals of the Glassy State, Optical and Electronic Materials and Devices–Fundamentals and Applications, Glass Technology and Cross-Cutting Topics, and a brand-new symposium on Glass and Water: Degradation of Amorphous Materials. Technical sessions consisting of both oral and poster presentations led by technical leaders from industry, national laboratories, and academia will provide an open forum for glass scientists and engineers from around the world to present and exchange findings on recent advances in various aspects related to glass science and technology.

Students are encouraged to enter their presentations in the annual student poster competition for professional recognition and cash awards. Students attending GOMD 2020 are also invited to attend a career roundtable discussion with scientists from industry, national laboratories, and academia about career opportunities and other topics in a casual environment. GOMD 2020 will provide a unique opportunity for students to learn, interact, and win!

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

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

We look forward to seeing you in New Orleans!

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SCHEDULE OF EVENTS

Sunday, May 17, 2020	
Registration	4 – 7 p.m.
Welcome reception	6 – 8 p.m.
Monday, May 18, 2020	
Registration	7 a.m. – 5:30 p.m.
Stookey Lecture of Discovery	8 – 9 a.m.
Concurrent sessions	9:20 a.m. – 5:40 p.m.
Otto Schott Award luncheon sponsored by Schott AG	Noon – 1:30 p.m.
GOMD general business meeting	5:45 – 6:30 p.m.
Poster session and student poster competition	6:30 – 8:30 p.m.
Tuesday, May 19, 2020	
Registration	7:30 a.m. – 5:30 p.m.
George W. Morey Award lecture	8 – 9 a.m.
Concurrent sessions	9:20 a.m. – 6 p.m.
The Norbert J. Kreidl Award for Young Scholars	Noon – 1 p.m.
Lunch on own	Noon – 1:30 p.m.
Conference banquet	7 – 10 p.m.
Wednesday, May 20, 2020	
Registration	7:30 a.m. – 5 p.m.
Varshneya Frontiers of Glass Science lecture	8 – 9 a.m.
Concurrent sessions	9:20 a.m. – 5:40 p.m.
Lunch on own	Noon – 1:30 p.m.
Thursday, May 21, 2020	
Registration	7:30 a.m. – Noon
Varshneya Frontiers of Glass Technology lecture	8 – 9 a.m.
Concurrent sessions	9:20 a.m. – Noon

2019–2020 GOMD OFFICERS

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SAVE THE DATE

May 17–21, 2020
Hotel Monteleone
New Orleans, Louisiana

TECHNICAL PROGRAM

S1: FUNDAMENTALS OF THE GLASSY STATE

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

S2: GLASS AND WATER: DEGRADATION OF AMORPHOUS MATERIALS

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

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

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

S4: GLASS TECHNOLOGY AND CROSS-CUTTING TOPICS

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

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Based on availability (Prevailing government rate):
Single/double: $199 plus tax
Triple: $224 plus tax
Quad: $249 plus tax

Reserve your room by April 20, 2020 to secure the negotiated conference rate.

Visit the hotel and travel page at ceramics.org/GOMD2020 to reserve your room today.

POSTER SESSION & STUDENT POSTER COMPETITION

Organizers
Joy Banerjee, Corning Inc., U.S.A.
Mostafa Ahmadzadeh, Washington State University, U.S.A.

Poster abstracts will be accepted for all sessions and symposia. Students are encouraged to enter their presentations in the annual poster competition for professional recognition and cash awards.

CAREER ROUNDTABLE

Organizers
Xiaonan Lu, Pacific Northwest National Laboratory, U.S.A.
Nicole Wiles, Cornell University, U.S.A.

Students attending GOMD 2020 are invited to attend an information roundtable discussion with scientists from industry, national laboratories, and academia. This discussion will be an opportunity for students to ask scientists questions in a casual environment on diverse topics (work-life balance, career opportunities, etc.). The scientists will rotate every 15 minutes so that students have a chance for candid discussions with several professional scientists during the session.

ceramics.org/PACCFMAs

PAN AMERICAN CERAMICS CONGRESS AND FERROELECTRICS MEETING OF AMERICAS (PACC-FMAs 2020)

July 19-23, 2020 | Hilton Panama | Panama City, Panama

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

The technical program will consist of a wide range of invited and contributed talks and poster sessions important to ceramic and glass professionals who live or do business in the Americas. It will provide an information exchange on the latest emerging technologies and facilitate open dialogue and discussion with leading experts from around the globe. The conference fee includes lunch each day, two receptions, a conference dinner, coffee breaks, and more.

PACC TECHNICAL PROGRAM

- Ceramics for Energy and Environment
- Advanced Ceramics and Composites
- Densification and Microstructural Evolution in Ceramics During Sintering
- Bioceramics and Biocomposites
- Advances in Cements, Geopolymers, and Structural Clay Construction Materials
- Refractories
- Science and Technology of Glasses, Glass ceramics, and Optical Materials
- Novel, Green, and Strategic Processing and Manufacturing Technologies
- Symposium for Young Professionals
- Ceramics for Sustainable Agriculture
- Materials Approach to Art, Architecture, and Archaeology in the Americas
- Special Symposium: Ceramics and Materials Education in the Americas (Speakers by invitation only)
- FERROELECTRICS MEETING OF AMERICAS

STUDENT TRAVEL GRANT PROGRAM

If you are a student (undergrad, graduate, or high school) who is giving a presentation at PACC-FMAs, you are eligible to apply for a travel grant valued up to $400. The application deadline is **May 15, 2020**.

Travel grant recipients will be notified by **June 15, 2020**. The travel grant covers both registration and full hotel stay for recipients. For more information and to apply online, visit ceramics.org/PACCFMAs.

SCHEDULE OF EVENTS

Sunday, July 19, 2020	
Conference registration	3:30 – 7 p.m.
Welcome reception	5:30 – 7 p.m.
Monday, July 20, 2020	
Conference registration	7 – 5 p.m.
Opening ceremony and plenary session	8:30 – 11:30 a.m.
Lunch/Technology fair	11:30 a.m.– 1 p.m.
Concurrent technical sessions	1 – 5:00 p.m.
Coffee break	3 – 3:20 p.m.
Technology fair and poster session, including reception	5:30 – 7 p.m.
Tuesday, July 21, 2020	
Conference registration	7 a.m. – 5 p.m.
Concurrent technical sessions	8:30 – 11:30 a.m.
Lunch/Technology fair	11:30 a.m. – 1 p.m.
Concurrent technical sessions	1 – 5 p.m.
Coffee break	3 – 3:20 p.m.
Wednesday, July 22, 2020	
Conference registration	7:30 a.m. – Noon
Concurrent technical sessions	8:30 a.m. – Noon
Technology fair	8:30 a.m. – Noon
Afternoon on own/ ACerS-organized Panama Canal tour available for an additional fee	Noon – 5 p.m.
Conference dinner	7 – 9 p.m.
Thursday, July 23, 2020	
Conference registration	8 a.m. – Noon
Concurrent technical sessions	8:30 a.m. – Noon

PAN AMERICAN CERAMICS CONGRESS TECHNICAL PROGRAM CHAIRS

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FERROELECTRICS MEETING OF AMERICAS CHAIR

Amar Bhalla, amar.bhalla@utsa.edu

PUBLISHING YOUR PAPER AT PACC-FMAS 2020

Submit your manuscript to the *International Journal of Ceramic Engineering and Science*, the official journal for the Pan American Ceramics Congress, which replaces conventional Proceedings. *IJCES* is the ACerS-approved, open-access journal of sound science and engineering studies, making it ideal for reporting the progress you presented at the Congress. The article processing charge for PanAm presenters is $100 USD, thanks to generous underwriting from The American Ceramic Society. Peer-reviewed and accepted papers presented at the meeting dealing with the topic of ferroelectrics will be published in the special volume of *International Journal of Ferroelectrics*.

ACerS special rates:
$105/single occupancy* | $120/double occupancy*
**Price includes breakfast and 2 mb wifi*

ACerS special rate cut-off date is June 25, 2020.

Visa information
Consult the Panamanian Embassy website to determine if you must apply for a visa to visit Panama. U.S. resident citizens do not require a visa.

CALL FOR PAPERS Abstract submission deadline: March 25, 2020

Hosted and organized by:
Energy Materials and Systems Division

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

4th Annual Energy Harvesting Society Meeting (EHS 2020)

Also organized by:
KIChE
The Korean Institute of Chemical Engineers

August 16–21, 2020

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

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

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

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

PROPOSED SYMPOSIA TOPICS

- **Materials for solar fuel production and applications**
- **Advanced materials for energy storage**
- **Challenges in thermal-to-electrical energy conversion technology for innovative novel applications**
- **Advanced materials for perovskite and next generation solar cells**
- **Spectral conversion materials for energy applications**
- **Materials for nanogenerators and self-powered electronics**
- **Advanced materials and nanodevices for sustainable and eco-friendly applications**
- **Advanced materials for fuel cells and high temperature electrolysis**
- **Critical materials for energy applications**
- **Life cycle impacts of clean energy materials**
- **Materials for super ultra-low energy and emission vehicle**
- **Materials and process challenges for sustainable nuclear energy**
- **Young scientists forum on future energy materials and devices**
- **Frontiers of theoretical and experimental insights in energy harvesting materials**

HONORARY SYMPOSIUM

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

Yoon-Bong Hahn

Session topics

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

Organizers

- **Sanjay Mathur**, University of Cologne, Germany sanjay.mathur@uni-koeln.de
- **Yeon Ho Im**, Chonbuk National University, Korea yeonhoim@jbnu.ac.kr
- **Min Jae Ko**, Hanyang University, Korea, mjko@hanyang.ac.kr

ABSTRACT SUBMISSION INSTRUCTIONS

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

MCARE 2020 ORGANIZING CO-CHAIRS

Gabrielle Gaustad, Alfred University, U.S.A.
Steven C. Tidrow, Alfred University, U.S.A.
Sanjay Mathur, University of Cologne, Germany
Yoon-Bong Hahn, Chonbuk Nation University, Korea
Eva Hemmer, University of Ottawa, Canada

EHS 2020 ORGANIZING CO-CHAIRS

Shashank Priya, The Pennsylvania State University, U.S.A.
Jungho Ryu, Yeungnam University, Korea
Yang Bai, University of Oulu, Finland

HYATT REGENCY BELLEVUE

Hyatt Regency Bellevue on Seattle's Eastside
900 Bellevue Way NE, Bellevue, Washington, USA

Rates: $199 Cut-off: July 24, 2020

Ferroelectric focus at the Electronic Materials and Applications Conference

(Credit all images: ACerS)

The 11th annual Electronic Materials and Applications Conference, jointly organized by ACerS Electronics Division and Basic Science Division, was held Jan. 22–24, 2020, in Orlando, Fla.

The meeting welcomed 325 participants, including 64 students, from 33 countries. This year was a big one for the meeting, as 2020 marks the 100th anniversary of the discovery of a valuable electroceramic property—ferroelectricity.

Since the discovery of ferroelectricity in 1920, ferroelectric materials have become huge commercial successes and drive an estimated $7 billion in annual business worldwide, although much remains to understand about these materials. Susan Trolier-McKinstry, professor at The Pennsylvania State University, presented a short history of the discovery and development of ferroelectric materials during lunch sponsored by Radiant Technologies on the second day of the meeting.

Penn State professor Susan Trolier-McKinstry gives a brief history on ferroelectric materials.

Guus Rijnders from the University of Twente in The Netherlands opened EMA on Wednesday with a plenary talk on novel functionalities in atomically controlled oxide heterostructures synthesized by pulsed laser deposition.

Elizabeth Dickey from North Carolina State University spoke at Thursday's plenary on "Defect disorder and dynamics in functional oxides." She noted, "In our community, we try to harness disorder," using the example of capacitors, "where you don't want things to move around."

In addition to these talks, EMA organizers scheduled plenty of networking opportunities, a poster session, student events and recognitions, and a conference dinner. The conference closed with its ever-popular Failure Symposium, where scientists come clean about the bumps in their road to success. This year, Brian Huey from the University of Connecticut and John Blendell from Purdue University shared the lessons learned from experiences that, at first glance, looked like failures.

Plan now to attend EMA 2021 in Orlando, Jan. 20–22, 2021. Read more about EMA 2020 at http://bit.ly/EMA2020wrapup. View images from EMA 2020 at http://bit.ly/EMA2020photos. ■

Several ‘firsts’ at the 44th International Conference on Advanced Ceramics and Composites

(Credit all images: ACerS)

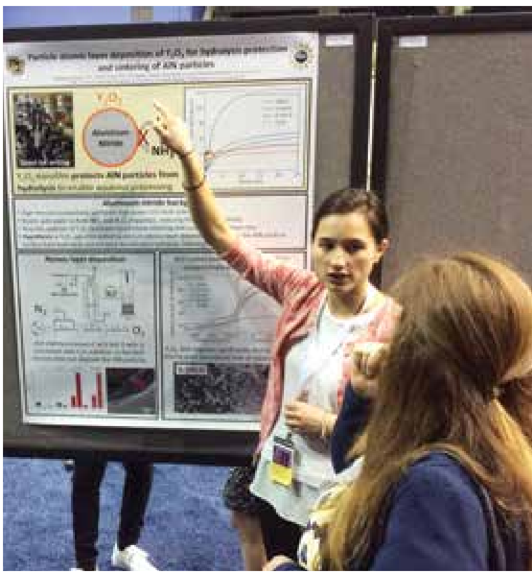
Fate was on the side of the 44th International Conference on Advanced Ceramics and Composites organizers this year. The meeting, held in Daytona Beach, Fla., January 26–31, came off without a hitch thanks to good weather on the eastern seaboard, a funded United States government, and taking place before the coronavirus impacted international travel.

ICACC, organized by the ACerS Engineering Ceramics Division, welcomed 1,003 attendees, including 299 students, from 37 countries with about 50% coming from outside the United States. Organizer Valerie

ACerS past president Sylvia Johnson, left, presents ICACC organizer Valerie Wiesner with an ACerS Global Ambassador award.

Wiesner, a research materials engineer with NASA Langley Research Center, says, “We had great engagement from the ceramics community to put together a high-quality program. We added an 18th symposium on ultra-high temperature ceramics and held the 4th Pacific Rim Engineering Ceramics Summit. An inaugural ‘Women in Ceramics Lunch’ was also held, bringing together about 45 women for lunch and discussion with a panel of five distinguished women from our field and was well received.”

The conference packed a lot of value into the week. Some technical program highlights included the traditional opening plenary session, 18 symposia (including the new symposium on ultrahigh temperature ceramics), five focus sessions, the 9th Global Young Investigators Forum, and two poster sessions.



Besides the technical program, Engineering Ceramics Division held its annual business meetings; new members were welcomed at a special reception, as were young professionals at their own reception; Wiley sponsored a skills-building seminar presented by ACerS journal editors for young journal authors on communicating the societal impact of scientific research; and students participated in engineering shot glass and SIFT competitions.

The two-night exhibition featured 30 exhibitors and the opportunity for conference attendees to shop for new instruments, equipment, and services. The two poster sessions also took place during the exhibition, giving everyone a reason to cross the street and enjoy some heavy hors d’oeuvres and good conversation.

Additionally, before ICACC, students participated in the annual Winter Workshop hosted by the Ceramic and Glass Industry Foundation. The workshop provided a combination of technical and professional development sessions, networking opportunities, and a tour of the Kennedy Space Center.

Plan now to attend ICACC 2021 in Daytona Beach, Jan. 24–29, 2021. Read more about ICACC 2020 at http://bit.ly/ICACC2020wrapup. View images from ICACC 2020 at http://bit.ly/ICACC2020photos. ■

resources

Calendar of events

March 2020

25–26 56th Annual St. Louis Section/Refractory Ceramics Division Symposium on Refractories – Hilton St. Louis Airport Hotel, St. Louis, Mo.; https://ceramics.org/event/56th-annual-st-louis-section

April 2020

13–17 2020 MRS Spring Meeting & Exhibit – Phoenix, Ariz.; www.mrs.org/spring2020

May 2020

5–6 6th Ceramics Expo – I-X Center, Cleveland, Ohio.; https://ceramics.org/event/6th-ceramics-expo

6–7 Ceramic Manufacturing Solutions Conference – I-X Center, Cleveland, Ohio; https://ceramics.org/event/ceramic-manufacturing-solutions-conference

17–21 2020 Glass and Optical Materials Division Annual Meeting – Hotel Monteleone, New Orleans, La.; www.ceramics.org/gomd2020

27–29 MagForum 2020: Magnesium Minerals and Markets Conference – Grand Hotel Huis ter Duin, Noordwijk, Amsterdam; http://imformed.com/get-imformed/forums/magforum-2020

June 2020

7–10 ➡ Ultra-high Temperature Ceramics: Materials for Extreme Environment Applications V – The Lodge at Snowbird, Snowbird, Utah; http://bit.ly/5thUHTC

July 2020

19–23 Pan American Ceramics Congress and Ferroelectrics Meeting of the Americas (PACC-FMAs 2020) – Hilton Panama, Balboa Avenida Aquilino de la Guardia, Panama City, Panama; www.ceramics.org/PACCFMAs

August 2020

2–7 ➡ Solid State Studies in Ceramics, Gordon Research Conference – Mount Holyoke College, South Hadley, Mass.; https://www.grc.org/solid-state-studies-in-ceramics-conference/2020

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

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

September 2020

21–23 China Refractory Minerals Forum 2020 – InterContinental Dalian, Liaoning, China; http://imformed.com/get-imformed/forums/china-refractory-minerals-forum-2020

October 2020

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

November 2020

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

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

January 2021

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

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

March 2021

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

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

August 2021

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

September 2021

14–17 20th Biennial Worldwide Congress Unified International Technical Conference on Refractories – Hilton Chicago, Chicago, Ill.; www.ceramics.org

October 2021

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

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

Entries in **BLUE** denote ACerS events.

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

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ADINDEX

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(Credit all images: ACerS)

JOIN ACERS PRESIDENT'S COUNCIL OF STUDENT ADVISORS

THE PRESIDENT'S COUNCIL OF STUDENT ADVISORS (PCSA) IS THE STUDENT-LED COMMITTEE OF THE AMERICAN CERAMIC SOCIETY (ACERS) COMPOSED OF AN ELITE GROUP OF HIGHLY MOTIVATED CERAMIC AND GLASS FOCUSED STUDENTS.

At the start of each year, the PCSA opens their application process and selects applications that most clearly show

- a strong interest in ceramics and glass,
- strong leadership qualities, and
- reliability and strong drive.

Students who are chosen as PCSA delegates will come together for the PCSA Annual Business Meeting, which takes place the weekend prior to the ACerS Annual Meeting at MS&T.

The PCSA is comprised of five committees: Programming, Communications, Recruitment, Outreach, and External Partnerships.

The **Programming Committee** organizes official PCSA sponsored programs, such as the highly attended Shot Glass competition held each year at ICACC.

The **Communications Committee** works to increase the visibility of ceramic and glass materials science. Among their activities are managing the *Deciphering the Discipline* articles that appear in the *ACerS Bulletin* and managing the PCSA's social media presence. New for this year is the collaboration with the Outreach Committee to offer the "Day in the Life" video series, which debuted on their Instagram Stories in December.

The **Recruitment Committee** manages the application process each year and communicates with faculty and PCSA alumni to spread the word. They work hard to make sure the PCSA delegate class includes undergraduate and graduate students from a broad range of universities across the globe.

The **Outreach Committee** aims to organize ways to communicate the concepts of ceramic and glass to K–12 students and the general public. To that end, this year they worked to connect with K–12 teachers in their area so that individual PCSA delegates can bring the Ceramic and Glass Industry Foundation's (CGIF) Materials Science Classroom Kit, with all of the lessons that they contain, to their classrooms.

The **External Partnerships Committee**, among a variety of projects, manages the PCSA's Mentor program, which has a total of 30 pairs of participants this year. Additionally, they created the Humanitarian Pitch Competition, which was first held at ACerS Annual Meeting at MS&T19 and will be held again at ACerS Annual Meeting at MS&T20.

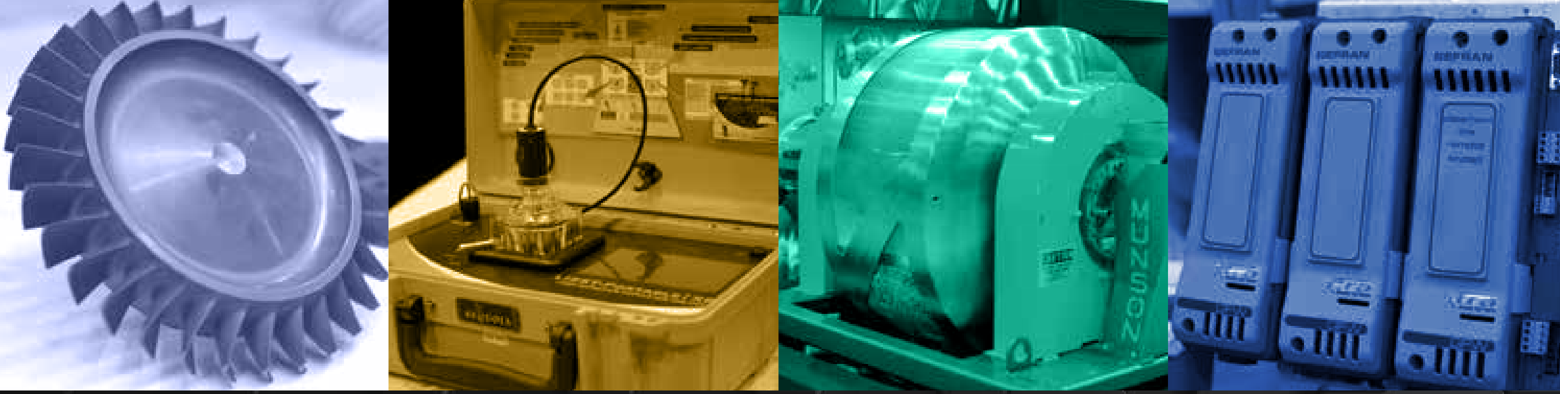
The PCSA currently is looking for dedicated and motivated undergraduate and graduate students to get involved and to help advance ACerS into the future. To learn more about the PCSA, visit www.ceramics.org/pcsa. Interested students should visit www.ceramics.org/applypcsa to learn more and how to apply. The deadline to apply for the 2020–2021 PCSA class is **March 30, 2020.** ■

Instagram, "Day in the life" of a PCSA delegate


Competitors from the first-ever Humanitarian Pitch Competition.


The 2019-2020 PCSA, which consists of 46 students from 30 universities, representing eight countries.


Shot Glass Competition 2020.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