AMERICAN CERAMIC SOCIETY

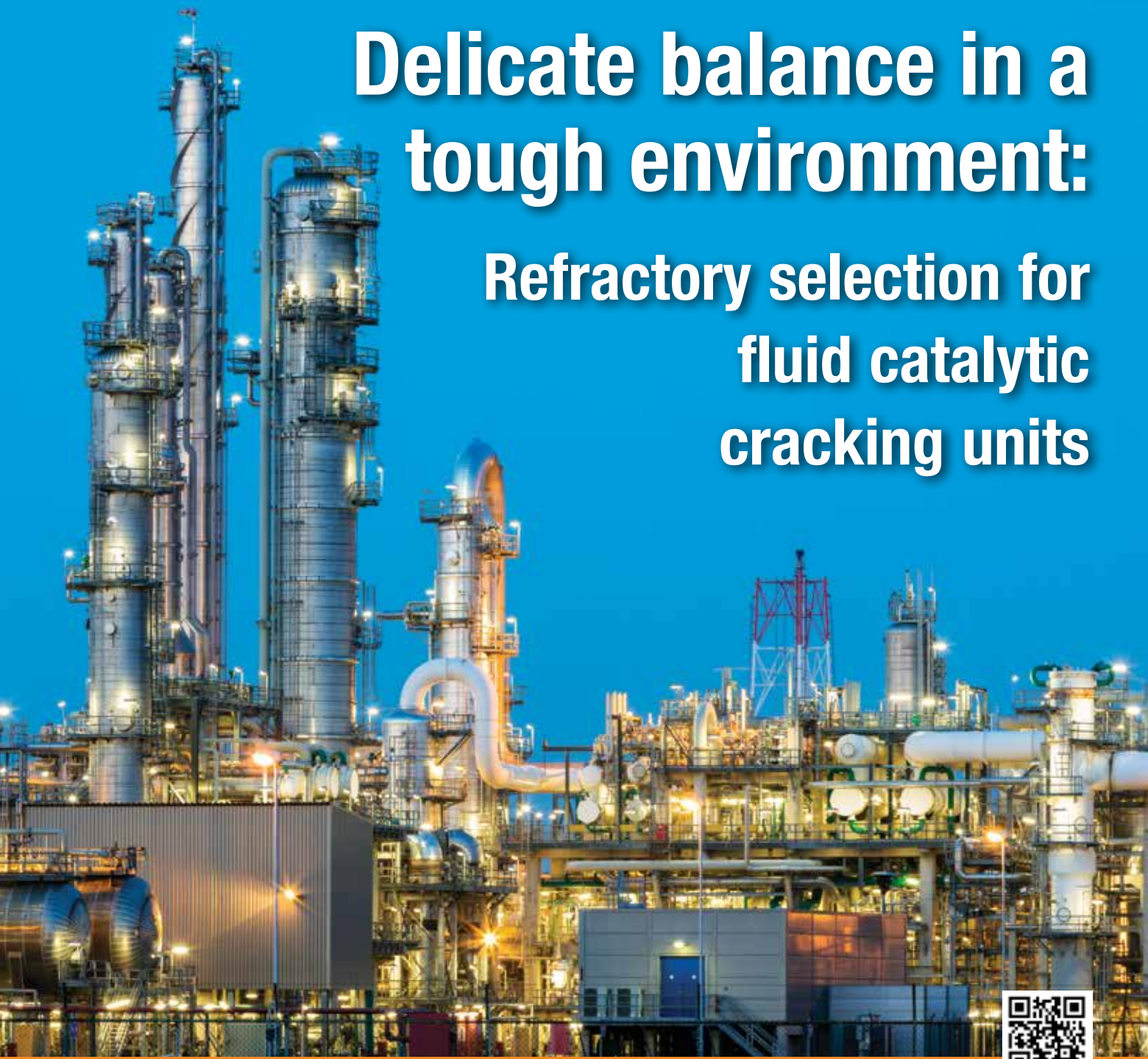
bulletin

emerging ceramics & glass technology

MARCH 2019

Delicate balance in a tough environment:

Refractory selection for fluid catalytic cracking units



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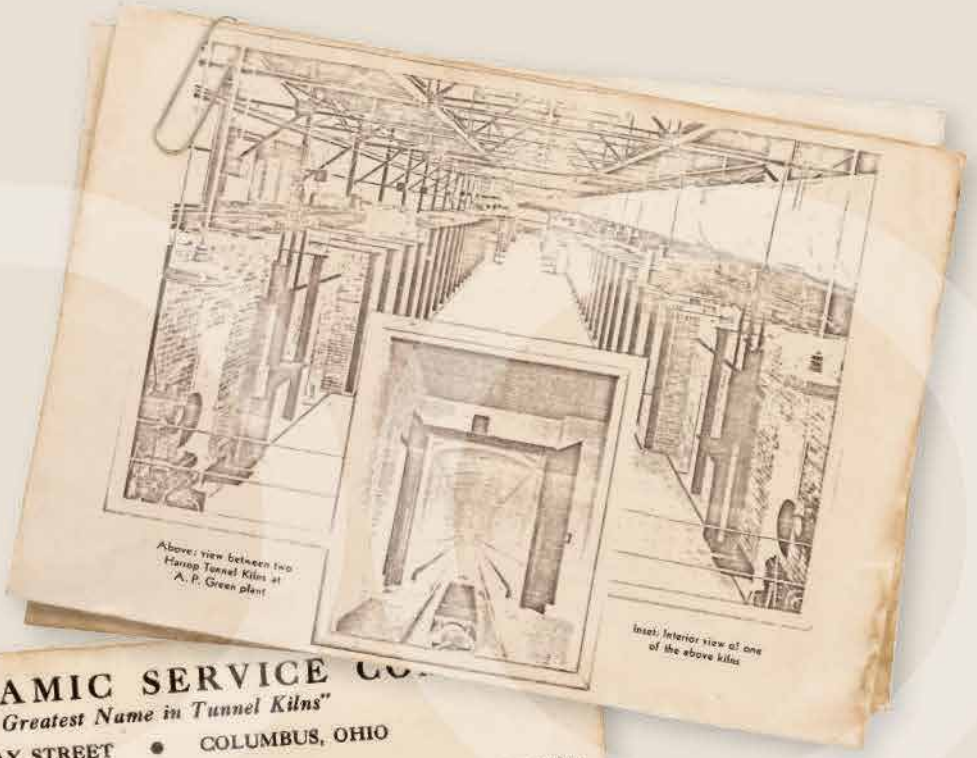

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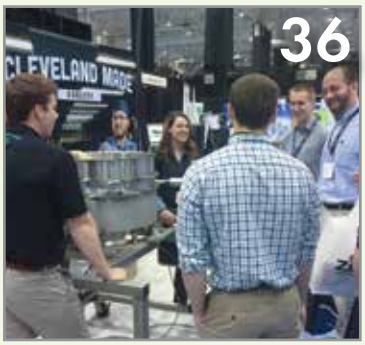
Petrochemical refining challenges refractory materials to handle not just heat, but abrasion, in changing harsh environments within the fluid catalytic cracking unit.

by Stephen Karns

Research and progress in castable refractory development

Adoption of monolithic castable refractories is one of the industry's great success stories, but was decades in the making.

by Charles E. Semler



Ceramics Expo 2019
I-X Center in Cleveland—April 29 - May 1

Channeling Ceramic Enterprise and Expertise

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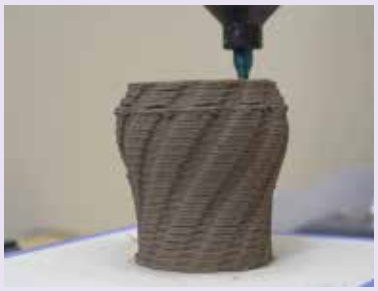
As seen on *Ceramic Tech Today*...



Credit: UTEP Miners, YouTube

Video: 3D printing creates ceramic sculptures...but is it art?

Students at The University of Texas at El Paso created 3D-printed ceramic sculptures for an art exhibition. The project raised questions among students about if 3D-printed objects are real art.

Read more at www.ceramics.org/ceramicsculptures

As seen in the January/February 2019 *ACerS Bulletin*...

Ceramic materials engineer a cleaner, safer world

Modular filters based on silver-coated ceramic granules provide sustainable, affordable access to clean water when water treatment infrastructure is lacking.

Read more at www.ceramics.org/cleanworld

American Ceramic Society Bulletin covers news and activities of the Society and its members, includes items of interest to the ceramics community, and provides the most current information concerning all aspects of ceramic technology, including R&D, manufacturing, engineering, and marketing. The American Ceramic Society is not responsible for the accuracy of information in the editorial, articles, and advertising sections of this publication. Readers should independently evaluate the accuracy of any statement in the editorial, articles, and advertising sections of this publication. *American Ceramic Society Bulletin* (ISSN No. 0002-7812). ©2019. Printed in the United States of America. *ACerS Bulletin* is published monthly, except for February, July, and November, as a "dual-media" magazine in print and electronic formats (www.ceramics.org). Editorial and Subscription Offices: 550 Polaris Parkway, Suite 510, Westerville, OH 43082-7045. Subscription included with The American Ceramic Society membership. Nonmember print subscription rates, including online access: United States and Canada, 1 year $135; international, 1 year $150.* Rates include shipping charges. International Remail Service is standard outside of the United States and Canada. *International nonmembers also may elect to receive an electronic-only, email delivery subscription for $100. Single issues, January–October/November: member $6 per issue; nonmember $15 per issue. December issue (*ceramicSOURCE*): member $20, nonmember $40. Postage/handling for single issues: United States and Canada, $3 per item; United States and Canada Expedited (UPS 2nd day air), $8 per item; International Standard, $6 per item.

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ACSBA7, Vol. 98, No. 2, pp 1– 48. All feature articles are covered in Current Contents.

Latest advances in wearable tech use graphene, silver nanowires

Wearables are the subject of much research in the past few years. According to Juniper Research, in comparison to conventional activity trackers like Fitbit and Garmin that are expected to increase 20 percent over the next four years, clothing- and ear-based fitness wearables are expected to grow from 4.5 million units in 2018 to nearly 30 million in 2022—an increase of more than 550 percent. Additionally, connected clothing will experience a 102 percent CAGR over the next two years.

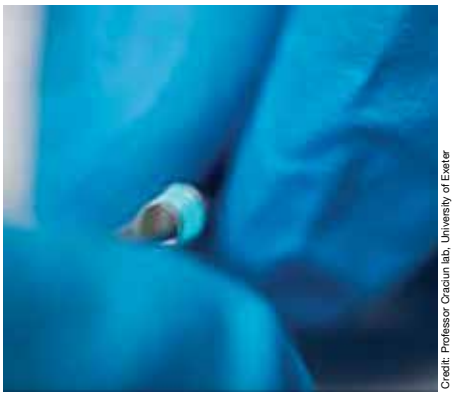
Most wearable technology that provides metrics for health and fitness-related activities are designed to be worn as accessories, mainly on the wrist. But in recent years, scientists have been working to incorporate the technology into clothing.

Here are two new examples of research in wearable tech.

Graphene fibers replace bulky wearable devices

In a collaboration between the University of Exeter engineering department, the Centre for Graphene Science at the University of Exeter, the Universities of Aveiro and Lisbon in Portugal, and CenTexBel in Belgium, researchers developed electronic fibers out of graphene that can be woven into fabric.

What makes this research different from current technology is that the electronic fibers integrate into the material, rather than attach at the surface. "For truly wearable electronic devices to be achieved, it is vital that the components are able to be incorporated within the



Credit: Professor Cracun Iab, University of Exeter

A European collaboration of researchers found a way to integrate graphene fibers into fabric rather than just attach at surface.

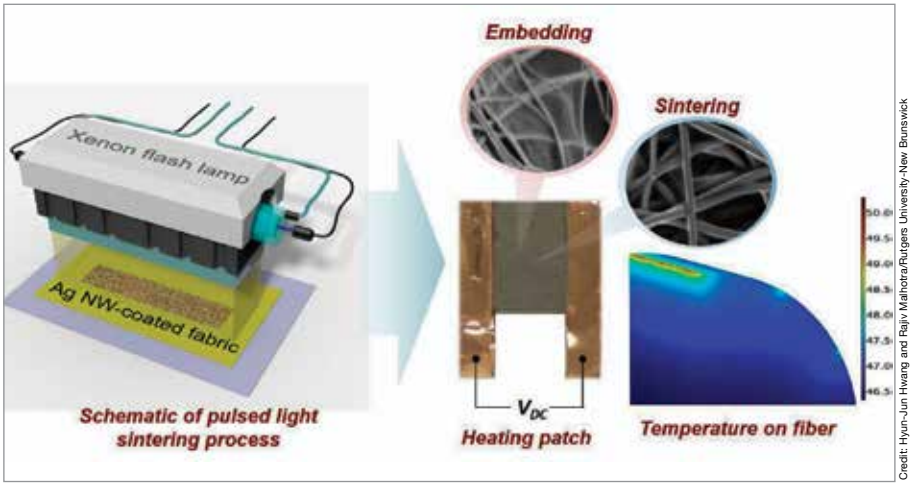
material, and not simply added to it," says Monica Craciun, University of Exeter professor in nanoscience and nanotechnology and lead researcher, in a University of Exeter news release.

The researchers wove graphene fibers into polypropylene fibers to create a material that eliminates the need for electrodes or wires in the semi-flexible devices that have typically been used to create wearable electronic devices.

"This new research opens up the gateway for smart textiles to play a pivotal role in so many fields in the not-too-distant future," suggests Torres Alonso, research scientist and former Ph.D. student of Craciun at Exeter, in the release. "By weaving the graphene fibers into the fabric, we have created a new technique to [allow] the full integration of electronics into textiles. The only limits from now are really within our own imagination."

The team believes their research could not only revolutionize the creation of everyday wearable electronic devices, but could also be used for health monitoring, such as heart rates and blood pressure, and medical diagnostics.

The open-access paper, published in *Flexible Electronics*, is "Graphene electronic fibres with touch-sensing and light-emitting functionalities for smart textiles" (DOI: 10.1038/s41528-018-0040-2).



Credit: Hyun-Jun Hwang and Rajiv Malhotra/Rutgers University-New Brunswick

Rutgers and Oregon State University researchers developed heating patches using silver nanowires to keep people warm in cold buildings.

Business news

Philippine Department of Trade and Industry to regulate flat glass as safety fears aired (**https://businessmirror.com.ph**) … SCHOTT setting up new pharma tubing tank facility in India (**https://www.schott.com**) … University of Pittsburgh and General Carbide research 3D printing methods for tungsten carbide (**https://www.engineering.pitt.edu**) … Gulf Glass Factory in alliance with Italy's Falorni Gianfranco to build country's first glass containers project (**https://www.gulf-times.com/**) … MIT launches additive manufacturing consortium ADAPT (**https://marketbusinessnews.com**) … Plibrico starts refractory distribution deal with Pli Group Europe (**http://www.globalcement.com/**) … Saint-Gobain to divest silicon carbide division (**https://www.chemengonline.com/**) … American Concrete Institute unveils Middle East regional office in Dubai (**https://www.aggregateresearch.com/**) … Corning introduces the industry's first AutoGrade glass solutions for automotive interiors (**https://www.marketwatch.com/**) ■

Silver nanowires heat the body, save energy

If we could heat our clothes instead of buildings, we could save a lot of energy—and money—that goes toward fueling a furnace. That is the thinking behind a new study in *Scientific Reports*. Researchers from Rutgers and Oregon State University developed heating patches that can be attached to essential areas on clothing that keep people warm in cold buildings.

According to the study, heating a building consumes 47 percent of the energy used in the world, and a little more than 80 percent of that energy goes toward heating empty spaces in buildings rather than people. "This is important in the built environment, where we waste lots of energy by heating buildings—instead of selectively heating the human body," explains Rajiv Malhotra, Department of Mechanical and Aerospace Engineering assistant professor at Rutgers University–New Brunswick, in a Rutgers Today news release.

To create the patches, the researchers fused silver nanowires to polyester fibers using an intense pulsed-light sintering process. The patches are flexible and inexpensive, according to the researchers, and also maintained their durability after being exposed to high temperatures, humidity, bending, and laundering.

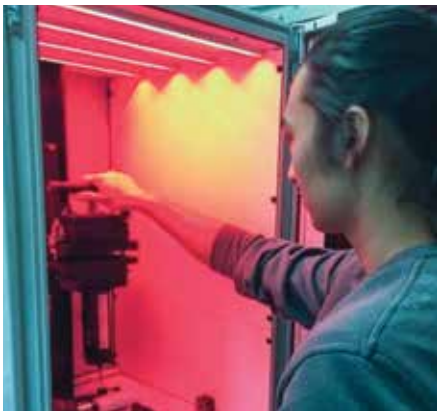
The researchers plan to continue their work with other smart fabrics to determine the best locations on the body to place the patches for maximum comfort.

The open-access paper, published in *Scientific Reports*, is "Rapid pulsed light sintering of silver nanowires on woven polyester for personal thermal management with enhanced performance, durability and cost-effectiveness" (DOI: 10.1038/s41598-018-35650-7). ■

Corporate Partner news

Lithoz CeraFab 8500 installed at Alfred University of Engineering

Alfred University's Inamori School of Engineering is the first in the country to



Credit: Alfred University

install a 3D printer capable of printing high-resolution ceramic materials.

Purchased through a United States Department of Energy Nuclear Energy University Program grant, the 3D printer—a Lithoz CeraFab 8500—is part of a suite of equipment at Alfred University that will form the Center for Advanced Ceramic Manufacturing and Education. The CeraFab 8500 will be used for research and education, as well as by industrial partners wanting to explore additive printing.

NSL now a member of America Makes

NSL Analytical Services, Inc. is now a member of America Makes, a collaborative partner in additive manufacturing and 3D printing technology research, discovery, creation, and innovation in the United States.

Nanoe expands its global presence to the US

After serving the European ceramic market for 10 years, Nanoe has now expanded to the United States, with a new office opening in Youngstown, Ohio.

With the goal to evolve into an international and diversified company, and having realized that the market for ceramic 3D printing is still very new and swiftly developing, Nanoe launched a new range of Zetamix, ceramic, and metal 3D printing filaments and Zetaprint, a ceramic and metal FDM 3D printer, just a few months ago. The new U.S. office will provide a platform for bringing these filaments closer to users. ■

IMFORMED insights

A snapshot of ceramic and glass raw material markets and trends from a non-metallic minerals industry expert.

Mike O'Driscoll
Guest columnist

Refractory mineral supply

Alternative solutions driven by China supply squeeze

This time last year I wrote an article entitled "2018: Year of the Dog likely to live up to its name for Chinese mineral consumers" (*American Ceramic Society Bulletin*, Vol. 97, No. 2, p.20). Well, it certainly did!

Already well into 2019, China's mineral supply squeeze continues to challenge world refractory (and other) producers, and from most indications, 2019 Chinese Year of the Pig is also likely to live up to its name.

A range of factors arising in 2017 and spilling into 2018 significantly compounded the shortage of key refractory (and other) mineral exports from China vital to the world's refractory manufacturing sector.

The situation created real problems for refractory manufacturers requiring dead burned magnesia (DBM), fused magnesia (FM), calcined bauxite, graphite, and fused alumina for making refractory shapes and monolithics.

China is well known as the world's primary source of most refractory minerals; there are perhaps >40 types of refractory raw materials (natural and synthetic) produced with a total production capacity of some >30m. tpa, of which 2–3m. tpa are exported.

What is fundamental to understand is that despite past supply bottlenecks occurring over the last two decades, these bottlenecks were short-lived. This time it is serious; it is not a cyclical phase. The fall-out is unlikely to be temporary for many Chinese mineral and refractory operations.

Unfortunately for the global refractories industry, where certain regions, such as India, have relied almost entirely on raw material supply from China, the crisis continues apace into 2019 and the world market must react and adapt to the new world of Chinese refractory mineral supply.

Credit: Mike O'Driscoll, IMFORMED, UK

Quality control at CMP's new calcined bauxite plant, Xiuwen.

China's minerals woe wears on

Although refractory mineral prices stabilised into early 2018, albeit remaining at high levels, 2017's "perfect storm" of robust pollution controls and environmental inspections (mine and plant closures), restricted and banned explosives provision (lack of primary ore availability), and closure of illegal businesses (reducing capacity) continued through 2018 to tighten refractory raw material supply and increase prices, thus living up to 2018's Chinese zodiac animal—Year of the Dog!

Uncertainty over physical supply availability and future pricing continues to challenge traders and refractory raw material buyers desperate to secure supply for 2019.

China's war on pollution, zealously driven by President Xi Jinping, accelerated in 2018 with the passing of a new Environmental Protection Tax Law and the old Ministry of Environmental Protection becoming the Ministry of Ecology and Environment (MEE).

November 2018 saw a new month-long round of environmental inspections in Jilin, Liaoning, Shandong, and Shanxi provinces—all key mineral production centers.

This crusade and its ramifications on Chinese industry is not going away anytime soon, particularly when 2020 has been officially designated a milestone year for China to be a "Moderately Prosperous Society."

Impact on magnesia, bauxite, and brown fused alumina

By Q3 2018, almost all production of high purity magnesia in Liaoning remained closed; all magnesite mining had closed, and had not yet restarted in the Anshan and Dashiqiao area, with some 90 percent of plants closed failing to meet new environmental standards.

Indeed, new emission standards for the magnesia refractory industry in Liaoning were enacted on Jan. 1, 2019, and have challenged both magnesia and refractory operating production capacity in the province.

Reports suggest there are plans to restart magnesite mining and exploration in the Haicheng area from mid-September 2019 at the earliest. The provincial government announced that in "the first half" of 2019, it will issue long awaited explosives to all "qualified mining enterprises," thus alleviating primary ore shortage.

Regarding bauxite supply, the primary producing provinces of Henan, Guizhou, and Shanxi have suffered serious interruptions of bauxite mining and calcined bauxite and fused alumina production, which will continue into 2019.

The government's drive to switch all plants from coal- to natural gas-fired kilns comes with technical and financial challenges to most producers, for example, adding some US$40–70/t to calcined bauxite prices.

In the key bauxite mining area of Xiaoyi, Shanxi province, raw bauxite production, which stood at about 10–20m tpa up to 2017, dramatically declined to just 3m tpa in 2018—this is raw feed-

CMP's new gas-fired rotary kiln for calcined bauxite started up in 2018 at Xiuwen, Guizhou.

Credit: Mike O'Driscoll, IMFORMED, UK

stock for both smelter grade alumina (majority of consumption) and non-metallurgical calcined bauxite grades.

By late November 2018, things had gotten worse. Reports from China stated that owing to high levels of pollution in Hebei, Shanxi, and Henan provinces, every plant was closed until further notice, regardless of whether they had secured environmental permits or had switched to natural gas.

At the time of writing, late January 2019, reports from China indicated that although some magnesia and bauxite operations had come back on stream, others had done so only to be shut down again, for example, Dazhong No.7 Grinding Wheel (fused alumina) on January 8, and Haicheng Magnesite Refractory General Factory on January 23.

Combined with the looming 3–4 week of "normal" disruption of supply chains by the Chinese New Year holidays from Feb. 5, 2019, prospects for a continuing squeeze on supply remain high.

Industry response: in China

There have been some positive moves forced upon the industry inside and outside China.

Within China, there is a drive to develop alternative and upgrade existing mineral processing methods to better utilise lower-grade refractory mineral deposits.

For example, a three-step fused magnesia production process using magnesite "rejects" via flotation has been developed at Liaoning Donghe Refractory Materials Group, and at least five flotation plant projects are in development and aiming to be on stream in 2019–20.

Meanwhile, there is also work on development of more remote magnesite sources, for example in Gansu province, and in Tibet.

Of significance has been the first move (in recent years) of a major western refractory producer to invest in China. In October 2018, Refratechnik GmbH, Germany, announced a major joint venture to develop a 100,000 tpa DBM flotation plant at Pailou, Haicheng, partnering with Haicheng Guotian Mining and Yingkou Jinlong Refractories. This may well light the fuse for more of such partnerships in 2019–20.

The new DBM flotation plant in construction at Pailou, Liaoning, for Refratechnik's joint venture with Haicheng Guotian Mining and Yingkou Jinlong Refractories.

Credit: Refratechnik

In Guizhou, where there is no mining ban in place (as yet) and pollution controls appear less stringent at present, there is a sense of opportunity by new players emerging to supply the large gap in the market from the closures in Henan and Shanxi.

CMP Guizhou Co. Ltd commenced calcined bauxite production with a new 100,000 tpa natural gas-fired rotary kiln near Xiuwen, fed by raw material from its own 2m tonne bauxite reserve Xiaotun mine.

Sky Metallurgy Mineral Co. Ltd owns 15 mines, a crushing plant, and a coke-fired rotary kiln in the Qingzhen area, which is expected on stream soon. Elsewhere in Guizhou, some 18 new gas-fired round (down draught) kilns and three new gas fired shaft kilns are in construction.

Other key areas of Chinese refractory development include using more silica and lime in refractories, evaluating new shapes of raw material grains, and synthetic raw materials, such as sintered alumina (tabular, modified, micro-pored, lightweight grades) to replace fused alumina grades, as well as increased refractory recycling.

Industry response: outside China

Outside China, certain refractory producers, such as Wonjin Wordwide, South Korea, have been forced to develop their own captive production of FM; likewise, world refractories leader RHI Magnesita restarted its Norwegian FM plant.

Unsurprisingly, the China situation boosted prospects of new and alternative refractory mineral projects in development worldwide, in particular: magnesite in Saudi Arabia, Serbia, Greece, Morocco, Turkey, Jordan, Australia, Brazil, Pakistan; bauxite in Guyana, Brazil, Australia; and graphite in Africa, Sri Lanka, Canada.

The ongoing U.S.-China trade war initially scared the U.S. refractory industry with all refractory minerals on the new import tariff list. However, industry lobbying succeeded in eventually excluding bauxite, BFA, DBM, FM, graphite, silicon carbide, and tabular alumina (remaining on the list are: andalusite, chamotte, dolomite, fused silica, kaolin, mullite, quartzite, sillimanite, zircon, abrasives, ceramics, refractories, slags, mineral wool).

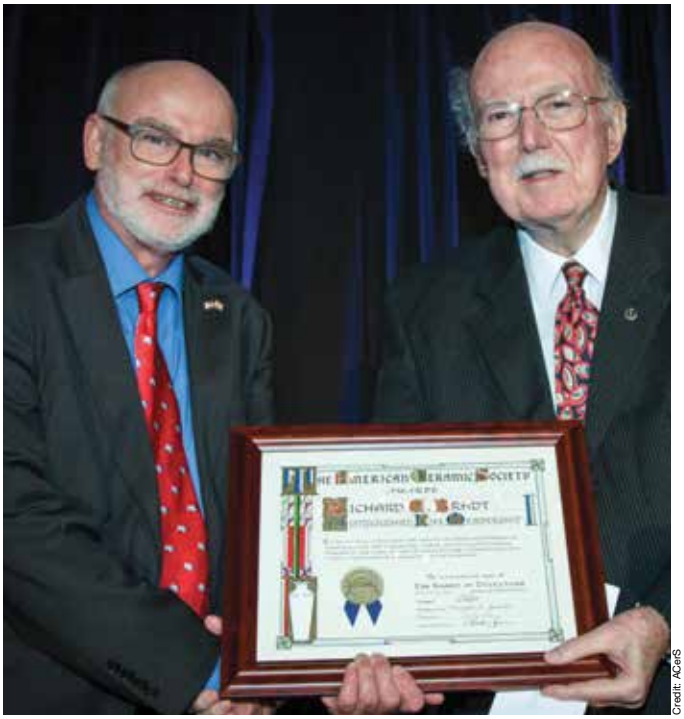
That said, there has been talk of some commodities possibly being reinstated on the list, so perhaps the U.S. industry is not out of the woods yet.

(continued to page 27)

The high grade refractory bauxite mining area at Qingzhen area, Guizhou, operated by Sky Metallurgy Mineral.

Credit: Mike O'Driscoll, IMFORMED, UK

Richard "Dick" Bradt, UNITECR cofounder, deceased



Credit: ACerS

Richard "Dick" Bradt, right, receives ACerS highest honor, Distinguished Life Member, from President Bill Lee in 2017.

The American Ceramic Society lost a Distinguished Life Member when Richard "Dick" Carl Bradt died on Jan. 3, 2019, at the age of 80.

Bradt grew up in the small town of Mascoutah, Ill., not far from St. Louis, Mo. The young Bradt went to MIT for his undergraduate education in metallurgy and Rensselaer Polytechnic Institute for M.S. and Ph.D. degrees in materials engineering.

On graduation, Bradt began a long career as a professor, holding positions at The Pennsylvania State University, University of Washington, University of Nevada-Reno, and University of Alabama, where he was emeritus professor. He was especially proud that three of those institutions won national football titles.

Over the years, Bradt supervised 45 Ph.D. students, 60 master's degree students, and published more than 400 articles in 50 professional journals. He secured more than $25M from government, industry, and private sources to support fundamental research in refractories, mechanical properties, minerals and mineral processing, eutectic solidification, and more.

His work has been recognized by his colleagues around the world with many awards, including the most prestigious awards in the refractories and ceramics community. Recognition from ACerS includes Distinguished Life Member, Kingery Award, Theodore J. Planje St. Louis Section Award, Fulrath Award, and John Jeppson Medal. His skill as a teacher was recognized with multiple awards from the universities where he taught.

Bradt's work took him all over the globe—to Japan, Brazil, Chile, Germany, England, and more. As his international perspective grew, he saw the need for the global refractories community to have a forum for exchanging ideas and building a global network. In 1987, Bradt and Japanese colleague, T. Hayashi, worked with four international organizations—ACerS; Technical Association of Refractories (TARJ), Japan; Latin American Association of Refractory Manufacturers (ALAFAR); and the German Refractories Association (GRA)—to organize the Unified International Technical Conference on Refractories (UNITECR). Held every two years since 1989, the conference brings together 700 engineers, scientists, educators, and business people from all parts of the globe. UNITECR quickly became the leading conference for the global refractories industry. Bradt and Hiyashi were honored for their vision when they were named the first Distinguished Life Members of UNITECR at its inaugural conference in 1989.

Bradt was well aware of his stature in the refractory and ceramics community and leveraged his influence to the greater good. After "retirement," he continued to consult globally and provide expert witness. He shared his vast knowledge by teaching short courses through ACerS on mechanical properties with his friend and colleague George Quinn. He alerted the community to the dangers of thermally strengthened glass baking dishes with an article in the September 2012 *ACerS Bulletin*. The rigor of his science prevailed against a vigorous lawsuit that followed. His motivation for the article was simple—he wanted to protect people from harm.

Bradt is survived by Elizabeth, his wife of 58 years, two daughters, Meredith and Claire, and three grandsons. ■

In memoriam

Darnell Burks
Dale W. Rice
Clarence Vance

Some detailed obituaries can be found on the ACerS website, www.ceramics.org/in-memoriam.

The American Ceramic Society names new executive director


Mecklenborg

The American Ceramic Society Board of Directors announced the appointment of Mark J. Mecklenborg as executive director effective Jan. 1, 2019. He succeeds previous executive director Charlie Spahr, who retired at the end of 2018. Mecklenborg is the Society's 11th executive director.

ACerS past president Michael Alexander says, "Mark brings an energy and passion for the Society. He understands the value of the membership to the Society, and he brings a depth of understanding of the Society's finances."

Mecklenborg joined the Society in 1995 and was director of membership, meetings, and publications. Mecklenborg's achievements include launching two new journals—*International Journal of Applied Ceramic Technology* and *International Journal of Applied Glass Science*—and negotiating a long-term publishing agreement with Wiley. Under his leadership, the Society introduced new membership opportunities for graduate students, expanded its local Section network, and started new Chapters for international members. He developed strategic partnerships with international ceramic and glass organizations leading to prominent conferences in the field, and he managed the ACerS meetings portfolio on a wide range of topical meetings in the United States and abroad.

Mecklenborg holds an MBA from The Ohio State University and a B.A. in English Education from Miami University (Oxford, Ohio). He belongs to the Council of Engineering and Scientific Society Executives, the Ohio Society of Association Executives, and the American Society of Association Executives.

"This is an exciting time at the Society. We've built strong momentum over the past five years, and I look forward to working with ACerS leaders and members to build an exceptional member experience for everyone working in the ceramic and glass industry," Mecklenborg says. ■

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

Corporate Partner news

Welcome ACerS newest Diamond Corporate Partner: Corning.

CORNING

ACerS' Corporate Partnership Program offers benefits that include advertising, sponsorships, meeting registrations, technical resources, and more. For more details, contact Kevin Thompson at 614-794-5894 or kthompson@ceramics.org. ■

Volunteer Spotlight

ACerS is pleased to announce a new feature through which we spotlight volunteers who demonstrate outstanding service to The American Ceramic Society through volunteerism.


Zapata-Solvas

Our first honoree, who has set a tremendous example for other Chapter and Section leaders, is Eugenio Zapata-Solvas, Chair of the UK Chapter of ACerS.

Eugenio earned a B.Sc. in Physics (2004) and a Ph.D. award (2008) from the University of Seville (Spain). He has nearly 15 years' experience dedicated to ceramic materials science, focusing on the study of advanced ceramics for extreme environments and energy-efficient sintering techniques in institutions such as the University of Oxford, Spanish National Research Council (CSIC), and Imperial College London.

Eugenio's volunteer roles include:

- Chair and founding organizer of the UK Chapter of The American Ceramic Society since October 2016, promoting and facilitating events to enhance interaction between the ceramics industry and ceramic early career researchers and academics within the UK,
- Named ACerS Global Ambassador in May 2017 for his oustanding leadership of the UK Chapter since its inception,
- Editorial Board member on "Chemical Physics" for *Scientific Reports* journal from Nature Publishing group since 2015.

He joined UCL BEAMS Research Coordination office (Office of the Vice Provost for Research) as a strategic research facilitator (Platforms & Industry) in July 2018, focusing on the strategic support and promotion of the modern Industrial Strategy from UK Government within University College London.

We extend our deep appreciation for Eugenio's service to our Society! ■

St. Louis Section/RCD 55th Annual Symposium on Refractories: March 26–28, 2019

The St. Louis Section and the Refractory Ceramics Division of The American Ceramic Society will hold the 55th Annual Symposium on Refractories with the theme "Shaped Refractories" on March 27–28, with a kickoff event on Tuesday, March 26. The meeting will be held in St. Louis, Missouri, at the Hilton St. Louis Airport Hotel. Co-program chairs are Beau Billet, Edward Orton Jr. Ceramic Foundation, and Dawn Hill, Xertech Specialties/Artech.

A block of rooms has been set aside at the Hilton (314-426-5500). To receive the $113 rate, mention the group code "ACS" when making your reservation. Make online reservations at https://secure3.hilton.com/en_US/hi/reservation/book.htm?execution=e1s1

For further information visit https://ceramics.org/event/55th-annual-st-louis-section-refractory-ceramics-division-symposium-on-refractories or contact Patty Smith at 573-341-6265 psmith@mst.edu. ■

Names in the news

Three ACerS members named Fellows of the National Academy of Inventors

Quanxi Jia, Nathan Newman, and Alan Weimer were named 2018 Fellows of the National Academy of Inventors, in recognition of them creating or facilitating outstanding inventions that have made a tangible impact on quality of life, economic development, and the welfare of society.


Jia

Jia is known for his seminal contributions to the development of coated superconductors and to the advancement of processing and application of metal-oxide materials, and holds over 49 United States patents.


Newman

Newman's research focuses on the growth, characterization, and modeling of novel solid state materials. He has been granted 13 U.S. patents for a wide range of applications, from high-powered electronics and ultra-low-power computing to direct energy generation from a nuclear source.


Weimer

Weimer is named inventor on 38 issued and eight pending U.S. patents. Specifically, he invented a platform technology for functionalizing particle surfaces with ultrathin ceramic films that are being commercialized to protect active materials in LEDs and high energy lithium-ion batteries. ■

Kurtis receives American Concrete Institute award


Kurtis

Kimberly E. Kurtis received the Arthur R. Anderson medal from the American Concrete Institute in recognition of her outstanding contributions to the advancement of knowledge of concrete as a construction material. Kurtis's research on multi-scale structure and performance of cement-based materials has resulted in more than 200 technical publications, as well as three U.S. patents. ■

AWARDS AND DEADLINES

New for 2019: The Navrotsky Award for Experimental Thermodynamics of Solids

Nominations Deadline: **March 30, 2019**

The Navrotsky Award for Experimental Thermodynamics of Solids is presented biennially to an author who made the most innovative contribution to experimental thermodynamics of solids technical literature during the two calendar years prior to selection. The award is a $5,000 cash prize accompanied by a certificate containing a citation of the achievement on which the award is based. The presentation of the award is made at the Annual Meeting of the Society and the recipient is expected to present a talk on the work cited for the award or closely related to it. More information may be found at https://ceramics.org/awards/navrotsky-award ■

Electronics Division names best student posters and best student oral presentation of EMA 2019

The Electronics Division presented awards for outstanding student work during the January 2019 Conference on Electronic Materials and Applications in Orlando, Fla. Congratulations to these students:

Best Posters

First place

Ferroelectric HfO_2 thin films with abundant dopants, **Shuhei Nakayama**, Sophia University

Second place

Investigating the roles of grain size, dopant choice, and orientation of ZnO thin film varistor prototypes, **Kevin Ferri**, The Pennsylvania State University

Third place

Property and structure analysis of novel 2D group-III oxides predicted by evolutionary algorithm, **Halee Lester**, University of Florida

Best Oral Presentations

First place

Design of ferroelectric polarization states during epitaxial growth, **Nives Strkali**, ETH Zürich

Second place

Polarization and permittivity dependence on electrode stress for ferroelectric $Hf_{0.58}Zr_{0.42}O_2$ films, **Shelby Fields**, University of Virginia

Joint third place

Ni coarsening in sintered $Li_4Ti_5O_{12}$ anode composites, **William Huddleston**, Case Western Reserve

Symmetry-based identification of 2D materials for piezoelectric appliances, **Joshua T. Paul**, University of Florida ■

Awards and deadlines (cont.)

Take note of three awards with a May 15th 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, 2019** deadline. Award eligibility for each can be found at 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 free MS&T registration.

Electronics: Edward C. Henry Award

This award is given annually to 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 2019 essay topic is "Novel Synthesis of Functional Ceramics."

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

A case for continuous membership

Picture this: You have been nominated to be an ACerS Fellow . . . but wait! You have not held continuous membership in ACerS. Sadly, that means that you do not qualify for the Fellows distinction.

What if this happened to you? Have you been counting on renewing your ACerS membership only when you attend a meeting or conference? If you miss that opportunity, you risk creating a gap in membership and an interruption of important members benefits, such as online access to journals and *Bulletin* archives.

That interruption would also make you ineligible to become an ACerS Fellow, which requires that candidates be persons of good reputation who have reached their 35th birthday and who have been members of the Society at least five continuous years at the time of nomination. So keep your membership current. You can easily renew online each year. For more information about Fellows and other awards eligibility, visit: https://ceramics.org/members/awards. ■

Credit: Pxhere

STUDENTS AND OUTREACH

Shot glass competition winners at ICACC 2019

One of the highlights of the Expo each year during the ICACC conference is the Shot Glass Competition with the shot glasses provided by Schott North America. The competition—mainly for fun and bragging rights—involves engineering a container composed only of pipe cleaners that is designed to protect a shot glass as it is dropped from increasing heights.

As in past years, the organizers arranged for a motorized lift to be available—and it was needed! There were 22 total teams, made up of 35 individuals with a large crowd to watch the excitement. Four total shot glass entries survived an over 21-foot drop.

The winners this year were: a team from Purdue University; a team from Rutgers University; a team from Missouri S&T, and a team from Kawasaki Heavy Industries, Japan. ■

Congratulations to SIFT competition winners at ICACC 2019!

Kimina Ghaffari, and Rafael Riera, both from the University of Florida, won the 2nd Student Industry Failure Trial (SIFT) competition at ICACC19, hosted by the ACerS President's Council of Student Advisors. Materials data were collected for previously failed ceramic parts provided from industry, which participants analyzed to determine the material and how the parts failed. Students then suggested possibilities for material improvement. Congratulations to Kimina and Rafael! ■

Show your expertise in ACerS Next Top Demo competition

Show off your demonstration skills! Get a group of fellow students together and submit a video of a ceramic or glass outreach demonstration. ACerS Next Top Demo is a virtual competition organized by ACerS President's Council of Student Advisors to help educate the public while advertising the community outreach that you and your university/group already perform. Visit www.ceramics.org/pcsa to view the PCSA Programs and find out how to compete and send in your video submissions for the Next Top Demo competition. Deadline is **April 15, 2019**. ■

Students and outreach (cont.)

ACerS GGRN membership for graduate-level 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)! ACerS GGRN is a membership in ACerS that 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 meeting and free webinars on targeted topics relevant to the ceramic and glass graduate student community.

ACerS GGRN is only $30 per year. If you are a current graduate student, focusing in ceramics or glass, visit www.ceramics.org/ggrn to learn what GGRN can do for you and to join directly. ■

MEMBER SPOTLIGHT

ACerS Lifetime Member gets considerable ROI from involvement in Society

Credit: S.K. Sundaram

ACerS Fellow S.K. Sundaram has accomplished a lot in his 20+-year career.

When he arrived in the United States from India in 1990 as a graduate student at Alfred University, he already had a technical degree in ceramic engineering. And as soon as he settled in at Alfred to begin his studies, he joined ACerS in 1991.

"I was aware of ACerS before I came to the U.S.," he explains in a recent interview. "I would access the *Bulletin* and read the articles, but back then I never thought I would end up in the United States."

"At Alfred, everyone joins the American Ceramic Society," he adds, smiling.

Since 2011, Sundaram has been Inamori Professor of Materials Science & Engineering at the Inamori School of Engineering, The New York State College of Ceramics at Alfred University, where he teaches and mentors students and secures funding for sponsored research. Prior to coming to Alfred, he spent 16 years at Pacific Northwest National Laboratory where he was chief materials scientist in the Energy & Environment Directorate.

Sundaram earned his Ph.D. at Georgia Institute of Technology before he joined PNNL. "Between Alfred

Member spotlight (cont.)

University and Georgia Tech it was a good educational experience," he recalls.

His career reflects a significant number of achievements that include nearly 200 technical presentations, 115 publications, 33 technical reports, seven patents, and more than 30 awards.

And while he was busy accomplishing all of that, he was immersing himself in various ACerS activities. Sundaram's early ACerS experience was mainly in attending meetings, he recollects. But he eventually realized he enjoyed networking and wanted to get more involved in organizing events.

Sundaram joined the Nuclear & Environmental Technology Division after joining ACerS, where he organized symposia and became NETD chair after holding other Division offices. He also was session chair, contributor, and presenter for many of the sessions.

"I like networking with a lot of people at meetings," he says, "and I especially liked the organizing part of it."

Sundaram says he attends all of the Division meetings, including the Society's Annual Meeting. He also attends what he refers to as "special" meetings, such as MCARE 2018.

As he "climbed the volunteer ladder" and participated in ACerS and NETD activities, Sundaram earned recognition along the way. He earned Best Paper Award for NETD. He also earned the D.T. Rankin Award for exemplary service to the Division. Sundaram (a team member) took first place in the ceramographic competition, earning the Roland B. Snow Award. He was eventually elevated to Fellow status in 2006.

Since he became a member, Sundaram has witnessed the giant strides ACerS has made to become a more global organization. "It's great that the Society has been reaching out internationally to a broader audience," he notes. "It makes me feel good that we're getting more international recognition." He became a Lifetime Member a couple years ago because of the value he found in joining ACerS.

What advice would he give to professors and students who are considering joining ACerS?

"ACerS has helped me a lot," he says. "The biggest reward is that you get a lot in return for the membership fee you pay. You get to meet and learn from a lot of experts and industry people. I always encourage my students to join.

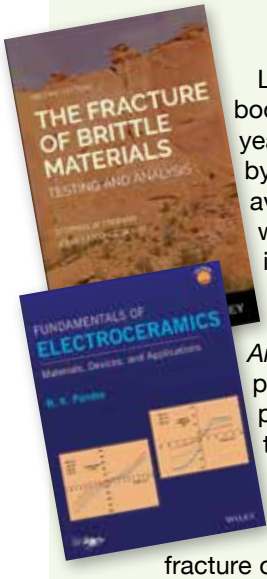
"It also helps in finding a job," he says referring to an important advantage for students. "You get the immediate benefit of having a network to meet people—which is more important than getting a job." In other words, Sundaram suggests that networking can eventually lead to a job.

And when Sundaram gets recognition from the Society, his employer notices. Sundaram says there is an unwritten benefit of being an ACerS member. "It's important for the employer because they look at my involvement as a big accomplishment," he says. "And our employer recognition goes up," he adds, referring to the recognition and exposure he receives from his ACerS awards and volunteer involvement.

"The biggest reward besides the networking is getting recognized for accomplishments," he says. "And becoming a Fellow was definitely an honor. I never imagined I would be a member, let alone become a Fellow." ■

ACERS BOOKSHELF

Check out new titles from ACerS and ACerS/Wiley



Looking for a new book to read this year? Two new titles by Wiley-ACerS are available on www.wiley.com/ceramics. *The Fracture of Brittle Materials: Testing and Analysis, 2nd Edition* provides a modern, practical approach to the understanding and measurement procedures relevant to the fracture of brittle materials.

Fundamentals of Electroceramics: Materials, Devices, and Applications provides in-depth treatment of electroceramics with emphasis on applications in microelectronics, magneto-electronics, spintronics, energy storage and harvesting, sensors and detectors, magnetics, and in electro-optics and acousto-optics.

Also available is the new *Progress in Ceramics Series: The Sintering of Ceramics*. This online resource compiles 118 articles on the topic of sintering selected from three different ACerS publications: *The American Ceramic Society Bulletin* (39 articles); *The Journal of the American Ceramic Society* (23 articles); and *Ceramic Transactions* (57 articles). Many of the articles in this collection are based on presentations from the 2009 and 2011 International Conference on Sintering.

CERAMIC AND GLASS INDUSTRY FOUNDATION

Winter Workshop 2019 exceeds expectations

The 2019 ACerS Winter Workshop took place Friday, January 25 through Tuesday, January 29, at the Hilton Daytona Beach Oceanfront Resort in Daytona Beach, Florida.

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 15 travel grants for international students, and a total of 52 students in all participated in the event.

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

Derek King, research scientist of UES, Inc: "Ceramic matrix composite constituent processing and properties for high temperature aerospace applications"

David L. Poerschke of the University of Minnesota: "Feeding the virtual test pipeline: Developing thermodynamic descriptions of deposit-induced degradation of thermal and environmental barrier coatings"

Anabel Lanterna of the University of Ottawa: "Light-responsive materials in heterogeneous photocatalysis: TiO_2 and beyond"

Roger Narayan of North Carolina State University: "Ceramics for medical applications"

In addition, career development was the theme of the afternoon sessions, with the following speakers:

Riccardo Marin of the University of Ottawa: "A colorful journey on the bandwagon of lanthanide ions through commitment, perseverance, and friendship"

David L. Poerschke of the University of Minnesota: "Communicating your science: Strategies to effectively (and ethically) engage diverse audiences"

Kimberly Hammer of GE Research: "The broken road has many treasures! A career discussion on risk, adaptability and opportunity"

Winter Workshop 2020 will take place in Daytona Beach, Fla., Jan. 24–28, 2020. ■

Transparent ceramics far tougher than tempered glass

Looking to minimize microstructure defects, a team of scientists at Forschungszentrum Jülich in Germany demonstrated feasibility of a promising concept: stabilizing transparent ceramic surfaces through functional coatings.

Transparent polycrystalline ceramics are a promising alternative to traditional glass technologies. Already, transparent ceramics are replacing glass in lasers due to their high refractive index. However, transparent ceramics' optical transparency is traditionally less than glass, and the ceramics do not reach their full strength potential because of microstructure defects, which limit their ability to function well as a cover glass.

"Our goal was to transfer the concept of strengthened glass to transparent ceramics for the first time," says Olivier Guillon, ACerS member and head of Materials Synthesis and Processing at Jülich's Institute of Energy and Climate Research in Germany, in a press release. "Similar to the idea behind Gorilla Glass, which is widely used in mobile phones, we aimed to stabilize the surface of transparent ceramics by applying a thin coating of another material."

However, instead of strengthening their material through ion-exchange—the process used to strengthen Corning's Gorilla Glass—the Jülich scientists used a coating and thermal treatment to strengthen their material.

They heated the surface of a transparent zirconia ceramic and then used vapor deposition to coat it with an ultrathin layer of yttria, less than a micrometer thick. They then annealed the material in argon atmosphere at 1,450°C for 1–12 hours and quenched in a furnace having relatively rapid natural cooling, approximately 10°C/min down to 800°C.

The yttria coating reduced light reflections on the transparent zirconia surface, but more importantly, the yttria helped generate a high compressive stress on the surface during cooling. "Due to the different thermal properties of the two materials—zirconia expands more than yttria when heated, and shrinks more when cooled—a high degree of compressive stress is generated in the coating during cooling," explains Martin Bram, head of the research group, in the press release. "This stress causes the surface of the component to compress, effectively preventing cracking. As a result, the component is more stable and its surface more resistant to scratches."

Credit: Hiltrud Moitroux, Forschungszentrum Jülich

Forschungszentrum Jülich scientists created yttria-coated transparent zirconia ceramics that demonstrated fracture toughness values far higher than tempered glass.

The researchers showed their method doubles or even triples the fracture toughness of transparent ceramics, achieving fracture toughness values far higher than tempered glass. Additionally, because the technique can be applied as an aftertreatment to finished workpieces and only takes a few hours to perform, it is suitable for industrial mass production. "Our results clearly indicate that the technique can be applied to real-life applications," note the researchers in the press release.

The paper, published in *Scientific Reports*, is "Increasing fracture toughness and transmittance of transparent ceramics using functional low-thermal expansion coatings" (DOI: 10.1038/s41598-018-33919-5). ■

Research News

Silicon paradox: Scientists discover "impossible" material according to modern chemistry laws

An international team of physicists and materials scientists from NUST MISIS, Bayerisches Geoinstitut (Germany), Linkoping University (Sweden), and the California Institute of Technology (U.S.) discovered an "impossible" modification of silica-coesite-IV and coasite-V materials, which should not exist based on modern laws of chemistry. According to Pauling's rules, "vertices" connect fragments of atomic lattice in inorganic materials. Because the compound by "faces" is the most energy-consuming way of forming chemical bonds, it should not exist in nature. However, the team showed experimentally and proved using calculations that such a connection is possible if materials are put in conditions of ultrahigh pressures. For more information, visit http://en.misis.ru/university/news/science/. ■

Spintronics "miracle material" put to the test

A team of researchers led by University of Utah physicists successfully incorporated hybrid perovskite into two spintronic devices. The first device is a spintronic light-emitting diode that uses a magnetic electrode and electron holes polarized to accommodate electrons of a certain spin. The second device is a spin valve that can not only flip the polarity of magnetic materials in the valve but can inject spin into the device and then cause the spin to wobble within the device using magnetic manipulation. Taken together, these experiments show that perovskite works as a spintronic semiconductor, and brings the idea of a spintronic transistor one step closer to reality. For more information, visit https://unews.utah.edu. ■

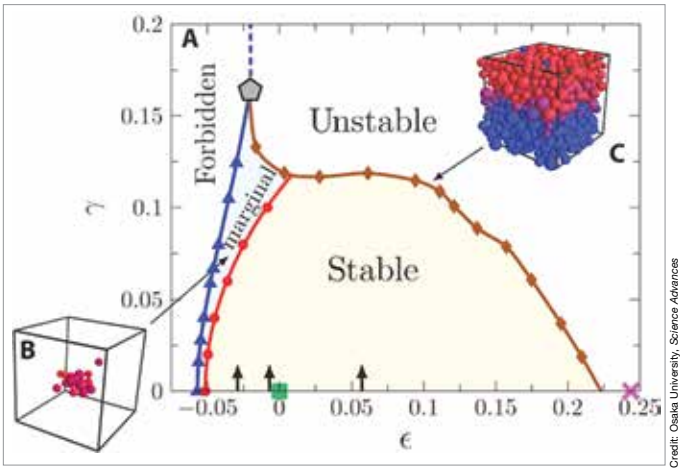
Mapping glass response to strain

Yuliang Jin, lead author and associate professor at Chinese Academy of Sciences, and his coauthors from Osaka University and CNRS used numerical simulations of hard spheres (a model glass former) to show how glass elasticity, plasticity, yielding, and jamming relate to how a glass is annealed.

Unlike ordinary states of matter such as gases, liquids, and crystals, properties of glass strongly depend on the details of the preparation protocol. That means the constitutive laws of glass, which characterize their macroscopic properties, depend on preparation protocols, such as annealing history.

"The spheres don't represent real molecules, but they do show whether such dense glasses are elastic," says Hajime Yoshino, coauthor and associate professor at Osaka University, in a press release. "We simulated how they responded to shear and normal [volume] strains. Our large supercomputers fully mapped out the strain phase-diagrams of glass formers for the first time, to explore their rheology."

Each simulated glass showed four basic trends. Under small strains they were perfectly elastic, but at higher strains they



Credit: Osaka University, *Science Advances*

A team of researchers led by Osaka University developed a phase diagram to understand the relationship between strain in glass and deformation behavior.

2D materials may enable electric vehicles to get 500 miles on a single charge

University of Illinois at Chicago researchers synthesized 15 different types of 2D transition metal dichalcogenides (TMDCs) and experimentally studied the performance of them as catalysts in an electrochemical system mimicking a lithium-air battery. Compared to conventional catalysts such as gold or platinum, TMDC reaction rates are much higher because they help speed both charging and discharging reactions occurring in lithium-air batteries. Additionally, the 2D TMDCs and the ionic liquid electrolyte act as a cocatalyst system that helps the electrons transfer faster, leading to faster charges and more efficient storage and discharge of energy. For more information, visit https://today.uic.edu. ■

became partially plastic, meaning they failed to recover their original state when strain was removed. As strain reached even higher levels, glass faced either of two opposite fates: total failure by fracturing (yielding) to release stress, or complete stop by jamming.

On the phase diagram, the region between yielding (brown line) and jamming (blue line) defined where glass remained stable. Importantly, the researchers did notice a difference between well-annealed and poorly-annealed glass when mapping the stable region for each.

"Our simulation results show that a well-annealed glass ... yields abruptly—it is brittle," say the researchers in the paper. "However, a poorly annealed glass ... may instead continuously yield into a plastic flow state—it is more ductile."

"We expect that near the melting point, even a well-annealed glass would behave similarly to a poorly annealed one, as it would become much 'softer' upon decompression," they add.

In addition to the specific findings of how annealing relates to glass deformation response, Jin says the results also reveal an important general finding. "Our work is the first to demonstrate that ultimate fate of a glass under shear strain can be either yielding or jamming," he says.

What do these results mean for glass modeling in the future? According to the researchers, an immediate application would mean modification of current mean field theory. "The possibility of two yielding mechanisms is missed by the current [mean field] theory," say the researchers in the paper. "A dynamical extension of MF might account for these effects."

The open access paper, published in *Science Advances*, is "A stability-reversibility map unifies elasticity, plasticity, yielding, and jamming in hard sphere glasses" (DOI: 10.1126/sciadv.aat6387). ■

Research News

MXene researchers find 2D transition metal carbides react with water

Researchers at Missouri University of Science and Technology discovered that 2D titanium carbide materials can react with water without the presence of other oxidizers. They systematically tested the hydrolysis and chemical stability of MXenes $Ti_3C_2T_x$ and Ti_2CT_x in water and nonaqueous colloidal solutions exposed to oxygen and/or inert gas environments in different combinations. The calculated time constant for degradation of $Ti_3C_2T_x$ dispersed in an inert gas environment exceeded five years, in contrast to the same MXene dispersed in water, where more than half of it would transform into titania in an oxygen-less atmosphere over about 41 days. For more information, visit https://news.mst.edu/2019/. ■

Smooth grain boundaries to lower operation temperatures

Ricardo H. R. Castro, ACerS member and professor and associate dean for research and graduate studies at the University of California, Davis, and his colleagues from UC Davis, Idaho National Labs, University of Utah, and Russian Academy of Sciences, looked at how to improve solid oxide electrolyte performance in a lower temperature range by mitigating the blocking effect of grain boundaries.

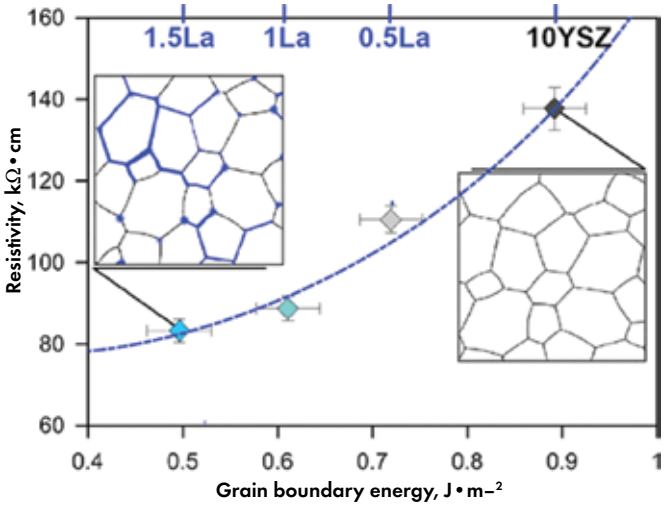
In their study, Castro and his colleagues looked to increase ionic conductivity in yttria-stabilized zirconia by smoothing grain boundaries by doping with lanthanum. "There are the same number of [grain] boundaries," Castro explains in an email, "but those [boundaries] have less defects (less broken bonds, for instance) and hence lower energy."

Using scanning transmission electron microscopy-based energy dispersive spectroscopy, they observed segregation of lanthanum to grain boundaries and a reduction in local excess energy.

When they then measured ionic conductivity using impedance spectroscopy in the range 300–550°C, they found that bulk values of conductivity between samples were similar, but grain boundary conductivity values demonstrated small incremental increases proportional to lanthanum concentration.

"The results suggest rare-earth ions with favorable grain boundary segregation enthalpy can smooth out the energy landscape across grain boundaries and thus facilitate ion mobility in the nanocrystalline electrolyte," say the researchers in the paper.

As encouraging as these results are, Castro says it is only the first step of the research process. "This was a proof of [concept] that the 'healing' of the blocking effect is possible by looking at the problem from an energetic viewpoint," says Castro. "But identifying the best dopant is still an on-going research."



Credit: Ricardo Castro. Reprinted with permission from *The Journal of Physical Chemistry C*, 2018, 122(46), pp. 26344-26352. Copyright 2018 American Chemical Society.

Researchers found that by smoothing grain boundaries in yttria-stabilized zirconia, they could increase the material's ionic conductivity at lower temperatures.

The open access paper, published in *The Journal of Physical Chemistry*, is "A strategy to mitigate grain boundary blocking in nanocrystalline zirconia" (DOI: 10.1021/acs.jpcc.8b08877). ■

Gelatin is key ingredient in new hydrogen fuel catalyst

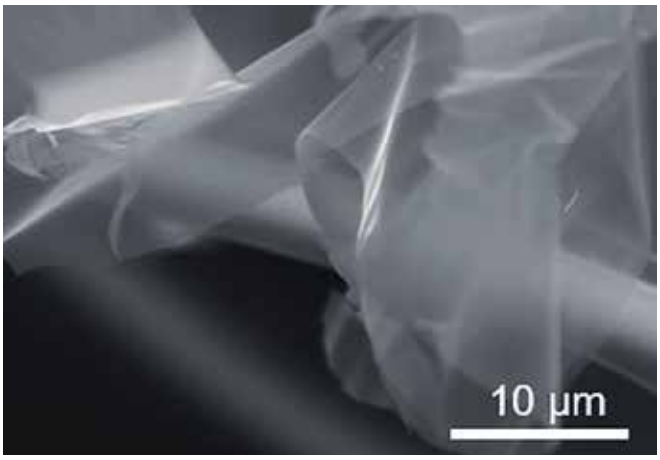
"Platinum is expensive, so it would be desirable to find other alternative materials to replace it," says Liwei Lin, professor of mechanical engineering at the University of California, Berkeley, in a UC Berkeley press release. Lin was senior author of a new UC Berkeley study that found a catalyst based on gelatin splits water molecules as effectively as—and much more cheaply than—the current best platinum-based catalyst.

To create the catalyst, the researchers mixed gelatin and a metal ion—either molybdenum, tungsten, or cobalt—with water, and then let the mixture dry. Lin says the gelatin self-assembles layer by layer as it dries, and because the metal ion is carried by the gelatin, the metal ions also arrange into flat layers. The researchers then heat the mixture to 600°C, triggering the metal ions to react with carbon atoms in the gelatin and form large, nanometer-thin sheets of metal carbide; the unreacted gelatin burned away.

When tested, molybdenum carbide split water most efficiently, followed by tungsten carbide and then cobalt carbide. Mixing molybdenum ions with a small amount of cobalt boosted the performance even more.

"We found that the performance is very close to the best catalyst made of platinum and carbon, which is the gold standard in this area," says Lin in the press release. "This means that we can replace the very expensive platinum with our material, which is made in a very scalable manufacturing process."

The paper, published in *Advanced Materials*, is "Self-assembly of large-area 2D polycrystalline transition metal carbides for hydrogen electrocatalysis" (DOI: 10.1002/adma.201805188). ■



Credit: Xining Zang, copyright Wiley

A magnified view of the 2D metal carbide catalyst that UC Berkeley researchers found splits water molecules as effectively as—and much more cheaply than—the current best platinum-based catalyst.

Creating diamonds at room temperature

In 2015, North Carolina State University researchers successfully created diamonds without high temperature nor high pressure by using high-power nanosecond laser pulses to convert carbon thin films into diamond. This year, the researchers extended their research to show the same technique can also convert carbon nanofibers and nanotubes.

"Our earlier work was on conversion [of] carbon thin films into diamond or Q-carbon," says Jagdish (Jay) Narayan, chair professor in the materials science and engineering department at NC State and corresponding author of the paper, in an email. "This breakthrough is focusing on conversion of carbon fibers and nanotubes into diamond fibers, which opens many more applications ranging from field emission frictionless motors to quantum sensing and computing."

Key to their success was undercooling. Unlike with carbon thin films, Narayan and his colleagues did not need substrates to ensure proper undercooling in carbon nanofibers and nanotubes.

"The sapphire, plastic, and glass substrates provide sufficient undercooling in the case of amorphous thin films of carbon," say the researchers in the paper. "In the present case, the restriction of heat flow (1D) in [carbon nanotubes/carbon nanofibers] provides enough undercooling to cause the conversion."

The researchers found carbon nanofibers and nanotubes responded similarly to the conversion process, but diamonds created from nanotubes had considerably sharper tips than diamonds created from nanofibers due to a smaller amount of available carbon.

Looking just at carbon nanofibers, the researchers discovered that below a critical diameter, the entire carbon fiber turned into diamond. Above that critical size, diamond nanocrystallites formed on the surface, some of which grew rapidly to form diamond nanorods. Compared to untreated carbon fibers, the laser-annealed fibers considerably enhanced diamond nucleation and growth.

Currently, Narayan says they are conducting field emission studies to create more efficient frictionless motors and display devices. Additionally, NC State has filed a patent for this new method of processing diamond fibers.

The paper, published in *Nanoscale*, is "Direct conversion of carbon nanofibers and nanotubes into diamond nanofibers and the subsequent growth of large-sized diamonds" (DOI: 10.1039/C8NR08823C). ■

Glass-ceramics offer a winning (and strong) smile

Researchers at Ångström Laboratory at Uppsala University in Sweden published a paper describing a new glass-ceramic they developed with enough strength to compete against other ceramics used in dental applications.

Compared to porcelain-based and zirconia crowns, glass-ceramics offer better color match to surrounding natural teeth. However, lithium disilicate glass-ceramics are not nearly as strong as conventional ceramic crowns, and must be used in conjunction with resin bonding cements.

"The dilemma in dentistry today is that existing strong materials are white in color (a white that does not look natural), and materials that are translucent are not as strong," explains Wei Xia, who heads the research team along with Håkan Engqvist and Le Fu, in a press release. "Our ceramics are three times stronger and also translucent."

Credit: Ivoclar Vivadent North America, YouTube

Lithium disilicate, the most common glass-ceramic used in dental applications, could be replaced by zircon glass-ceramics developed by researchers in Sweden.

In their research, Xia and his colleagues prepared zircon (ZrO_2–SiO_2) nanocrystalline glass-ceramics comprising monocrystalline zirconia nanoparticles embedded in an amorphous silica matrix. When they measured flexural strength of the material, they found it averaged 1 GPa. Not only was this value well above the average flexural strength of lithium disilicate, the most-common dental crown glass-ceramic (flexural strength between 200 to 500 MPa), this value was close to the strength of yttrium partially stabilized tetragonal zirconia (about 900 to 1,200 MPa), which is the strongest zirconia-based ceramic used in dental applications.

Notably, these zircon glass-ceramics achieved their flexural strength without the need for resin bonding cements. Instead, their strength came from the zirconia nanoparticles bonding strongly with the silica matrix to form a zirconium-oxygen-silicon superlattice.

The paper, published in *Nano Letters*, is "Ultrastrong translucent glass ceramic with nanocrystalline, biomimetic structure" (DOI: 10.1103/PhysRevMaterials.3.013602). ■

Reducing air pollution: Insulating ceramic rocket stoves

According to the World Health Organization, about 3 billion people cook using polluting open-air fires or simple stoves fueled by kerosene, biomass (e.g., wood, animal dung), and coal. These cooking techniques emit large quantities of health-damaging particulate matter, and each year close to 4 million people die from illness attributable to these pollutants, the majority of whom are women and children.

Because most of the 3 billion people relying on solid mass for fuel live in developing and emerging countries, any proposed stove design to limit pollutants must be affordable, accessible, and easy to use. One proposed design comes from Reid Harvey, a ceramic industrial designer and senior scientist at TAM Ceramics.

Harvey came up with the idea for insulating ceramic rocket stoves by adapting the basic rocket stove design, a type of low-mass stove designed to burn small pieces of wood very efficiently.

Unlike other stoves that have metal components, Harvey says his design uses only small, curved bricks consisting 50/50 of clay powders and combustible materials, like fine sawdust and rice husks. Harvey says using clay instead of metal in his stoves makes them not only cheaper than other rocket stoves, but fabrication can be done on-site by local clay workers using local clays and combustibles, meaning there is no need to import stoves.

"All that might come from outside would be chicken wire wrapped around, which tends to be very inexpensive," says Harvey in an email. "This will make the stoves a little more durable as well as being semi-portable."

One drawback to the stove—as with every rocket stove—is the fact only one size pot can fit in the stove. To tackle this drawback, Harvey and his colleagues are creating four master molds. These molds will allow stoves to be fabricated for cook pots of any diameter between 24 to 48 centimeters (9.5 to 19 inches). Additionally, master molds will mean more people can be trained to create the stoves and not just local experts.

While the ultimate goal would be proliferation of these stoves to all areas in need, Harvey is working with an Anglican priest, Father Bartholomew Segu, to begin spreading the stoves around Tanzania. Currently, they are working to secure funding to produce the master molds.

"Bart Segu and I have been communicating with several prospective supporters for continuation of the project and prospects look good," says Harvey. "At the first real indication of new support I'll be engaging a local plastic factory, nearby Niagara Falls, to put together plastic master molds."

For more information on the insulating ceramic rocket stoves project, visit http://tzenvirohealth.wixsite.com/tzenvirohealth. ■

Credit: Reid Harvey

Ceramic industrial designer Reid Harvey designed insulating ceramic rocket stoves to help decrease air pollution for people who rely on burning solid mass for fuel.

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Delicate balance in a tough environment:

Refractory selection for fluid catalytic cracking units

By Stephen Karns

Petrochemical refining challenges refractory materials to handle not just heat, but abrasion, in changing harsh environments within the fluid catalytic cracking unit.

A fluid catalytic cracking unit (FCCU) is the heart of most oil refineries. It is here where much of the profit of a refinery can be made. This unit transforms low-value bottom-of-the-barrel tars with high molecular weights into high-value, profitable high-octane fuels and petrochemicals by breaking down the hydrocarbons. Fluid catalytic cracking is a secondary refining process that uses catalysts to produce high-octane gasolines, olefinic gases and other petroleum products. About one third of all the crude oil processed at a refinery with a FCCU is refined in this unit, making it a valuable asset. At present, there are about 135 refineries in operation in the United States. Refractory selection for FCCUs depends on where in the processing unit the refractory is placed.

In general, refractories are strong and dense, or light and soft. Every combination exists in between, and there are always trade-offs between properties to consider when selecting refractories. Determining which of a wide variety of refractories to use in a specific area can be quite challenging. Some areas require abrasion resistance, while others need to have a better insulating effect. It helps to simplify the task and break down the unit into four main areas: the riser, cyclones, reactor and regenerator, and

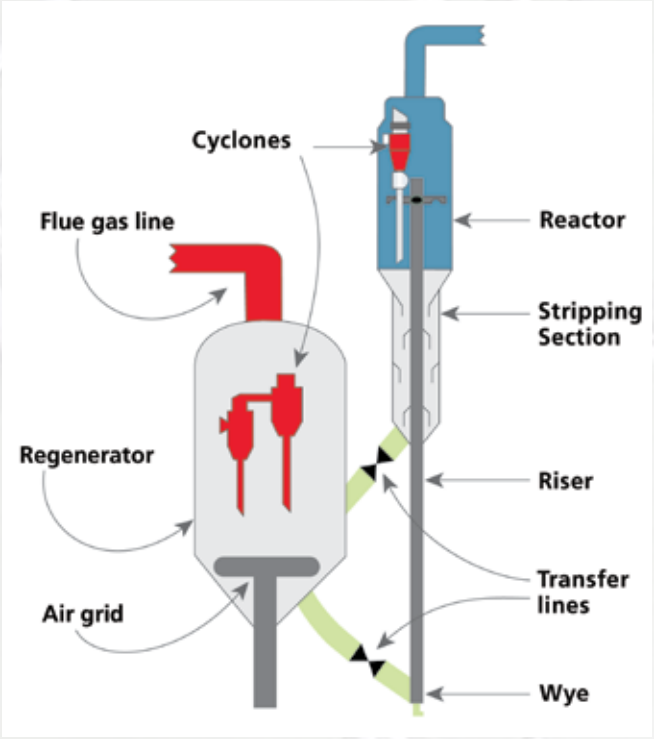

Figure 1. Schematic of fluid catalytic cracking unit showing the primary components requiring refractory.

transfer lines. These areas are pointed out in Figure 1, along with other specific areas mentioned below.

Risers, regenerators, and cyclones

In the riser, hot catalyst feeds in from the regenerator and is fluidized and blown upward using air. Long-chain hydrocarbons, such as asphaltene and other tar-like oils, are preheated and sprayed into the fluidized catalyst. With heat and aid of the catalyst, the hydrocarbons crack and break down into shorter hydrocarbon chains such as gasoline or propylene, which are much more profitable for a refinery than the original long-chain hydrocarbon feed. This reaction also produces excess carbon that deposits on the surfaces of catalyst particles. The conditions created in the riser with this process can be hellishly extreme, so it is often a difficult area for solving refractory problems. A great deal of refractory abrasion results from the high gas velocities used to fluidize and blow the catalyst and feed upward. The heat created from the catalyst is also a concern, but the reaction is endothermic, and therefore, having the best insulation is not necessarily a primary factor.

The refractory lining in the riser is about six inches thick on the walls and is usually gunned into place. In general, the riser will need refractory with very good abrasion resistance; some specific areas will need even more thickness. As mentioned, the lining will also need more insulating value where it is possible and makes sense. For the most part, abrasion resistance of products used in risers should be rated at 10 cc loss or less (after firing to 1,500°F, tested with ASTM C704/ C704M-15[1]). The lower the loss value, the more abrasion resistant the refractory. Figure 2 shows an example of samples after abrasion testing.

Density is generally used to assess the insulating value of refractory; the lighter a refractory is the more insulation it will provide. But the lighter it is, the less strength and abrasion resistance it will have. In the riser, products with densities about 135 pounds per cubic foot (pcf) and higher are used. In areas of the riser with especially extreme wear, such as the wye section corners or injector nozzles, products with densities from 160 to 180 pcf with abrasion resistance of 6 cc loss down to 3 cc loss are frequently used. Other properties, such as cold crushing strength (CCS) and thermal conductivity, generally relate to abrasion resistance and density, respectively. These properties are also important, but for the sake of narrowing down the options, abrasion resistance and density are the major factors. Also important is permanent linear change (PLC, shrinkage or expansion after firing), typically measured after firing 1,500°F using ASTM C113-14.[2] This property should almost always be a maximum of –0.3%; the closer to 0%, the less shrinkage cracking and other issues will arise during operation. This applies to all areas of the FCCU. Most products that meet this PLC requirement also will be capable of operating in the temperature ranges found inside most FCCUs, but PLC should be double-checked when selecting refractory for any area.

The riser typically feeds directly into two sets of cyclones inside the reactor vessel. The function of the cyclones in the reactor is identical to those in the regenerator: to filter catalyst particles from the hydrocarbon products (in the reactor) or the flue gas (in the regenerator). This is done by swirling the catalyst and gases inside the cyclone at high speeds and using centrifugal force to swirl catalyst particles downward, while the gases exit through the top and into the next set of cyclones, or on to the next processing vessel. The conditions created by all this centrifugal force and particulate creates an extremely abrasive environment at temperatures in the 1,000–1,200 °F range. For this reason, the cyclones have an internal layer of abrasion-resistant refractory that is usually only one inch thick. The density of the product installed inside the cyclones is irrelevant because they are contained inside the reactor or regenerator and do not require any heat insulation.

Refractory selection for changing conditions

Refractory selection in cyclones is based primarily on choosing the best abrasion resistance possible, but other concerns like ease of installation are also a factor. The type of refractory used here is nearly always a phosphate-bonded ramming type product. These are often referred to as plastic refractory products and are installed using a mallet or pneumatic ramming tool into hex-mesh, s-bar, or k-bar anchors. Typical plastics come premixed in slabs that can be rammed into place right out of the box with plenty of working time before they set. The downside is that they are usually heat-setting and may require some sacrificial support that will burn out during the initial firing, especially when installed overhead. Another concern with this type of phosphate-bonded plastic is that typical formulations are water soluble until fired above 650°F. So FCCUs that are started-up with steam can cause damage to

Credit: HWI

Figure 2. Before (left) and after (right) refractory abrasion testing in accordance with ASTM C704 protocol. The example shows 11.5 cc loss on a Clipper DP refractory brick used for test demonstration purposes. Different refractories are used in abrasive situations such as the riser and should be rated at 10 cc loss or less.

this type of refractory unless treated to 650°F first.

Other types of phosphate-bonded products are designed to set exothermically at ambient conditions. These are shipped dry in a bag and mixed onsite with a special acidic solution or water to the desired consistency. The advantage of these types of materials is that they form water-insoluble linings that are resistant to the steam that might be used during startup. The disadvantage is that these materials can be very difficult to install because the set time is usually less than 15 minutes. This can lead to wasted time and material.

Regardless of which type of phosphate-bonded refractory is selected, the critical property to meet is abrasion resistance. This should be maximized as much as possible, so a maximum of 4 cc loss is often the acceptable threshold. Areas with the worst abrasion resistance, particularly the areas immediately around the cyclone inlet, should be even less with a maximum of 2 or 3 cc loss. Materials with this level of abrasion loss typically have densities of about 170 to 180 pcf, but the density is irrelevant if the proper abrasion resistance is achieved. Phosphate-bonded products are frequently used in cyclones because these products achieve excellent strengths at the temperatures experienced here, ~1,000°F. Most cement-bonded products have weaker strength in this moderate temperature range, but greater green and high-temperature strengths, in addition to a wider variety of installation options.

As described, the cyclones are contained within the reactor and regenerator. The catalyst falls out the end of the cyclones through tubes called dip-legs into a collector at the bottom of the vessels. In the bottom of the reactor, the catalyst falls over a series of baffles to interact with steam that is injected from the bottom and rises upward. This steam strips

extra hydrocarbons from the catalyst before the catalyst enters a transfer line to the regenerator. In the regenerator, the carbon on the catalyst burns off, which requires that the temperature in this vessel is hotter, typically around 1,500°F and up to 2,000°F. The catalyst is fluidized with an air grid on the bottom of the regenerator, and the cyclones separate flue gases from the catalyst. The catalyst collects at the base of the vessel, below the air grid. The conditions in both these vessels are less severe with respect to abrasion, particularly in the walls. This means that more insulating refractory products can be used over stronger, denser options. There are still areas with some abrasion issues, particularly in the bottom of each vessel where the catalyst collects and rubs the refractory.

In the walls of the regenerator and reactor where abrasion is lightest, a lighter weight product should be used, but some strength is still needed for long-term reliability. The density of refractory in these areas should be 70 to 90 pcf with a CCS greater than 1100 psi (after firing to 1,500°F). The refractory does not necessarily have to be abrasion resistant, so the CCS property is used to determine the strength. Using insulating refractory in the walls helps keep the heat inside the system. Too much heat loss can create problems, though some designs of FCCUs incorporate special parts off the regenerator designed to cool the catalyst to a specified temperature. As for the bottoms of these vessels where the catalyst collects, refractory selection must find a balance between density and abrasion. Middle-weight products have been designed to work very well in these areas. They provide both low thermal conductivity and abrasion resistance but do not necessarily excel at either. These products should have a density of 100 to 130 pcf with an abrasion resistance rated to less than 12 cc loss.

Connecting all these vessels together are transfer lines. These lines contain and control the flow of catalyst between each part of the process. Slide gates in the transfer lines control the flow. Transfer lines also have some tricky thermal expansion to address between the different vessels created, so complex expansion sections are used to account for it. All the refractory on the transfer line walls should be both insulating and abrasion resistant, same as the bottom sections of the reactor and regenerator. The slide gates often experience more wear from abrasion, but also do not require as much insulation, so higher density products can be used for them.

The refractory properties required in transfer line walls are very similar to those in the reactor and regenerator. A middle-weight product with a density of 100 to 130 pcf with an abrasion loss of less than 12 cc is ideal. For the slide gates, similar products as those used in the cyclones can be rammed into hex-mesh anchoring. Products with 5 cc abrasion loss or less will work well.

Proper refractory selection in the FCCU is critical to the operational requirements and overall reliability of the unit. Understanding the conditions present inside each area is just as important as understanding the properties of refractories and how they work under those conditions. Every FCCU operates differently, and conditions in one unit may be more or less severe than the next. Refractory selections should be tailored to combat special situations in each piece of the process to provide great insulating value in addition to excellent abrasion resistance and achieve the optimal balance of properties.

About the author

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(continued from page 7)

A "temporary truce" to deescalate trade tensions was agreed on at the G20 Summit in Buenos Aires on Dec. 1, 2018, which resulted in the US refraining from increasing the tariffs that were slated to increase from 10 percent to 25 percent on Jan. 1, 2019.

Outlook for Year of the Pig

The outlook is one of expected continued tight supply of refractory raw materials from China, remaining at relatively high price levels, although unlikely to rise much higher, for the foreseeable future.

Certainly, some of the larger western refractory producers will seek to do what they can to secure and "stabilise" as much as possible mineral supply from their favoured sources in China—and Refratechnik is demonstrating one way of achieving this.

But will that be enough? And what kind of guarantee of uninterrupted availability and prices can be given under these conditions?

So, at the same time there will be urgent evaluation by the refractory sector for securing raw material supply outside China combined with the increasing likelihood of a step-change in refractory formulations.

The latter will prompt use of alternative materials and more recycled materials to be assessed with more zeal, and with special regard to increasing the "recyclability" of refractories for the future.

About the author

Mike O'Driscoll is director of IMFORMED and has over 30 years of experience in the industrial minerals business. IMFORMED has conferences this year covering industrial minerals outlook, magnesia, oilfield, fluorspar, and India's industrial minerals—see www.imformed.com for more information. Contact O'Driscoll at mike@imformed.com. ■

Research and progress in castable refractory development

By Charles E. Semler

Adoption of monolithic castable refractories is one of the industry's great success stories, but was decades in the making.

Over the decades, the refractories industry has continuously worked to advance the body of knowledge and technology, and improve products, which has resulted in countless major and minor improvements, as confirmed by the improved performance and increased service life of refractories. And, a significant reduction in the refractory usage in most manufacturing applications (markets) has resulted in a continual decrease in annual refractory production of most industrialized nations (China excluded). Several examples of notable refractory improvements are:

a. Increased attention to the fine, ultrafine, and nanoscale particles included in refractory mixes,
b. Development of alumina-chromia refractories,
c. Steel ladle refractories: bloating fireclay, zircon-pyrophyllite, alumina-magnesia-carbon,
d. Zirconia addition to refractories for thermal shock resistance.

Together with the many "minor" developments in refractories, there have been some HUGE, revolutionary, transformational advances that have had major impacts on refractory manufacturers, suppliers, contractors, and users worldwide. Several examples of such revolutionary advances in refractories are:

a. Magnesia-graphite/carbon engineered-composite bricks and shapes,
b. Gunned and shotcast installation of refractories,
c. The production/use of sea-water magnesia, tabular alumina, fused aggregate, fused cast blocks, and other high-purity, synthetic raw materials (e.g., spinels, mullite, bonite),
d. High-tech castable refractories, including precast shapes.

Focus on castable refractories

"There is not a discovery in science, however revolutionary, however sparkling with insight, that does not arise out of what went before. 'If I have seen further than other men,' said Isaac Newton, '"it is because I have stood on the shoulders of giants.'"

–Isaac Asimov, *Adding a Dimension: Seventeen Essays on the History of Science*

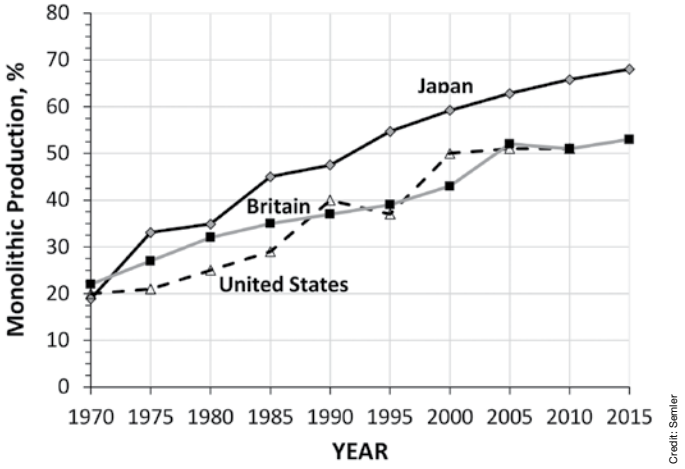
To advance in any subject, including R&D on refractory materials/products, researchers benefit when they make diligent efforts to become fully familiar with the prior history of those materials/products, to avoid redundant effort, wasted time, and unnecessary cost. Specifically, considering the ongoing advancement of monolithic refractories by refractory technologists, it is important to know the key developments and improvements that have driven the huge increase in usage of monolithic (unshaped) refractories, in most industrial manufacturing applications.

Monolithic refractory types include castables, plastics (moldable formulations), gunning/shotcast products, injectable products, ramming mixes, mortars, and coatings. The increasing development, availability, and use of monolithic/castable refractories can be seen in the trend in annual production (percent of total annual refractory production) of monolithic (unshaped) refractories, in Japan, Britain, and the United States for the years 1970 to 2015, as shown in Figure 1.

Because castables caused a major transformation for manufacturers, suppliers, contractors, and users of refractories worldwide, this paper provides a limited look at some notable castable studies, especially for the early years (1950-1960), and into the 1990s, when countless advances were made that resulted in the change from simple mixes to sophisticated, high-tech castables. Even today, these studies provide the foundations for advances in monolithic refractory technology.

The American Ceramic Society (ACerS), in conjunction with its Refractory Ceramics Division (RCD) and the ACerS St. Louis Section, has addressed monolithic refractories in meetings, symposia, and sessions, and provided valuable published information through the decades. These articles, proceedings, and books show the many developments that contributed to the advancement of monolithic, and specifically castable refractories technology. With this paper, it is hoped that readers and researchers/authors will be reminded of or informed about some of the most important early studies (mainly reported in ACerS publications), that contributed to the development and advancement of castable refractories.

While this information is of historical significance, today's refractory researchers will benefit from being reminded of prior art that might easily be overlooked or forgotten with the passing of time, as they continue development, innovation, and use of castable refractories.



Credit: Semler

Figure 1. Annual production of monolithic (unshaped) refractories increased significantly from 1970 to 2015, for Japan, Britain, and United States. Monolithic refractories overtook annual refractory production (>50 percent) in 1993 in Japan, 2000 in United States, and 2004 in Britain. Data from Japan Refractories Assn., U.S. Dept. of Commerce, and *Refr. World Forum*, 10 (4) 30 (2018).

Adoption of monolithics encountered resistance even as the major increase in the technical advancement and usage of monolithics was underway. There were "traditionalists" in refractories, even into the 1990s, who insisted that a "castable" could never have properties or service life as good as pressed and fired refractory bricks. Figure 2 is one of many examples which illustrate that the hot strength of a 60 percent alumina, high-tech (low cement) castable is greater than a comparable fired, 60 percent alumina brick.

But it must also be stated that there are some applications where bricks are still the best choice, although the negative bias about castables has been proven wrong in a large majority of cases. Castables have properties that commonly can be better than fired bricks, and they show better performance in service, as well as significant time savings, cost effectiveness, adaptability to complex/unique lining designs, and other benefits.

Early breakthroughs in castable development: 1950–1960

In 1950/1954, Heindl and Post[1,2] wrote "Refractory castables consist primarily of crushed and sized fireclay brick and cement. The cement used is different than Portland Cement in that it is composed of calcium aluminates (CA), rather than calcium silicates; the calcium aluminate cement (CAC) has greater resistance to destruction at high temperature." This work was conducted on castable mixes containing crushed fireclay brick or calcined flint clay grain with 10–30 percent CAC, with attention given to the effects of particle sizing, cement:water ratio, molding, and curing time on flow, strength, and modulus of elasticity. Their results indicated that

(a) most proprietary castables contain more CAC than is necessary, and (b) a water:cement ratio of about 1.75 gave the highest strengths in lab-size mixes.

West and Sutton[3] revealed that "Refractory castables have met with some disfavor by the consumers of refractory products. Presently most producers and users of refractory castables have little knowledge of cements, their mineral composition, and hydration reactions. And most people in the cement industry have little understanding of the uses of their cements in the refractories. Much progress could be made by bringing the refractory and cement people together." West and Sutton determined that the quality of refractory castables is influenced by (1) the type of cement/bond, (2) amount, type, and particle size of clay used, (3) amount and purity of added water, and (4) amount, type, and particle size of refractory aggregate (calcined fireclay preferred over ground fireclay brick).

Snyder[4] offered a more upbeat view of castables than West and Sutton, saying that, "Improved castable refractories, with increased density and increased strength, at intermediate temperatures can possibly lead to a revolutionary change in refractory practices in many furnaces. The surface has hardly been scratched in the development of refractory castables, and further improvements may find them (castables) replacing refractory brick in many applications."

In 1954, commercial castables were being successfully used in refinery fluid catalytic cracking units (FCCU), which experienced service temperatures generally ranging from 900°F to 1,200°F. Wygant and Bulkley[5] said that refractory castables for refinery linings were usually composed of aluminous hydraulic cement and calcined clay aggregate, and designed for use below 1,500°F, whereas most commercial castables were designed for use at >1,800°F. They noted that only one CAC was made in the United States (since ~1924, Lumnite CAC by Universal Atlas), and thus was a component of most commercial castables; the most common aggregate was calcined fireclay. The best high-strength commercial castables, at the time, contained about 60 percent coarse (4–100 mesh) calcined fireclay, 15 percent fines (28–325 mesh), and 25 percent CAC. They concluded that (a) castables are not ideal as vessel linings, but when correctly selected and installed they give relatively good, economical service, and (b) very careful attention should be given to the proper installation and curing of the castable to develop the best physical properties, and (c) many improvements are possible, both in properties and methods of use of castables, but the cooperative efforts of refractory manufacturers and refinery users will be required.

Paul[6] offered practical comments about the use of castables in FCC units: Labor costs for castables are 50–60 percent less than using firebrick, and they give excellent service for the conditions involved. Up to three grades of castable are used in FCC units, including lightweight (50–75 lbs/cu.ft), heavy (100–120 lbs/cu.ft), and very heavy (125–150 lbs/cu.ft). Paul noted the weight of each castable determines the service for which it is best suited. The use of very heavy castable has not been accepted throughout the industry, but preliminary information and use has indicated that it shows promise where erosion protection is required.

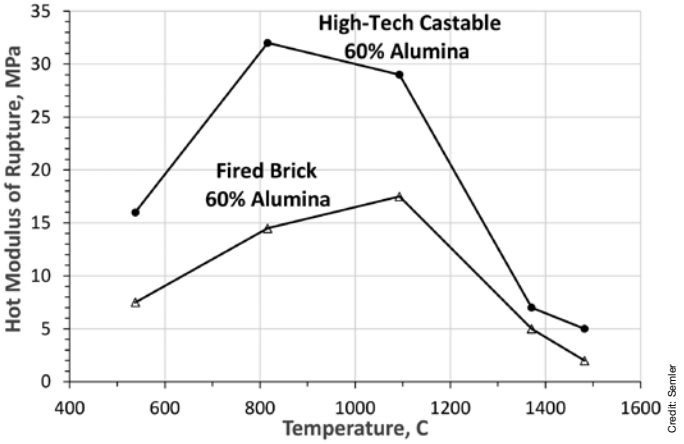


Figure 2. Hot strength of a 60 percent alumina, high-tech (low cement)) castable and 60 percent alumina fired brick[22] illustrate that with the advancement of technology, castables can and do have properties better than pressed, fired bricks. Data source: Reference 22.

Hansen and Livovich[7] evaluated the strength characteristics of 1:4 (by volume) mixes of CAC and crushed fireclay brick, with and without 10 percent plastic fireclay, fired in the range 500°F to 2,200°F. They determined that stronger and denser castables were obtained for mixes with coarser aggregate and increasing CAC content.

Work by Gitzen, Hart, and MacZura[8] addressed the growing need for improved castables. Stimulated by the memorable phosphate-bonding study by Kingery,[9] they developed castables composed of sintered alumina (tabular alumina) aggregate bonded with phosphoric acid. These phos-bonded castables showed high bond strength, dimensional stability, and resistance to erosion, for temperatures up to 3,400°F. The resistance to erosion was about 10× that of existing erosion-resistant castables, so they found use in field applications, and performed much better than the existing castables. Note that this study was an early example where high-purity, synthetic aggregate was used instead of crushed fireclay brick or natural, mined grain.

Because of the need for castables that could be used up to 3,000°F, and higher, Gitzen, Hart, and MacZura[10] evaluated six higher purity CAC, with 64–86 percent Al_2O_3. Three commercial CAC's at the time had alumina content of 42–70 percent, and 30–40 percent CaO, and were useful in castables, only up to 2,700°F. Lab testing by Gitzen et al. showed that a CAC with 80 percent Al_2O_3 and 18 percent CaO was the best choice. Tabular alumina castables with 15–25 percent of the improved CAC showed excellent hot strength and resistance to erosion, abrasion, and metal penetration.

In 1958, an urgent early warning was issued by King and Renkey.[11] They noted that stronger castables with higher purity CAC, which are useful at higher temperatures, have a propensity to explode when first heated. The explosions result from a build-up of steam on heating that needs to be released. Their patent claimed that the addition of as little as 0.02 wt.% of

boric acid to CAC-bonded castables was a simple and inexpensive way of eliminating or minimizing the explosion tendency of castables.

In 1959, Venable[12] compared the erosion resistance of seven ceramic materials, including castables, based on the importance of this property for refractories used in FCC units. He noted that castables have disadvantages including the necessity of proper mixing (with the correct water content), installation, and curing. Unfortunately, these critical process parameters do not always receive the attention and supervision required during installation. (This phenomenon persists today and is managed through anchoring design and a careful burn-in schedule.) He also mentioned that castables with tabular alumina and high-purity CAC had been developed recently and were being successfully used in FCC installations.

Eusner and Hubble[13] studied 85 commercial and 80 lab-made castables, to evaluate the use of a consistency meter to control/optimize the water addition to castables. They determined that the consistency meter gave good results, and recommended it as a standard test method, for lab and field measurements. Their lab-made castables were composed of sized flint clay aggregate, low-purity CAC, plastic clay, and kyanite. They found that CAC contents of 17–20 percent were beneficial for strength, but more than 20 percent increased strength only slightly, and greatly reduced the refractoriness. The use of gap grain sizing and the addition of plastic clay and kyanite all contributed to improved castable strength.

Accelerated progress in castable development, up to ~1985

The 1950s were a springboard during which industry discovered the practical and economic benefits of castables, which led to increasing demands for further study and improvement of castables. Thereafter, there was significant acceleration in the progress of castable R&D, with the availability of more, higher-grade natural and synthetic aggregates, more and higher-purity CAC options, increased attention to the control of particle sizing, and use of ultrafine materials, dispersants, powdered metals, and other additives. Based on the increased practical and scientific knowledge, the materials available, test methods, and user demands, major progress was achieved, resulting in a transition from high-CAC, conventional castables to lower-CAC, high-tech castables. Significant property and performance benefits accompanied the big reduction in CAC content from 10–30 percent for traditional/conventional castables (CaO >2.5 percent), to 0–8 percent in the new high-tech castables (low-cement – LCC (CaO 1–2.5 percent, ultralow-cement – ULCC (CaO 0.2–1 percent), and no-cement – NCC (CaO < 0.2 percent)). Certainly there have been thousands of studies and innovations that contributed to the major advances in castable technology, and performance in service, but only a very few can be mentioned in this article.

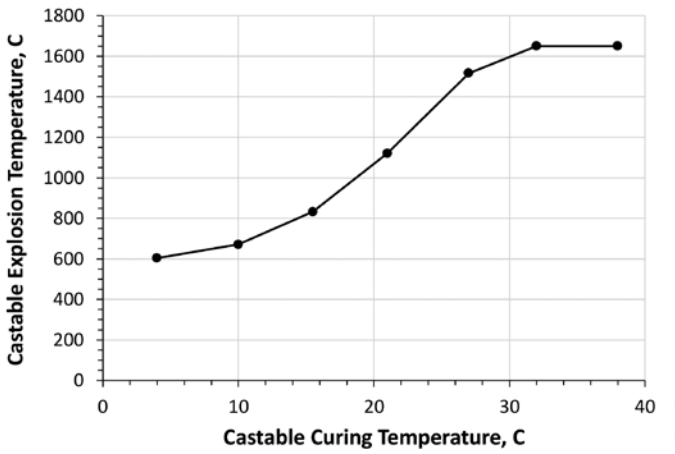
In 1961, Gitzen, Hart, and MacZura[14] addressed the significant problem of castable explosion upon initial heatup; i.e., the castable "defect" that King and Renkey[11] warned about in 1958. Their study of a castable with tabular alumina aggregate and 80 percent alumina, 18 percent CaO CAC showed a relationship between the castable curing temperature and the explosion temperature upon heating, as shown in Figure 3. They observed that the castable exploded at lower temperature when cured at less than 70°F, so they recommended that installing/curing a castable at 70°F to 90°F would increase the permeability and explosion temperature, and reduce the probability of explosion. They also suggested that reducing the cement surface area, and the cement content, would help reduce the explosion tendency.

During this period, there were other studies addressing castable explosion, including Crowley and Johnson,[15] and Hipps and Brown.[16] The potential for castable explosion upon initial heatup can be reduced by adding organic fibers, which burn out to create a micro-channel network that provides an escape pathway for the release of steam. The solution was introduced in the 1976 patent by Ivarson and Blom,[17] and discussed by Kleeb and Caprio.[18] Severin[19] described his observations and comments about castable explosion from the practical field experience of a dryout contractor. But despite the abundance of research and recommendations of how to minimize/eliminate the explosion of castables, the problem of, and potential for, castable explosion has not yet been eliminated. Further research continues.

Successful installation alone is not enough for success, especially in situations requiring mechanical strength in addition to heat containment. Lankard and Sheets[20] presented lab and field data illustrating the beneficial effects of adding 1-inch long, 310 stainless steel fibers to a high-alumina, 3,400°F, CAC-bonded castable. They observed that adding stainless steel or carbon steel fibers to castables significantly improves flexural and compressive strength, thereby giving increased service life for castables in applications where the service life was reduced by thermal-shock and/or mechanical impact. Lab tests suggested a maximum use temperature of 1,500°F or less, but some field experiences showed that, with the temperature gradient in linings, steel fiber-containing castables can be used in applications where the hot face temperature was up to 2,800°F. This innovation was widely accepted, and it is still a common practice to add 1–4 wt.% steel fibers to dense castables (2–6 wt.% in insulating castables) for many applications.

In 1984, The American Ceramic Society, Refractory Ceramics Division, and the Refractory Concrete committee of the American Concrete Institute (ACI) organized an international symposium on "New Developments in Monolithic Refractories," to create an international exchange of information and document the state-of-the-art technology. There were 200 attendees from 30 countries. The symposium included sessions on:

a. Worldwide usage of monolithic refractories (Japan, Europe, U.S.)
b. Testing of monolithic refractories
c. Installation and bakeout of monolithics
d. Low-cement castables (LCC)
e. Monolithic refractories for blast furnace usage
f. Miscellaneous new applications for monolithics



Credit: Semler

Figure 3. Lab test results for a tabular alumina castable with 15 percent CAC,[14] show the relationship between curing temperature and explosion temperature with initial heatup. To minimize the potential for costly, damaging explosions upon initial heatup, castables should be installed/cured at temperatures in the range 70°F to 90°F. Data source: Reference 14.

ACerS published a special volume[21] of 32 papers from the Symposium to capture the information shared, and make it available as a reference of state-of-the-technology of castables in 1985. For example, Clavaud et al.[23] discussed the status, properties, and service options for the high-tech castables LCC and ULCC.

Increased R&D, and use of castables, continued into the 1990s

In 1990, Krietz, Fisher, and Beetz[24] wrote that "more R&D has been done on castable technology in the past 10 years than in the previous half century; a variety of new or improved raw materials have been introduced, so refractories technologists have a much wider choice of materials than ever before. Castables are no longer simple blends of aggregate and cement; some castables now are complex refractory mixes with high-quality, precision-sized aggregate blends, modifying fillers, binders, and additives. As a result, castables have evolved from secondary materials of choice for general applications, to primary materials for use in many critical high temperature applications."

The title of the 1994 ACerS St. Louis Refractories Symposium was "Fundamentals of Refractory Castables." The Symposium program, which included the following seven papers, gives a general indication of the topics of interest at the time:

R. German – Fundamentals of particle packing theory

M. George – Aspects of CAC hydration

B. Myhre – Effect of particle-size on flow of refractory castables

L. Struble – Rheology of flocculated and dispersed cement paste

J. Funk – Particle-size control for high solids castable refractories

N. Severin – Controlled temperature dryouts of refractory linings

J.F. Young – Macro-defect-free (MDF) cements

Final Notes

This article provides a limited overview of the early development of castable refractories from 1950 into the 1990s, based mainly on ACerS publications. It is hoped that this information will give readers some understanding of how and why the castable revolution has been so successful. In closing, it should be mentioned that there are many other good sources of information about current and past castable development. Included are publications such as UNITECR Proceedings, ALAFAR (Latin America) Proceedings, IREFCON (India) Proceedings, Annual ACerS/St. Louis Symposium Proceedings, Refractories World Forum (Germany), RHI Annual Bulletin (Austria), Taikabutsu Overseas (TARJ-Japan), Krosaki Annual Report (Japan), Shinagawa Annual Report (Japan), China's Refractories, and IRMA Journal (India). A book that gives an overview of castables and other monolithic refractories was written by S. Banerjee, "Monolithic Refractories," ACerS and World Scientific, 311 p., 1998. And for a thorough presentation of the scientific and technical details of high-tech castables, readers are directed to the recent book, "Refractory Castable Engineering," by A.L. da Luz, M.A.L. Braulio, and Victor C. Pandolfelli, F.I.R.E. Compendium Series, Göller Verlag, 734 p., 2015.

About the author

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Science for the future at the Electronic Materials and Applications Conference

(Credit: all images: ACerS)

The annual Electronic Materials and Applications Conference held January 23–25 in Orlando, Fla., reached a key milestone: The conference celebrated its 10th anniversary.

The meeting, jointly organized by ACerS Electronics Division and Basic Science Division, welcomed more than 330 participants from around the globe. The conference's 13 symposia covered topics ranging across superconductors, ferroic oxides, complex oxides, chalcogenides, materials for 5G, and much more.

Attendees presented talks on the theoretical science and engineering research driven by increasing demand for sophisticated electronics in just about every application, a theme echoed in the plenary sessions.

AcerS' Greg Geiger (left) greets John Blendell, Basic Science Division's conference organizer.

Electronics Division invited Jon-Paul Maria to provide the Wednesday plenary talk. Maria, a professor at The Pennsylvania State University, presented his group's work on electroceramic thin films for infrared plasmonic applications.

According to Maria, "Most work has been done on metals, which are readily available, but limited to visible light." However, conducting electroceramics can access IR carrier density values and thus open up applications such as perfect absorbers/emitters, IR detectors, surface sensors, and more.

Thursday's plenary speaker, invited by Basic Science Division, was Yet-Ming Chiang, Kyocera Professor at MIT and serial entrepreneur. Chiang spoke about ceramic materials for the next generation of energy storage technologies, especially for transportation and large storage systems for power systems. According to Chiang, "There's always a new frontier."

The organizers built much more than symposia into the meeting with plenty of networking opportunities, a poster session, student events and recognitions, and a conference dinner. Electronics Division organized a workshop to give students a preview of the meeting and ensure they got the most out of it. Basic Science Division followed up with a tutorial on impedance spectroscopy, an important characterization tool for the science found at this conference.

The conference closed with its ever-popular Failure Symposium, where scientists come clean about the bumps in their road to success.

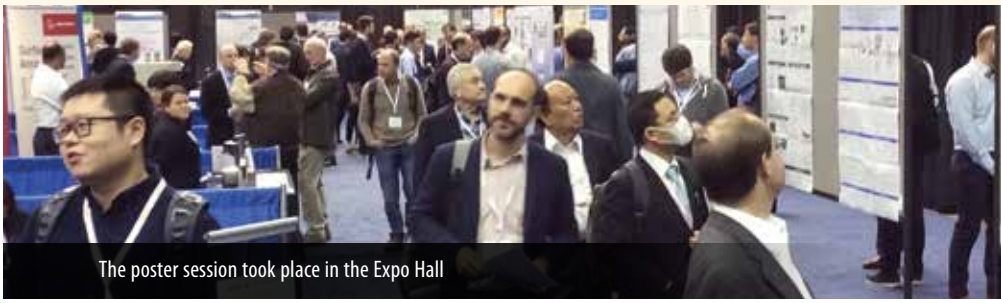
Plan now to attend EMA 2020 in Orlando, Jan. 22-24, 2020. Read more about EMA 2019 at http://bit.ly/EMA2019wrapup. View images from EMA 2019 at http://bit.ly/EMA2019photos. ■

The poster session led to many lively conversations.

ICACC organizers dodge curveballs and make conference a success

(Credit all images: ACerS)

Expo at Daytona Beach



The poster session took place in the Expo Hall

Organizers of the International Conference on Advanced Ceramics and Composites that took place in Daytona Beach, Fla., dodged a bullet when the government shutdown ended just in time for the conference. Up until the last moment, organizers did not know whether the United States partial government shutdown would impact the conference. While Department of Defense and Department of Energy employees were not impacted, NASA and NIST (Department of Commerce) employees only found out days before the conference that they were "back on the job" and able to attend.

Just over 1,000 attendees from 42 countries made it this year, with about 60 percent of attendees coming from outside the U.S. Organized by the ACerS Engineering Ceramics Division, ICACC19 packed a lot of value into the week, including the traditional opening plenary session, 17 symposia, four focus sessions, the 8th Global Young Investigators Forum, and a special symposium commemorating the 40th anniversary of the Fulrath Award Symposium.

"The quality of the presentations has been really high, and the student participation has been great," says Surojit Gupta, conference organizer and associate professor of materials science and engineering at North Dakota State University.

Besides the technical program, Engineering Ceramics Division held its annual business meetings; new members were welcomed at a special reception, and young professionals were welcomed at a separate reception; graduate students participated in an abstract writing workshop presented by ACerS journal editors-in-chief; and students participated in engineering shot glass and SIFT competitions.

An accompanying two-night exhibition featured 30 exhibitors and the opportunity for conference attendees to shop for new instruments, equipment, and services. Additionally, the two poster sessions that took place during the exhibition gave everyone a reason to cross the street and enjoy some heavy hors d'oeuvres and good conversation.

ACerS executive director, Mark Mecklenborg (left), and president Sylvia Johnson (right) recognize Kyoung Il Moon with a Global Ambassador Award.

Happy to be at ICACC!

Be sure to mark your calendar for the 44th ICACC, taking place Jan. 26-31, 2020, in Daytona Beach. The conference will be a success regardless of weather and other factors!

Read more about ICACC19 at http://bit.ly/ICACC19wrapup. View images from ICACC19 at http://bit.ly/ICACC19photos. ■

A packed plenary session

ceramics expo

April 30–May 1, 2019
I-X Center
Cleveland, Ohio, USA

Founding partner

The American Ceramic Society
www.ceramics.org

Ceramics Expo–Channeling ceramic enterprise and expertise

ACerS came on board as a founding member of Ceramics Expo back in 2014, the *Bulletin* was named as its official magazine, and here we are already looking forward with much anticipation to the fifth staging of this important gathering, returning once again to the I-X Center in Cleveland (April 30–May 1).

An almost sold-out show, more than 300 organizations represented on the exhibit floor, 45+ expert speakers lined up for conference sessions, and more than 3,000 visitors are expected to the 2019 event.

"Ceramics Expo has established itself as the materials, manufacturing, and components event, still totally free to attend, and the ultimate comprehensive supply chain exhibition that speaks both to, and of, technical ceramics, glass-ceramics, glass, composites, and associated materials," expo director Danny Scott says.

Scott also confirmed the new format for this year, a two-day rather than three-day duration, but with extended hours. There are clear benefits for participants, not least of which are a shorter time away from the office or plant, and reduced accommodation and associated costs. "We'll deliver more exhibits, great conference sessions, and lively networking into two longer, more productive days," Scott adds. An addition to the program is a reception and meet-and-greet event for exhibitors and invited guests, slated for a four-hour run starting at 5 p.m. on Monday, April 29.

Global showcase

Visitors can expect a broad range of dynamic presentations in the exhibit area, including live product demonstrations and stopping points on an innovation trail, from companies drawn from all across the world. Indeed, the ever-widening internationality of Ceramics Expo

only serves to underline its extended resonance in this vital industry. Below is just a snapshot of the exciting showcase lineup in Cleveland.

Top-of-the-line materials are required in order to facilitate the manufacture of products demanded by advanced industries such as aerospace, medical, automotive, energy, defense, and telecommunications. World-renowned suppliers will lead the way.

One of Japan's leading chemical companies, Showa Denko, continues to innovate in the field of alumina, boron nitride, and abrasive grains. At Ceramics Expo, Showa Denko will launch a new type of roundish alumina, designated AS-C. This alumina is a low-cost alternative to the AS grade of high-purity alumina, offering improved thermal conductivity and filling density, plus low abrasivity, due to its unique particle geometry. AS-C offers all of the potential found in AS grades, but at a fraction of the cost. Coming up with materials for the future often requires a novel approach to preparing them, and another giant in the industry, Corning, did just that. The company invented a new way to manufacture high-quality, fully dense alumina ceramic ribbon in roll-to-roll format, which is a revolution in the processing of ceramic materials. Corning Alumina Ribbon Ceramic can be made thinner than a piece of paper, and can conform to smooth, curved surfaces. Its flexibility enables it to bend, but not break, during exposure to high-temperature gradients. Therefore, it can undergo rapid thermal shock and be run through high-temperature processes at fast speeds without mechanical failure. Also, due to its high thermal conductivity and thinness, it has a low thermal resistance and dissipates heat from actives similarly to aluminum nitride.

Form and function

When it comes to forming, visitors always seek technologies that take products beyond prototyping and small batch, not least in the field of ceramic additive manufacturing (AM). A leader in this area since 2011, Lithoz from Austria will introduce its CeraFab system, designed to enable industrial series production of additively manufactured, high-performance ceramics. The modular design allows for a cascade of up to four production units per control station, greatly increasing output productivity and minimizing the risk of production loss. It features high-resolution DLP (2560 × 1600 pixels) and enables high-precision manufacturing of a diverse array of ceramic materials. Also specialized in high-performance ceramic AM applications is Creatz3D Ceramics, ready to reveal its work on fascinating ceramic applications, such as complex manifolds, sensors, honeycombs, and micro-lattice structures. Visitors will be able to learn about novel items from customized single-lattice structures through to large components, these being designed and supplied to industries such as biomedical, defense, semiconductors, chemical processing, and aerospace.

When it comes to heat work, we know furnaces need to operate at higher temperatures, in unique atmospheres, and in extreme cycling, often exceeding the capability of traditional refractory linings. This year, regular exhibitor Blasch Precision Ceramics will showcase its StaBlox Reformer Tunnel. This engineered, mechanically stable system—consisting of a series of stackable, interlocking blocks—provides ease of installation and a higher level of reliability with its customizable design. Blasch will also introduce new materials and product designs along with a vast array of silicon carbide support structures. Talking of demanding thermal cycles, Johnson Matthey is showcasing its HTX high-strength platinum thermocouple wire that withstands the most demanding environments, from glass furnaces and nuclear reactors to jet engines and semiconductor applications. Not only does HTX wire provide superior durability, but it also maintains excellent functionality after 1,200 hours at 1,400°C with 400 psi tensile loading during accelerated life testing, while showing exceptional measurement accuracy, meeting IEC 60584-1 class 1 tolerance.

Meanwhile, those producers with specialty lines often need the high-tech support of a company such as IBU-tec, a specialist for rotary kilns and thermal treatments and in this case, rocket science. IBU-tec comes

to Cleveland with a new pulsation reactor, specifically designed to allow users to explore and exploit the possibilities offered by thermal shock treatment. The pulse reactor platform derives directly from pulsejet rocket technology. A precursor is sprayed into a pulsating hot gas stream, where flash calcination occurs, resulting in amorphous structures and a narrow property distribution. Altering reactor conditions or raw materials can result in distinct product properties. The process can be especially suitable for challenging end product applications, such as those in nanomaterials, 3D printing, and technical ceramics. The reactor will provide a cost-effective option for trials, developing submicron powders and coated particles—zinc oxide, zirconia, iron oxide, magnesia, spinels, and many others.

Capturing every angle

For the above-mentioned products, materials knowledge is everything and the most advanced characterization equipment will be in evidence at Ceramics Expo. Keyence brings its VR-5000, a non-contact optical profiler designed to provide form, contour, and roughness measurements over a 4 in x 8 in (10 cm x 20 cm) area with submicron resolution. Unlike traditional contact-based 3D measurement systems, which capture point or line data, the VR-5000 is able to capture the full surface data. Built-in AI, smart measurement, automates the data acquisition process. Users simply place their sample on the stage and click a single button. The system automatically determines the boundaries of the part and the optimum settings to use and begin measuring the surface. The post-processing analysis software provides advanced measurement capabilities,

ceramics expo

making it easier to tie measurements to decision making. Also returning, Horiba Instruments' particle experts will answer questions on the best approaches to determining particle size, shape, surface area, zeta potential, and concentration. This year, Horiba is featuring its compact laser diffraction analyzer, the Partica LA-350. The combination of performance, price, and easy-to-use software offers pre-integrated analysis tools for large families of products that adhere to stringent quality control requirements in ceramics applications. Visitors are encouraged to bring their samples along—and any necessary liquid dispersants—for on-site analysis and discussion (however, no hazardous materials, please!).

Fine finish

Come the end of the process, in this industry we are often looking at an extremely complex piece with high value—not the time to inflict catastrophic damage. One of the experts in the field of finishing is Top Seiko, and it will feature its CNC machining service for ultrahard materials such as engineering ceramics, quartz/sapphire glasses, and refractory metals. Typically, the company machines components in these materials to customer order. At Ceramics Expo 2019, it will showcase some samples to demonstrate its capabilities. The Quartz Colosseum, for instance, is a prime example, showing Top Seiko's sophisticated programming and high-precision machining skill. Working over a four-day period, the company machined a 190 mm × 190 mm × 105 mm (7.5 in × 7.5 in x 4.1 in) quartz block into an elaborate shape with no damages or cracks. Also featuring at the expo will be samples of micro-deep hole drilling and complex 3D machining.

Expert knowledge forum

The Ceramics Expo Conference, North America's only such forum to present as a totally free-to-attend opportunity, will be the perfect platform for analysis, assessment, and open debate of key topics and pressing issues affecting ceramic design, innovation, manufacture, use, markets, and regulation.

Always popular with delegates, the opener is an interactive panel discussion with a broad sweep across growth areas, future opportunities, and challenges in the ceramic industry. This will be moderated by Eileen De Guire, ACerS director of technical content and communications. Panelists include Willard Cutler (Corning), Patty Mishic (CoorsTek), Mark Wolf (Kyocera), and Johannes Homa (Lithoz). Expect wide-ranging discussion on energy storage, hybrid auto and aircraft, consumer electronics and cell phones, biomedical innovations, Internet of Things, and ceramics additive manufacturing to feature on the first morning.

This will be followed (Track 1) by hot topics facing all in the industry—including threats to the global advanced ceramics supply chain (led by Michael Silver, American Elements)—and a business leaders session that will open up the box on principal factors for success, identifying key market demand, challenges and resolution pathways, and managing the talent drought in ceramic engineering.

Track 1 goes into the afternoon with an examination of cutting-edge applications of ceramics for energy storage. The special combination of characteristics displayed by technical ceramics—hardness and strength, very high melting points and durability, chemical inertness, and good electrical and thermal insulation—make them the optimum material for energy storage and we see them being utilized by industries in thermal, solar, kinetic, chemical, and nuclear energy. Discussions here will concentrate on

- Applications in the automotive industry and the use of ceramic substrates in solid-state batteries,
- How ceramics are being used in the coating layer for solid-state batteries,
- The various ways to manufacture and process ceramics for solid-state batteries,
- Using ceramic and glass electrolytes in redesigning battery structure.

Track 1 continues in the afternoon with considerations around thermal management. Advanced ceramics offer thermal conductivity second only to diamond among insulating materials, and also possess exceptional thermal management properties. This session will address how ceramics are being used for their heat dissipation and thermal resistance properties, highlights being

- Examining heat dissipation properties of advanced ceramics,
- Use of ceramic coatings for nuclear power stations to resist high temperatures,
- Applications in aerospace: thermal barrier coatings, use of carbon matrix composites in engines, and turbine blades,
- Developments in propulsion systems.

Over in Track 2 at this stage is the place for anyone with an interest in silicon carbide, its processing, and lightweighting. The properties for which silicon carbide is valued are those that cause difficulties during the manufacturing process: a material almost as hard as diamond can be difficult to mold and shape into the required end product. This session will address how this can be managed and achieved, with focus on

- Working with ceramic matrix composites for high-temperature applications,
- Processing techniques to ensure the correct shape of the end product,
- Upscaling production.

Ceramic AM continues to be studied by various user industries, with an eye to both rapid prototyping and production scale solutions, and the time and place for this one is Day 2, Track 2 (appropriately, a.m.). It is understood that AM is widely used for prototyping and the production of conventional ceramic parts with complex geometries. However, it is less established when it comes to printing actual parts. There is also growing R&D interest in printing with more exotic ceramics and ceramic composites. This session will address how to specifically design for AM, how best to ensure superior quality of the end product, and printing with UV-curable polymer-derived ceramic resins.

Moving to the afternoon session in Track 2, there is the important discussion on embedding sustainability, recycling, and also resource management in the R&D process. In a world where natural resources are scarce and consumption is at an all-time high, it is imperative to dedicate R&D resources to developing a sustainable approach. This session will address how industry can recycle and reuse ceramic materials from existing products, and the technologies that are available to enable this, including

- Managing the use of toxic materials such as lead in ceramic products,
- The use of rare earths and ensuring a supply that is not controlled by China,
- Recycling and reusing solutions for magnets, hard drives, and other components,
- The use of robotics and AI in disassembling and reusing.

This is just a glance at what you can expect at the Ceramics Expo Conference. Taken as a whole, the sessions cover all the swirling discussion around ceramics, glass, and associated technologies. In addition to those mentioned, the speaker roster also includes expert voices from: CeramTec, Hidden Point Consulting, Colorado School of Mines, Alfred University, Morgan Advanced Materials, Lucideon, Toshiba American Electronic Components, Semplastics, NIST, Freiman Consulting, USACA, Golisano Institute for Sustainability, NASA, Honeywell Aerospace, Cactus Materials, General Electric, Penn State University, NASA Glenn Research, Knowles Corp, Oak Ridge National Lab, HRL Labs, Lockheed Martin Space, GrainBound, University of Colorado, PIRE, Carnegie Mellon University, Ford Motor Company, GE Aviation, Saint-Gobain, Imerys, US Army Research Lab, Saxon Glass Technologies, and General Motors. The full agenda and speaker list can be found at www.ceramicsexpousa.com/conference. ■

Conference agenda at-a-glance

TUESDAY, APRIL 30, 2019

PLENARY

9:20 a.m.	Welcome address
9:35 a.m.	Interactive panel discussion: Discussing Growth Areas, Future Opportunities and Challenges in Ceramics
10:30 a.m.	Threats to the Global Advanced Ceramics Supply Chain in the 21st Century – Challenges and Solutions
11:00 a.m.	Panel interviews: Business leaders session: Examining the Keys to Success and Remaining at the Forefront of Development
11:30 a.m.	Lunch

TRACK 1

1:00 p.m.	Examining Cutting-Edge Applications of Ceramics for Energy Storage
2:30 p.m.	Networking coffee break and activities on show floor
3:00 p.m.	Innovative Applications of Ceramics for Thermal Management

TRACK 2

1:00 p.m.	Panel: Efficiently Sourcing Raw Materials at Optimum Quality and Cost
1:30 p.m.	Internal Interfaces in Ceramics: Where the Action is
2:30 p.m.	Networking coffee break and activities on show floor
3:00 p.m.	Advanced Nanoscale Characterization of Grain Boundaries in a Solid Oxide Fuel Cell Electrolyte
3:30 p.m.	Understanding the Benefits of Manufacturing with Polymer Derived Ceramics (PDCs)

WEDNESDAY, MAY 1, 2019

TRACK 1

9:30 a.m.	Investigating Advances in Applications for Glass
10:35 a.m.	Exploring Advances in Electro-Ceramics
11:30 a.m.	Lunch
1:00 p.m.	Embedding Sustainability, Recycling and Resource Management in the R&D Process
2:00 p.m.	Networking coffee break and activities on show floor
2:30 p.m.	Materials and Manufacturing Opportunities for the Electrified Aircraft Market
3:00 p.m.	Title soon to be announced

TRACK 2

9:30 a.m.	Examining Advances in Additive Manufacturing Techniques and Materials
11:30 a.m.	Lunch
1:00 p.m.	A New Statistical Methodology for Assessing Mechanical Reliability of Full-Scale
1:30 p.m.	Panel: Testing and Managing the Properties of the Ceramic End Product

25TH International Congress on Glass (ICG2019)

Hosted by ACerS Glass & Optical Materials Division

100 years

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Make your plans now to attend the International Congress on Glass (ICG) 2019 in Boston, Mass., June 9–14, 2019 and join the expected 1,000 attendees and more than 900 papers and posters representing the best and brightest glass science and technology minds in the world.

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- Student poster contest

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Group rate from **$254** + tax is based on availability. Cut off is on or before **May 8, 2019**.

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SCHEDULE AT A GLANCE

Saturday, June 8, 2019

ICG Technical Committee meetings (tentative)	8 a.m. – 5 p.m.

Sunday, June 9, 2019

ICG Technical Committee meetings (tentative)	8 a.m. – 5 p.m.
Registration	3 – 6 p.m.

Monday, June 10, 2019

Registration	7 a.m. – 5 p.m.
ICG opening ceremony, awards presentation, and plenary session	8 a.m. – Noon
Technology Fair	10 a.m. – 8:30 p.m.
Lunch and GOMD 100th Anniversary Celebration	Noon – 1:30 p.m.
Concurrent sessions	1:30 – 5:00 p.m.
Welcome reception, poster session (1 of 2) , and Technology Fair	6 – 8:30 p.m.

Tuesday, June 11, 2019

Registration	7:30 a.m. – 5 p.m.
Concurrent sessions	8 a.m. – 5 p.m.
Technology Fair	10 a.m. – 7:30 p.m.
Lunch (optional ticketed) and Technology Fair	11:30 a.m. – 1 p.m.
Poster session (2 of 2), Technology Fair, and reception	5:30 – 7:30 p.m.

Wednesday, June 12, 2019

Registration	7:30 a.m. – 5 p.m.
Concurrent sessions	8 a.m. – 5 p.m.
Technology Fair	10 a.m. – 3:30 p.m.
Lunch (optional ticketed)	11:30 a.m. – 1 p.m.

Thursday, June 13, 2019

Registration	7:30 a.m. – 5 p.m.
Concurrent sessions	8 a.m. – 5 p.m.
Lunch on own	11:30 a.m. – 1 p.m.
Dinner banquet	7 – 9:30 p.m.

Friday, June 14, 2019

Registration	7:30 a.m. – 3 p.m.
Concurrent sessions	8 a.m. – Noon
Closing ceremony	Noon – 3 p.m.

SYMPOSIA AND SESSIONS

Symposium I: **Glass Structure and Chemistry**

Symposium II: **Glass Physics**

Symposium III: **Glass Technology and Manufacturing**

Symposium IV: **Emerging Applications of Glass**

Symposium V: **Glass Education (TC23)**

Symposium VI: **Archaeometry (TC17)**

Symposium VII: **Arun K. Varshneya Festschrift**

2nd Global Forum on Advanced Materials and Technologies for Sustainable Development (GFMAT-2)

4th International Conference on Innovations in Biomaterials, Biomanufacturing, and Biotechnologies (Bio-4)

www.ceramics.org/gfmat-2-and-bio-4

July 21–26, 2019 | Marriott Downtown at CF Toronto Eaton Centre Hotel, Toronto, Canada

The global population growth and tremendous economic development has brought us to the crossroads of long-term sustainability and risk of irreversible changes in the ecosystem. Sustainability has become an integral component of research for the 21st century. The key motivating factors are: Rapid urbanization, population growth, and aging population; the large amount of waste yearly disposed to landfill; the global depletion of natural resources and environment (fossil fuels, minerals, water and energy scarcity); declining infrastructure; the emergency of carbon dioxide emissions; and climate change.

For instance, the development of new biomarkers for reliable detection of diseases at early stages, molecular imaging, targeting and therapy are crucial for a healthy society, while the development of more efficient energy conversion technologies, fuel cells, and batteries are an essential step facing the increasing demand for energy supply. Energy efficient and eco-friendly technologies and systems are critically needed for further growth and sustainable development. Consequently, recent research trends globally cover the search for alternative and reusable energies, for fast and reliable medical diagnostic and therapeutic methods, and for new functional materials—as well as new (greener, more efficient) synthesis approaches—that exhibit unique properties allowing for their implementation in health, energy, and environment-related applications.

Organized by ACerS

GFMAT-2 Plenary Speakers

Delmas

Claude Delmas, CNRS research director at the Bordeaux Institute of Condensed-Matter Chemistry, University of Bordeaux 1, France

Title: *TBA*

Singh

Mrityunjay Singh, chief scientist, Ohio Aerospace Institute, USA

Title: *TBA*

BIO-4 Plenary Speakers

Pilliar

Robert M. Pilliar, professor emeritus, Faculty of Dentistry and Institute of Biomaterials and Biomedical Engineering, University of Toronto, Canada

Title: *Porous calcium polyphosphates—Biodegradable bone substitutes and beyond*

Best

Serena M. Best, professor, Materials Science, University of Cambridge, United Kingdom

Title: *Optimizing bioactive scaffolds: Cellular response to calcium phosphate composition and architecture*

HOTEL INFORMATION

Marriott Downtown at CF Toronto Eaton Centre Hotel
525 Bay St. Toronto, Ontario, Canada
1-416-597-9200

Group rate from **$229 CAD + taxes** (currently 16%) based upon availability. The cut off is on or before **June 18, 2019**, or until the blocks sells out.

Bio-4 is organized by ACerS and its Bioceramics Division and endorsed by:

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ROSS offers improvements to the dual-post hydraulic lift and seal design of its 1,500-gallon multishaft mixer (Model PVM-1500). The new lifting design is a double-acting, fully hydraulic cylinder operating at a much higher pressure, allowing for a smaller cylinder and significantly less oil for operation. In addition, the new seal arrangement allows seal replacement without removing agitator shafts. The pictured PVM-1500 features three independently driven agitators: a screw auger, a high-speed disperser, and a three-wing anchor agitator.

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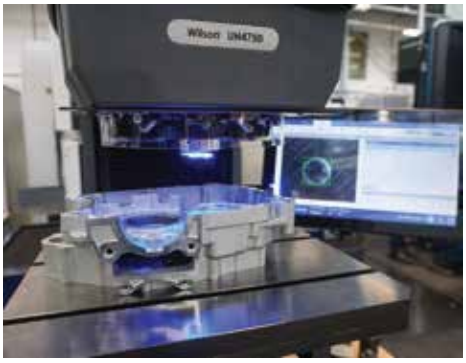

Buehler offers the Wilson UH4000 series, a robust universal hardness tester that tests Rockwell, Vickers, Knoop, and Brinell hardness scales within the selected tester load range. The tester has a sturdy steel casting frame to ensure durability in production and workshop environments, and is controlled by the industry leading DiaMet software, the most intuitive hardness control software on the market. The UH4000 series is available in two different configurations: UH4250 (hardness scale 0.5–250 kgf) and UH4750 (hardness scale 3–750 kgf).

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Calendar of events

March 2019

10–15 ➨ Electric Field Enhanced Processing of Advanced Materials II: Complexities and Opportunities – Hotel Dos Templarios, Tomar, Portugal; www.bit.ly/ElecFieldProc

26–28 55th Annual St. Louis Section/Refractory Ceramics Division Symposium on Refractories – Hilton St. Louis Airport Hotel, St. Louis, Mo.; www.bit.ly/StLouis2019

April 2019

8–10 Imformed Rendezvous – Les Jardins du Marais; Paris, France; http://imformed.com/get-imformed/forums/imformed-rendezvous

22–26 2019 MRS Spring Meeting & Exhibit – Phoenix, Ariz.; www.mrs.org/spring2019

30–May 1 5th Ceramics Expo – I-X Center, Cleveland, Ohio; www.ceramicsexpousa.com

May 2019

13–15 MagForum 2019, Magnesium Minerals & Markets Conference; Occidental Bilbao; Bilbao, Spain; http://imformed.com/get-imformed/forums/magforum-2019

June 2019

9–14 25th Int'l Congress on Glass – Boston Park Plaza Hotel and Towers, Boston, Mass.; www.ceramics.org/icg2019

16–18 10th Advances in Cement-Based Materials – University of Illinois at Urbana-Champaign, Champaign, Ill.; www.ceramics.org/cements2019

24–27 ACerS Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Omni Severin Hotel, Indianapolis, Ind.; www.ceramics.org/scpd2019

July 2019

10–11 Ceramics UK colocated with The Advanced Materials Show – The International Centre, Telford, UK; www.ceramics-uk.com

21–26 4th Int'l Conference on Innovations in Biomaterials, Biomanufacturing, and Biotechnologies (Bio-4), combined with the 2nd Global Forum on Advanced Materials and Technologies for Sustainable Development (GFMAT-2) – Toronto Marriott Downtown Eaton Centre Hotel, Toronto, Canada; www.ceramics.org/gfmat-2-and-bio-4

August 2019

19–23 Materials Challenges in Alternative & Renewable Energy 2019 (MCARE2019) – Lotte Hotel, Jeju Island, Republic of Korea; www.mcare2019.org

September 2019

4–6 3rd Annual Energy Harvesting Society Meeting (EHS19) – Falls Church Marriott Farview Park, Falls Church, Va.; www.ceramics.org/ehs2019

22–27 ➨ HTCMC10: 10th Int'l Conference on High-Temperature Ceramic-Matrix Composites – Palais des Congrès, Bordeaux, France; www.ht-cmc10.org

29–Oct. 3 MS&T19 combined with the ACerS 121st Annual Meeting – Portland, Ore.; www.matscitech.org

October 2019

13–16 ➨ UNITECR 2019: United Int'l Technical Conference on Refractories – Pacifico Yokohama, Yokohama, Japan; www.unitecr2019.org

27–31 ➨ PACRIM 13: 13th Pacific Rim Conference on Ceramic and Glass Technology – Okinawa Convention Center, Ginowan City, Okinawa, Japan; www.ceramics.org

28–31 ➨ 80th Conference on Glass Problems – Greater Columbus Convention Center, Columbus, Ohio; www.glassproblemsconference.org

November 2019

18–20 Indian Minerals & Markets Forum 2019; JW Marriott Mumbai Juhu; Mumbai, India; http://imformed.com/get-imformed/forums/india-minerals-markets-forum-2019

December 2019

1–6 2019 MRS Fall Meeting – Hynes Convention Center, Boston, Mass.; www.mrs.org/fall2019

January 2020

22–24 EMA2020: Electronic Materials and Applications – DoubleTree by Hilton Orlando at Sea World Conference Hotel, Orlando, Fla.; www.ceramics.org

26–31 ICACC20: 44th Int'l Conference and Expo on Advanced Ceramics and Composites – Daytona Beach, Fla.; www.ceramics.org

April 2020

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

May 2020

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

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

Entries in **BLUE** denote ACerS events.

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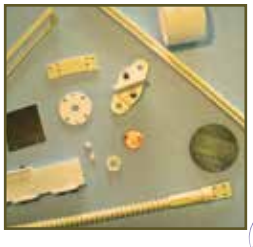

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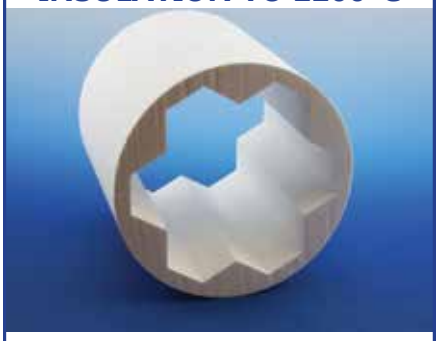

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Arjak Bhattacahrjee
Guest columnist

Traditional ceramic technology in service of humanity

An Indian story based on potteries

Each country in the world has its own uniqueness to offer all other nations. India is unique not only for being a global leader in spirituality and for globally promoting the concept of "unity in diversity," but also for its contributions to science and technology, contributions which lead inquisitive minds in wonder across the globe.

Since ancient times, ceramic technology has been associated with every part of human life. For people who live in India, ceramics are considered an enlightened material due to their blessings in daily life. The first application of ceramics in India and other Asian countries was pottery, and to this day pottery continues to be one of the most important applications of ceramic technology in Indian society.

The pottery industry is connected with rural life in India not only for economic reasons, but also as a part of the country's social and cultural heritage. Even today most Indian social and cultural events (for example, marriage ceremonies and worshiping God) are not possible without various pottery products including lamps, dishes, glasses, and water storage vessels made of clay.

However, the small-scale pottery industries in India are facing extreme economic hardship in terms of sustainability and imbalance of investment and return. The major cause of this problem can be attributed to the availability of polymer products, which weigh less and are less fragile than ceramics, and inadequate technical support for potters. The question now is: how can this industry be made sustainable in today's world?

Since my childhood, apart from dreaming of becoming a good researcher, I possessed a parallel dream of becoming a professional movie director one day. Probably, through opting for an undergraduate education in ceramics, my destiny wrote its own screenplay in that direction! During my bachelor education at the Government College of Engineering and Ceramic Technology in Kolkata, India, I used to feel quite disheartened seeing how unaware nonscientists are of ceramic technology. This unawareness motivated me to show the world how important ceramics are for the overall development of humanity and led me to direct India's first documentary on ceramics, titled "Oneness with the Infinite,"[1] during my master's studies.

While working on the movie, I met with some potters and learned about their dream to see the pottery industry flourish, as well as the continuous challenges they are facing to survive. Hearing their challenges inspired me greatly, and so before coming to the United States to pursue a Ph.D., I went to the shooting place again and did a detailed meeting with the potters to understand their struggle. Based on that survey, I submitted a funding proposal to PCSA-External Partnership Committee asking for money to buy some advanced equipment (automatic pug mill) for the potters, by which their overall production could be enhanced by about three times.

Pottery products can be a boon to supply fresh drinking water in developing countries. Currently, polymer-based water storage vessels are used in most developing countries for storing pure drinking water. However, clay-based water storage vessels not only keep water relatively cooler by allowing dissipation of heat through its inherent porosity, but clay also restricts bacterial growth and chances of contamination, which is very common in polymer-based containers. In addition to pottery, another old ceramic-based technology, ceramic-based water filters, provides Indian citizens with fresh water.

In the era of the 21st century, we can reach the pinnacle of ceramic technology only by properly combining ancient Indian knowledge of potteries with funding and industrialization concepts of the western world. For bulk supply of pure drinking water in underprivileged areas of developing countries like India, we need to join our hands together for providing proper funding and technical support, which will surely lead to bulk scale manufacturing of ceramic water filters and can save precious lives of countless individuals who need a pure drinking water supply.

Credit: Arjak Bhattacahrjee

Bhattacahrjee's short movie, "Oneness with the Infinite," won two international awards by The American Ceramic Society and the India-International Science Film Festival 2017.

Currently I am a Ph.D. student working with Prof. Susmita Bose and Prof. Amit Bandyopadhyay at Washington State University. While my current research is on additive manufacturing of ceramic-based implants for orthopedic applications, I daily fuel my burning dream of returning to India after finishing my education so that I can serve my country in terms of doing humanitarian research projects focusing on pure water supply using ceramic water filters.

References

[1]Bhattacharjee, A. & Dubey, S. [IIT KANPUR]. (23 June 2017). *Oneness with the infinite–A short technical movie on Ceramics and Glass* [Video file]. Retrieved from https://www.youtube.com/watch?v=KeLWMMJEmwU

Arjak Bhattacahrjee is a first year Ph.D. student at Washington State University. Apart from research, he is passionate in leadership and humanitarian activities, and communicating science through documentaries. Arjak received a gold medal from the current president of India for overall best performance among all post graduate students at IIT Kanpur's 2018 convocation.

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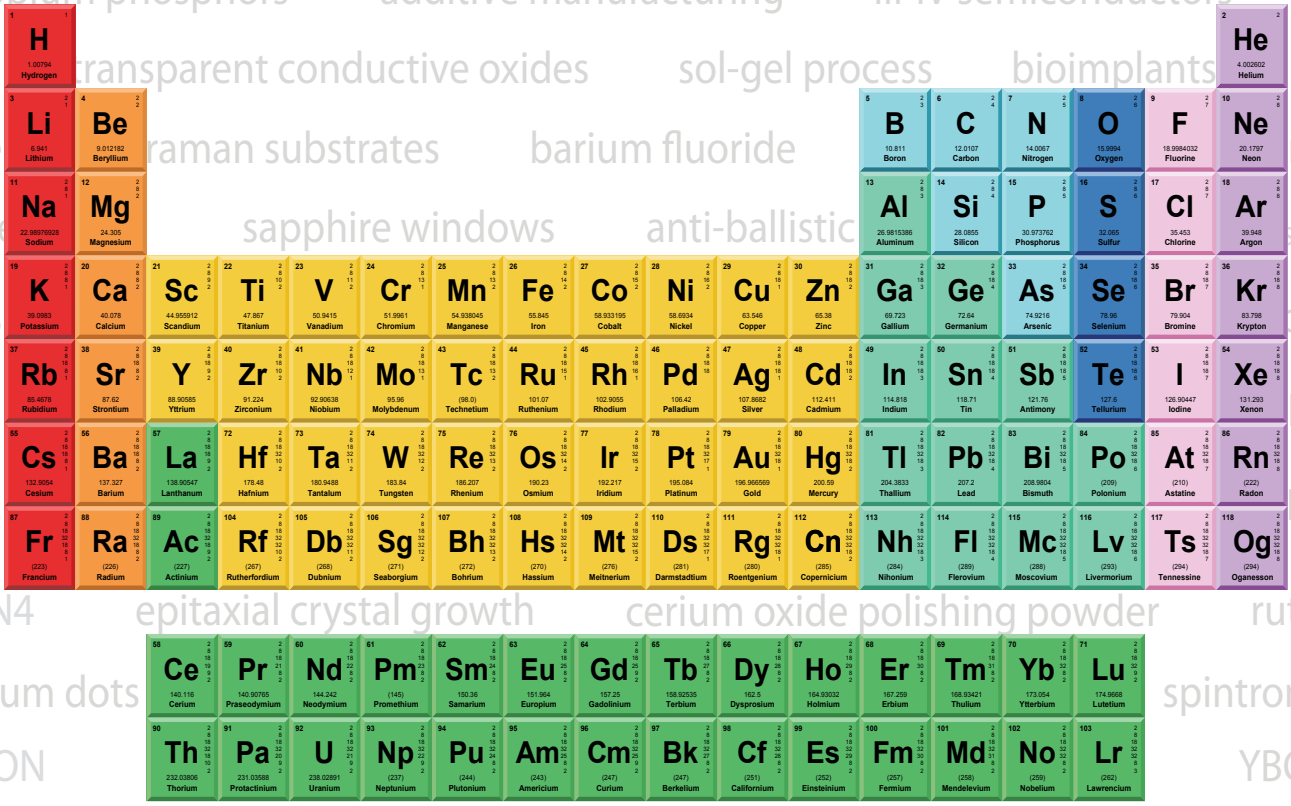

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