AMERICAN CERAMIC SOCIETY
bulletin
emerging ceramics & glass technology
MARCH 2022

Refractory issues related to the use of hydrogen as an alternative fuel

Plus—UNITECR meeting abstracts

Portable melt process optimization system | Refractories in the glass industry

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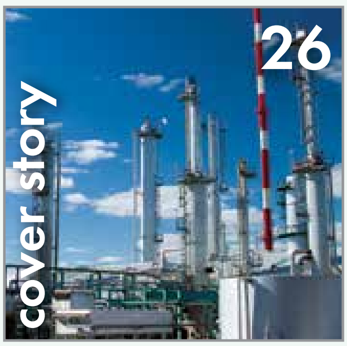
feature articles



An important message about this printed magazine

To our valued subscribers: We've been informed by our printer that supplies of the paper we use to print our magazines is currently at historically low levels. During the pandemic, paper mills have struggled to produce adequate supplies of numerous paper stocks to ensure that the mills and the printers themselves have emergency reserves. As such, upcoming issues of publications like this one are at risk of not being printed.

We know how much you cherish flipping through and reading each issue. We do too! Should the situation arise that we are delayed in printing an upcoming issue, be assured that the online version of the magazine will continue to be released and available as scheduled. Please visit our website www.ceramics.org for future updates on this situation.

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As seen on *Ceramic Tech Today*...

Credit: United Soybean Board, Flickr (CC BY 2.0)

A new horizon for fertilizers—iron oxide nanomaterials support efficient soybean production

The use of nanotechnology as crop fertilizers is a growing area of interest for farmers. A new study led by Jiangnan University researchers compares the performance of fertilizers based on iron oxide nanomaterials to typical iron chelate fertilizers in promoting soybean growth.

Read more at www.ceramics.org/crop-growth

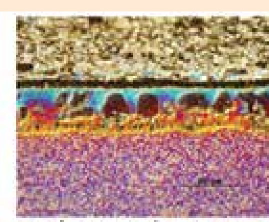
Also see our ACerS journals...

Influence of the MgO grade in MgO-C refractory material and steel melt temperature on the inclusion population in Al-treated steel
By F. Kerber, P. Malczyk, V. Stein, et al.
International Journal of Ceramic Engineering & Science

Determination of temperature dependent static Young's modulus of refratory ceramics using RUL tests
By M. Henze, W. Reichert, T. Tonnesen, et al.
International Journal of Ceramic Engineering & Science

Investigation of fracture behaviour of typical refractory materials up to service temperatures
By E. Brochen, C. Dannert, J. Paul, and O. Krause
International Journal of Ceramic Engineering & Science

Wettability and interfacial phenomena in the liquid-phase bonding of refractory diboride ceramics: Recent developments
By R. Asthana, N. Sobczak, and M. Singh
International Journal of Applied Ceramic Technology



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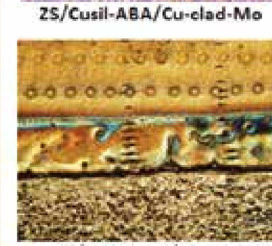

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Journal of the American Ceramic Society | International Journal of Applied Ceramic Technology | International Journal of Applied Glass Science | International Journal of Ceramic Engineering & Science

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ACSBA7, Vol. 101, No. 2, pp 1– 48. All feature articles are covered in Current Contents.

international year of glass

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

A legacy of refractories commitment to glass advancements

By HarbisonWalker International

The impact of glass on our civilization is nothing less than astounding, which is why the United Nations has designated 2022 as the International Year of Glass.

For every glass marvel throughout history and looking ahead to the future, refractories continue to be an essential enabler of progress in glass manufacturing. For HarbisonWalker International (HWI), the relationship began in 1864 when Charles Taylor and Sons opened a small firebrick business in Ohio to serve glass manufacturers. Today these origins are part of a rich history for HWI, which provides the largest refractory manufacturing capacity to the glass industry in North America.

Addressing global industry challenges

During the past century of HWI's history, the company's research and development teams serving the glass market have pioneered a host of innovative solutions that continue to impact how glass is manufactured today. Sustainability has been and continues to be a significant focus for the glass industry, which has been seeking solutions for energy reduction in melting glass and employing even more recycling solutions throughout product lifecycles.

Almost 30 years ago, as concerns about the environmental impact of chromia alumina refractories grew, HWI created the first reuse program for these products to provide alternatives to hazardous waste landfilling for glassmakers. Today, all suppliers of refractories to the glass industry have followed this lead.

Refractory design and engineering for energy reduction also have been a focus at HWI for decades. Since 2008, for instance, HWI has used outside technologies such as high emissivity coatings to increase efficiency, reduce emissions, prevent oxidation and corrosion, and reduce maintenance in the manufacture of glass.

Laser mapping the future of glass furnaces

As we look to the future, refractories innovations in predictive analytics will have a significant positive impact on glass manufacturing energy reduction, higher production, extended furnace life, safety improvements, and cost savings. Integrating high-temperature laser mapping with processed data will provide a more precise measure of refractory performance compared to the subjectivity of visual inspection or thermal imagery. As scanning is incorporated into production processes, it will provide real-time data and more exact control over operations and decision-making, all without production delays. Drawing on laser mapping innovations developed for the steel industry, HWI was recently granted a new continuation on its patented predictive refractory performance measurement system, extending this process for use in glass furnaces.

An exciting future of continued innovation

Additional areas of innovation in refractories include a shift to larger shapes of refractories in furnace design, in recognition that fewer joints can reduce the potential influx of cooler air and offer greater energy efficiencies. In addition to continued product development to accommodate this trend, HWI is collaborating closely with customers and cross-functional teams to increase installation capabilities. For example, it is initiating opportunities to employ robotics in installation practices. HWI's successful partnership with the robotic MULE-R used in refractory installation for other industries holds potential for glass furnaces. Many teams are working together to determine how to maximize the deployment of this technology to benefit glass manufacturers.

As the glass industry moves toward a sustainable future, refractories will continue to play an essential role in ensuring that glass manufacturers around the world continue to innovate, maximize furnace performance, and improve energy efficiencies. ■

Drawing on laser mapping innovations developed for the steel industry, HWI's patented predictive refractory performance measurement system extends the process for use in glass furnaces. *Credit: HarbisonWalker International*

news & trends

James Webb Space Telescope's 30-year journey to launch

On Dec. 25, 2021, astronomers received a Christmas gift that was three decades in the making—the launch of the James Webb Space Telescope (JWST).

JWST is NASA's latest flagship mission, developed with contributions from the European Space Agency and the Canadian Space Agency. Intended to succeed the Hubble Space Telescope, JWST features improved infrared resolution to seek light from the first galaxies in the early universe and to explore our own solar system, as well as planets orbiting other stars.

While JWST represents a technological marvel, it also is a case study in project mismanagement. What follows is a look at JWST's 30-year journey to launch and ways that NASA could restructure its approach to large-scale projects in the future.

1990s—Start of an idea

When the Hubble Space Telescope launched in 1990, scientists hailed it as the dawn of a new age for astronomy and astrophysics. Yet even before the launch, astronomers were planning for what would come next, as explained on the James Webb Space Telescope website.[1]

In September 1989, the Space Telescope Science Institute and NASA co-hosted the Next Generation Space Telescope Workshop. The workshop, which brought together more than 130 astronomers and engineers, discussed the science drivers and technical capabilities of a follow-up telescope to Hubble, which was then estimated to reach end-of-use in 2005.

In September 1993, the Association of Universities for Research in Astronomy, at the behest of the Space Telescope Institute Council and with support from NASA, appointed

Credit: NASA's James Webb Space Telescope, Flickr (CC BY 2.0)

Testing of the James Webb Space Telescope before launch. In 2021, NASA considered renaming the telescope after a petition signed by more than 1,200 people requested a change in light of allegations that former NASA administrator James Webb was involved in persecuting gay and lesbian people during his career in government. After an investigation, NASA declined to rename the telescope.

the Hubble Space Telescope & Beyond Committee. The committee was tasked to study possible missions and programs for ultraviolet optical infrared astronomy in space.

In 1996, the 18-member committee released a report[2] formally recommending that NASA develop an infrared light-based space telescope (and that Hubble be operated beyond its original termination in 2005).

Following the report, three teams consisting of private and public sector scientists and engineers met to determine whether NASA could realize the committee's vision. All three concluded that the proposed telescope would work, so in 1997 NASA agreed to fund additional studies on the technical and financial requirements for building the telescope.

2000s—3, 2, 1...delay

By 2002, NASA had selected teams to build the instruments and a group of astronomers to provide construction guidance for the telescope. The telescope also received its formal name of the James Webb Space Telescope, after the NASA administrator who led development of the Apollo program in the 1960s.

Construction on JWST began in 2004. In 2005, an Ariane 5 rocket was chosen as the launch vehicle, and the European Space Agency's Centre Spatial Guyanais spaceport in French Guiana was chosen as the launch site.

Despite this initial progress, JWST development soon slowed down immensely due to technical and management challenges, contractor performance issues, and low levels of cost reserve. As a result, NASA moved the original launch date of 2007 to the early 2010s and increased the project's cost estimate considerably—from $500 million estimated in 1996, to $1–3.5 billion estimated in 2002, to $5 billion estimated in 2008.

That is when Congress started taking a closer look at how the project was being managed.

Congress scrutinizes JWST project management

As outlined in a *Space News* article,[3] Congress first strongly confronted NASA about JWST's swelling costs and delays during the fiscal year 2012 budget cycle deliberations.

In July 2011, appropriators in the Republican-controlled House passed a spending bill that would have canceled the JWST project. In the Senate, where Democrats had a majority, appropriators insisted on funding the project fully.

JWST was eventually funded, but the project went through an extensive replan that involved setting a new launch date for 2018 and capping the cost at $8 billion. However, NASA did not meet these new targets either.

In September 2017, NASA announced it would delay launch until spring 2019. Then in March 2018, it pushed the launch until spring 2020 and raised the cost estimate to $8.8 billion, with an extra $837 million requested for operating the telescope once it was in space. Finally, in June 2018, NASA moved the launch date to March 2021.

In July 2018, the House Science Committee held a two-day hearing to investigate the recent delays that caused JWST to breach its statutory cap on development costs once again. Then House Science Committee Chair Lamar Smith (R-TX) opened the hearing by censuring NASA's handling of the project.

"It is truly staggering to behold how this space telescope's cost and schedule projections went from costing the same as a space shuttle mission—around half a billion dollars with an original launch date in 2007—to now becoming an expenditure exceeding $9 billion with a new launch goal in March 2021. This is 19 times the original cost and a delay of 14 years. It doesn't get much worse than that," he said.

During the hearing, congresspeople heavily debated Northrop Grumman's role in the delays. Since 2002, when Northrop Grumman acquired TRW Inc., the corporation that helped design JWST, Northrop Grumman became the prime constructor of JWST.

While errors are expected for a project as complex as JWST, independent reviews determined that the errors made under Northrop Grumman's watch were avoidable.

"Workers used the wrong solvent to clean the observatory's propulsion valves. A wiring error severely damaged the spacecraft's pressure transducers. During an important test, the fasteners designed to hold the sun shield together came loose, scattering dozens of bolts that took months to find. These mistakes alone resulted in a schedule delay of about 1.5 years and $600 million," an article on *The Atlantic* explains.[4]

When congresspeople tried to hold Northrop Grumman accountable during the hearing, the company skirted answering if it should be responsible for covering the cost overruns, as detailed in an *FYI* article.[5]

Instead, the focus became how NASA could improve the structure of its contracts and the bidding process. For example, retired aerospace executive Tom Young suggested that instead of NASA entertaining bids offering a "lowest credible cost," NASA should establish a "most probable cost" before inviting bids and set criteria for awarding contracts to attract bids that emphasize good performance.

Two years after the House hearing, NASA announced another delay in July 2020, pushing the launch date to October 2021 due to the COVID-19 pandemic. In September 2021, the launch was delayed slightly more to December. Finally, on Dec. 25, 2021, JWST launched into space—more than 30 years after it was initially conceived and at a cost of $10 billion.

Visit news9live.com for a more detailed timeline of JWST project development.[6]

The future of and after JWST

Now that JWST is launched and what appears to be successfully deployed, what happens next?

First, NASA needs to make some final adjustments to JWST's mirrors. Then, NASA will direct JWST to fly directly to Lagrangian point 2, a spot 1 million miles away where Earth and the sun's gravity cancel out, allowing the telescope to orbit the sun with Earth permanently at its back. After reaching this point and following final alignment, JWST can start collecting data no sooner than mid-summer 2022.

As for future projects, a big concern for Congress is avoiding the effects that JWST's delays and cost overruns had on other projects in NASA's portfolio, such as the Laser Interferometer Space Antenna (LISA) and the Wide-Field Infrared Survey Telescope (WFIRST).

To avoid future flagship missions crowding out funding for other important projects, the National Academies' latest astronomy and astrophysics decadal survey suggests implementing a new "Great Observatories Mission and Technologies Maturation Program."

"The survey explains that flagship missions routinely have development timescales stretching multiple decades and that immaturity of their component technolo-

Credit: NASA's James Webb Space Telescope, Flickr (CC BY 2.0)

Dec. 25, 2021: Arianespace's Ariane 5 rocket launches with NASA's James Webb Space Telescope onboard from the ELA-3 Launch Zone of Europe's Spaceport at the Guiana Space Centre in Kourou, French Guiana.

gies has in the past led to costly difficulties. 'By investing more in the maturation process, NASA could develop missions to a level where there is significantly more confidence in the costs and requisite cost profiles before seeking congressional approval for the final implementation,' it states," an *FYI* article explains.[7]

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[1]"Mission Timeline," Webb Space Telescope. Accessed Jan. 12, 2022. https://webbtelescope.org/webb-science/the-observatory/mission-timeline

[2]"HST and beyond: Exploration and the search for origins: A vision for ultraviolet-optical-infrared space astronomy," report of the Hubble Space Telescope & Beyond Committee. Published May 15, 1996. Accessed Jan. 12, 2022. https://www.stsci.edu/stsci/org/hst-and-beyond-report.pdf

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[4]Koren M, "Who should pay for the mistakes on NASA's next big telescope?" *The Atlantic*, published July 27, 2018. Accessed Jan. 12, 2022. https://www.theatlantic.com/science/archive/2018/07/nasa-james-webb-space-telescope-northrop-grumman-cost/566186

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[6]Madanapalle A, "Looking back in time: Development and delays of the James Webb Space Telescope," news9live.com, published Dec. 25, 2021. Accessed Jan. 12, 2022. https://www.news9live.com/science/looking-back-in-time-development-and-delays-of-the-james-webb-space-telescope-142428?infinitescroll=1

7. Thomas W, "Astro2020 Decadal Survey arrives: Priorities for major facilities," *FYI*, published Nov. 4, 2021. Accessed Jan. 12, 2022. https://www.aip.org/fyi/2021/astro2020-decadal-survey-arrives-priorities-major-facilities

DOE SunShot and Energy Earthshots initiatives support move toward clean energy

The U.S. Department of Energy plays an instrumental role in the move toward clean and renewable energy technologies. In the past decade, two initiatives have specifically focused on supporting expansion of such technologies—the SunShot and Energy Earthshots initiatives.

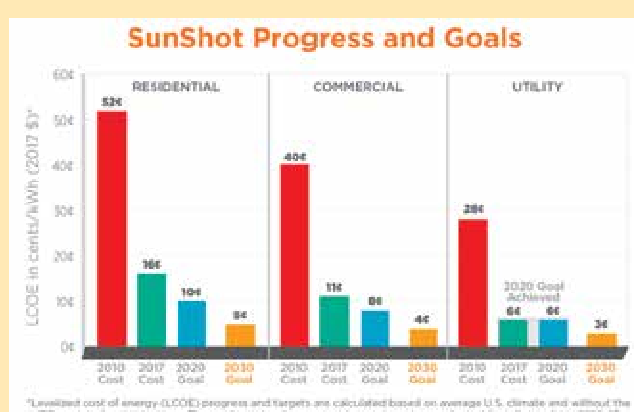
The DOE under the Obama administration launched the SunShot Initiative in February 2011. Inspired by President Kennedy's 1962 "moon shot" speech that kickstarted the U.S. lunar program, the SunShot Initiative aimed to reduce total costs of solar energy by 75% by the end of the decade, thus making it cost competitive at large scale with other forms of energy without subsidies.

In September 2017, DOE announced that the SunShot Initiative successfully met the utility-scale solar cost target of $0.06 per kilowatt hour three years earlier than expected. DOE is now working toward SunShot 2030 goals. Learn more about the SunShot Initiative at https://www.energy.gov/eere/solar/sunshot-2030.

The Energy Earthshots initiative is a new initiative that launched in 2021 under the direction of the Biden administration. This initiative is designed to advance a variety of energy technologies by driving integrated program development across DOE's science and applied energy offices and ARPA-E.

Since summer 2021, DOE has announced three Energy Earthshots: Hydrogen Shot, to reduce the cost of clean hydrogen; Long Duration Storage Shot, to reduce the cost of grid-scale energy storage; and Carbon Negative Shot, an all-hands-on-deck call for innovation in technologies and approaches that will remove carbon dioxide from the atmosphere and durably store it at meaningful scales.

DOE expects to announce a total of six to eight Energy Earthshots by the end of 2022. Learn more about the Energy Earthshots at https://www.energy.gov/policy/energy-earthshots-initiative.



Glass-ceramics: Global markets to 2026

By BCC Publishing Staff

The global glass-ceramics market was valued at $1.4 billion in 2021 and is estimated to grow at a compound annual growth rate of 5.8% to reach $1.8 billion by 2026.

Glass-ceramics are a polycrystalline substance manufactured through controlled crystallization of base glass, between 30% [m/m] and 90% [m/m].

Factors driving growth of the glass-ceramic market include

- **Rapid urbanization**. Global urbanization is on the rise, mainly in Asia-Pacific, with large rural populations moving to city areas for employment and elevated standards of living. Thus, there is a strong need to develop residential areas, with well-equipped electrical systems/devices and kitchens.
- **Infrastructure development**. Globally, governments are making substantial investment into major infrastructure projects that boost the economy, which is likely to boost glass-ceramic demand in the near future.
- **Surging pharmaceutical industry**. The growing elder population, increasing rates of chronic disease, and the pandemic contribute to higher demand for medication. Glass-ceramics generally offer better bioactivity and biocompatibility compared to sintered ceramics.
- **European manufacturing**. Europe has witnessed a sharp increase in terms of industrial production and domestic manufacturing capabilities, especially in Germany. With surging manufacturing activities, the need for machinable glass-ceramics has grown.
- **Electricals and electronics demand**. Over the last few years, the electronics industry has gone through a rapid change due to advancements in technology and the increasing buying power of consumers. The overall market for glass-ceramics is driven by semiconductors, televisions, computers, optical devices, and sensors. Glass-ceramics also play a crucial role in information processing and electronic technologies.

Factors restraining growth in the glass-ceramic market include

- **High price**. The price of glass-ceramics is controlled largely by the cost of ceramic fibers. Generating the glassy matrix also contributes to higher prices because the process requires expensive batch processes at high temperatures in a controlled atmosphere.
- **Customization requirements**. Original equipment manufacturers in aerospace and automotive industries prefer customized glass-ceramics for components. Production of customized components is not always feasible because it increases production cost and time.

North America holds a decent share of the global glass-ceramics market (26.1% in 2020), which is mainly attributed to technological advancements. However, the Asia-Pacific region holds a significant share (40.6% in 2020) and will reach 43.2% by 2026. This region is witnessing high government and private spending in medical, electronics, and building and construction, resulting in new plants/factories in developing countries.

Table 1. Applications of glass-ceramics

Subject	Application
Thermal	Cookware, cooktops, hot plates, low thermal expansion glass-ceramics, sealants, fireproof windows and doors
Armor	Bulletproof and missile-proof components, bulletproof vests
Magnetic	Magnetic head actuators, magnetic information storage media, substrates for magnetic storage devices
Energy	Solid oxide fuel cells, LEDs, solar cells
Biology	Bioactive scaffolds, antimicrobial glass ceramics, anti-inflammatory glass-ceramics, glass-ceramic powders for cosmetics
Architecture	Decorative substrates, building components
Chemical	Catalytically active glass-ceramics, photocatalyst supports, corrosion-resistant glass-ceramics, ion-exchanged glass-ceramics, glues
Mechanical	Abrasives, machinable glass-ceramics, high-strength glass-ceramics
Dental	Dental restorations, dental prosthetic devices
Optical	Transparent glass-ceramics, luminescent glass-ceramics, colored glass-ceramics, lasers, lenses, mirrors
Electronics	Electronic components, substrates for electronic devices, plasma display panels
Electrical	Solid electrolytes, lithium-ion-conducting glass-ceramics, semiconductor substrates

Table 2. Global markets for glass-ceramics, by application, through 2026 ($ millions)

Application	2020	2021	2026	CAGR % (2021–2026)
Semiconductors and electronics	429.8	456.2	635.7	6.9
Kitchenware	330.7	341.6	414.0	3.9
Optical	152.6	163.3	236.1	7.7
Medical	115.1	124.2	186.7	8.5
Aerospace and military	79.5	83.6	111.3	5.9
Building and construction	51.4	52.8	61.4	3.1
Automobile	32.9	34.2	43.0	4.7
Others	107.9	110.4	126.4	2.7
Total	**1,300**	**1,366.3**	**1,814.6**	**5.8**

About the author

BCC Publishing Staff provides comprehensive analyses of global market sizing, forecasting, and industry intelligence, covering markets where advances in science and technology are improving the quality, standard, and sustainability of businesses, economies, and lives. Contact the staff at Helia.Jalili@bccresearch.com.

Resource

BCC Publishing Staff, "Glass ceramics: Global markets to 2026" BCC Research Report AVM220A, November 2021. www.bccresearch.com.

SOCIETY DIVISION SECTION CHAPTER NEWS

Welcome new ACerS Corporate Partner

ACerS is pleased to welcome its newest Corporate Partner

CARBO murugappa

Carborundum Universal Ltd.

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

Japan Chapter participates in the 60th Symposium on Basic Science of Ceramics

The Japan Chapter and The Ceramic Society of Japan jointly organized the International Session at the 60th Symposium on Basic Science of Ceramics, Jan. 8–9, 2022.

Congratulations to the speakers who were recognized for best oral presentations:

- Kyusung Kim, National Institute of Advanced Industrial Science and Technology
- Yunzi Xin, Nagoya Institute of Technology

Additionally, congratulations to Theresa Davey, who was honored as an invited lecturer (inset photo). ■

Dayton/Cincinnati/Northern Kentucky Section extends Elevator Pitch Competition deadline

The Dayton/Cincinnati/Northern Kentucky Section has extended the deadline for its first virtual Elevator Pitch Competition for undergraduate and graduate students. Students are invited to submit a 60-second video addressing the impact of ceramics in society, such as their dissertation work, research project, or topic learned in class. The top 10 entries will be selected.

Winners will receive a one-year GGRN membership (graduate students only) and $100 toward an ACerS conference in the 2022–2023 year that begins after the ACerS Annual Meeting in October 2022.

For more information, students are encouraged to visit the Section webpage at https://ceramics.org/members/member-communities/sections/dayton-cincinnati-northern-kentucky. ■

Dayton/Cincinnati/Northern Kentucky Section plans outing at Dayton Art Institute

The Dayton/Cincinnati/Northern Kentucky Section will gather for socializing and a ceramic and glass themed scavenger hunt at the Dayton Art Institute on March 26. Watch the Section webpage at https://ceramics.org/members/member-communities/sections/dayton-cincinnati-northern-kentucky for details and registration information. ■

Sections and Chapters welcome new leadership

- **Carolinas Section: Secretary**, Fei Peng, Clemson University, Clemson, S.C.
- **Dayton/Cincinnati/Northern Kentucky Section: Social/outreach chair**, Chris Kassner, UES, Inc. at Air Force Research Laboratory at Wright-Patterson
- **Thailand Chapter: Chair**, Jakrapong Kaewkhao, and **vice-chair**, Naratip Vittayakorn, King Mongkuts Institute of Technology Ladkrabang. ■

NEW program—YPN+1

The Young Professionals Network Steering Committee put together a new program of leadership opportunities for ACerS YPN members.

The YPN+1 program offers YPN members seeking leadership roles opportunities to serve as YPN Division Liaisons and YPN Symposium Coorganizers.

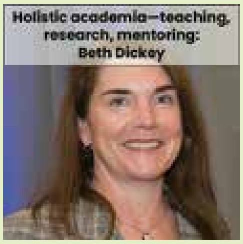
Learn more about the YPN+1 Program at https://ceramics.org/ypn1-program. Open opportunities will be posted throughout the year. ■

IN MEMORIAM

AC Bakken
Philip Berneburg
Paul Buckles
Douglas Mattox
Keith Reeve
Richard Waugh

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

Ceramic Tech Chat: Beth Dickey



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

In the January episode of Ceramic Tech Chat, Beth Dickey, Teddy & Wilton Hawkins Distinguished Professor and department head of materials science & engineering at Carnegie Mellon University, describes her work to attract and retain the next generation of materials scientists, including by incorporating data science into university materials science curricula, developing new faculty mentorship programs, and in a variety of leadership roles in The American Ceramic Society.

Check out a preview from her episode, which features Dickey explaining her approach to mentoring.

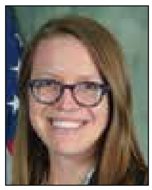
"So, I view mentoring as kind of a network thing. There's not just one specific person. I think you need to be cognizant of who is in your mentor network, because if you think about who's influencing you and who you're learning from, if you step back, you kind of see that there's a large group of people probably that are in some way helping you and mentoring you. … Through The American Ceramic Society, I think we have an opportunity to do a lot more around mentoring. There's a lot with our students, and a very robust mentoring program with the President's Council of Student Advisors. But, as you know, part of the strategic plan moving forward is to really provide more opportunities for mentoring through people's careers, not just as they're students but as they're young professionals or mid-career professionals."

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

more SOCIETY DIVISION SECTION CHAPTER NEWS

Volunteer spotlight

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


Rueschhoff

Lisa Rueschhoff is a materials research engineer in the Composites Branch at the Air Force Research Laboratory in Wright Patterson Air Force Base, Dayton, Ohio. She received her B.S in materials engineering from Iowa State University and her Ph.D. in materials engineering from Purdue University.

She has coauthored 12 peer-reviewed articles and presented at 23 research conferences and seminars. Her research awards include NSF Graduate Research Fellowship, ACerS Graduate Excellence in Materials Science Sapphire Award, and Purdue Materials Engineering Outstanding Graduating Graduate Student Award. In 2019, she received the inaugural ACerS International Jubilee Global Diversity Award.

Rueschhoff's activities in ACerS include serving as communications chair and chair in the President's Council of Student Advisors, coorganizer of the inaugural ACerS Winter Workshop, and current mentor to the PCSA Programming Committee. She also is a reviewer for the *Journal of the American Ceramics Society*, an associate editor for the *International Journal of Applied Ceramic Technology*, and coorganizer of three symposia for the International Conference on Advanced Ceramics and Composites. She currently is chair of the Member Services Committee and serves on the Strategic Planning for Emerging Opportunities Committee.


Halbig

Michael C. Halbig is a senior materials research engineer and technical lead for additive manufacturing and joining and integration of composite materials at NASA's Glenn Research Center in Cleveland, Ohio. He has a bachelor's degree in physics from Illinois State University, a bachelor's degree in ceramic engineering from the University of Illinois, and a master's degree in materials science and engineering from Case Western Reserve University.

Halbig has authored or coauthored more than 75 journal articles and proceedings papers and two book chapters. He is an associate editor for the *International Journal of Applied Ceramic Technology*.

An ACerS Fellow (2020), Halbig has also received the Engineering Ceramics Division Global Star Award (2012) and the Richard M. Fulrath Award (2013).

Halbig's service to ACerS is long-standing. During his 26 years of membership, he has served as program chair for the 38th International Conference on Advanced Ceramics and Composites and for the 14th Pacific Rim Conference on Ceramic and Glass Technology. He has served on the Nominating Committee, Samuel Geijsbeek PACRIM International Award Committee, Richard M. Fulrath Award Committee, and the W. David Kingery Award Committee. He is a past chair and current trustee of the Engineering Ceramics Division, as well as chair of the ECD Jubilee Global Diversity Award Committee.

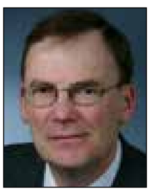
We extend our deep appreciation to Rueschhoff and Halbig for their service to our Society! ■

Names in the news

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

Barsoum

Michel Barsoum, FACerS, Distinguished Professor in the materials science and engineering department at Drexel University, ranked first in the materials science subfield in an updated citation study led by a Stanford University researcher. The study analyzed 2020 citation metrics from Scopus and excluded self-citations.



Conradt

Reinhard Conradt was elected president of the International Commission on Glass for the 2021–2024 term, which began in December 2021. He is retired professor and chair of Glass and Ceramic Composites of RWTH Aachen University, Germany.

Durán

Alicia Durán, research professor at the Spanish Research Council, was awarded the 2022 Otto Schott Research Award by the Board of Trustees of the Ernst Abbe Fund. The award will be presented at the 26th International Glass Congress in Berlin, Germany, in July 2022. ■

AWARDS AND DEADLINES

EDiv names best student posters and student oral presentations of EMA 2022

The Electronics Division presented awards for outstanding student work during their 2022 Virtual Conference on Electronic Materials and Applications. Congratulations to these students.

Poster Competition EMA 2022

First prize

Surface decoration of $Pr_{0.1}Ce_{0.9}O_{2\text{-}\delta}$ electrodes with binary oxides measured by in-situ PLD technique; **Christoph Riedl**, Institute of Chemical Technologies and Analytics, TU Wien

Second prize

Exploring point defects and trap states in undoped $SrTiO_3$ single crystals; **Matthäus Siebenhofer**, TU Vienna

Third prize

Electrical characterization of lithium cobalt oxide nanosheets; **Bridget Powers Beggs**, Case Western Reserve University

Oral Presentation Competition EMA 2022

First prize (tie)

Engineering grain boundary anisotropy to suppress abnormal grain growth in alumina; **Bryan Conry**, University of Florida

Grain and grain boundary photoconduction in perovskite solar cells with tomographic AFM; **Luis Ortiz**, University of Connecticut

Second prize

Developing a standard reference material for 5G millimeter wave; **Lucas Enright**, NIST

Third prize

Configurational disorder in high entropy T' phase Ruddlesden-Popper perovskites; **Daniel J. Rossi**, James Madison University ■

Take note of fast-approaching award deadlines

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

Contact: Erica Zimmerman | Member engagement manager | ezimmerman@ceramics.org | 614.794.5821

Division	Award	Nomination Deadline	Contacts	Description
Bioceramics	**Young Scholar**	April 1	Ashutosh Goel ag1179@soe.rutgers.edu	Recognizes excellence in research among current degree-seeking graduate students and postdoctoral research associates.
Bioceramics	**Global Young Bioceramicist**	April 1	Ashutosh Goel ag1179@soe.rutgers.edu	Recognizes the outstanding young ceramic engineer and materials scientist who has made significant contributions to the area of bioceramics for human healthcare around the globe.
Bioceramics	**Larry L. Hench Lifetime Achievement**	April 1	Ashutosh Goel ag1179@soe.rutgers.edu	Recognizes the outstanding young ceramic engineer and materials scientist who has made significant contributions to the area of bioceramics for human healthcare around the globe.
Bioceramics	**Tadashi Kokubo**	April 1	Ashutosh Goel ag1179@soe.rutgers.edu	Recognizes an individual's outstanding achievements in the field of bioceramics research and development.
GOMD	**Alfred R. Cooper Scholars**	May 15	Steve Martin swmartin@iastate.edu	Recognizes undergraduate students who demonstrated excellence in research, engineering, and/or study in glass science or technology.
EDiv	**Edward C. Henry**	May 30	Elizabeth Paisley eapaisl@sandia.gov	Recognizes an outstanding paper reporting original work in the *Journal of the American Ceramic Society* or the *Bulletin* during the previous calendar year on a subject related to electronic ceramic.
EDiv	**Lewis C. Hoffman Scholarship**	May 30	Elizabeth Paisley eapaisl@sandia.gov	Recognizes academic interest and excellence among undergraduate students in the area of ceramics/materials science and engineering.

MEMBERSHIP SPOTLIGHT

Exploring the edge between science and art

We recently heard from Edward "Ted" Lilley, FACerS, about his second career as an artist who explores the intersection of materials and art. After a career as an industrial researcher at Corning International and Norton (now Saint-Gobain) and an academic stint at University of Sussex in the U.K, he is applying his experimental muscle and powers of observation to a new exploration of materials. Lilley belongs to the AACS Division.

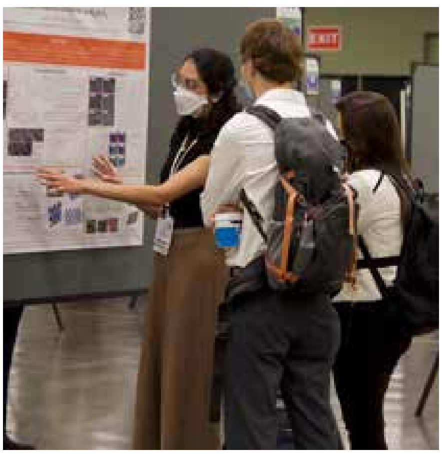
"In art we often combine images or objects in unusual ways. Frequently artists show 'found objects.' That is not what I do. I started with a dysfunctional lap top computer which is sleek and I think beautiful. I first painted it all black to transform it. I could have stopped at that point but I decide to cover the screen with small black glass spheres making an attractive array. That I thought would be the end point. I showed it to a few people and then folded it for storage. The next time I opened it up some of the spheres fell off. Inadequately glued down. This immediately gave me the idea of Abacus. EUREKA! So I developed this idea and with a brass name plate it became Abacus.

I am trying to show the irony in this piece which stretches from ancient times to today, from the most primitive counting method to the most incredibly powerful device."

–Ted Lilley

See more of Lilley's materials science art at www.tedlilleystudio.com.

STUDENTS AND OUTREACH



Basic Science GEMS Award deadline is March 15

Sponsored by ACerS Basic Science Division, the annual Graduate Excellence in Materials Science Awards recognize the outstanding achievements of graduate students in materials science and engineering. The award is open to graduate students making oral presentations in any symposium at MS&T22. To be eligible to apply for these awards, you must first submit your abstracts by **March 15, 2022**, to MS&T2022 at https://www.matscitech.org/MST22. ■

Apply today for 2022–23 ACerS PCSA class

The President's Council of Student Advisors, ACerS' student-led committee, is looking for dedicated and motivated undergraduate and graduate students focused on ceramics and glass to get involved and help advance ACerS into the future. Visit www.ceramics.org/applypcsa to learn more and how to apply. Application deadline is **March 18, 2022.** ■

ACerS Associate Membership and Young Professionals Network

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

Also, consider joining ACerS Young Professionals Network (YPN) once you've become an ACerS member. ACerS YPN is designed for members who have completed their degree and are 25 to 40 years of age. YPN gives young ceramic and glass scientists access to invaluable connections and opportunities. Visit www.ceramics.org/ypn for more information or contact Yolanda Natividad at ynatividad@ceramics.org. ■

ACerS GGRN—graduate student membership

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

GGRN graduate student 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. Visit www.ceramics.org/ggrn to learn what GGRN can do for you and to join. ■

FOR MORE INFORMATION:

ceramics.org/students

ACERS BOOKSHELF

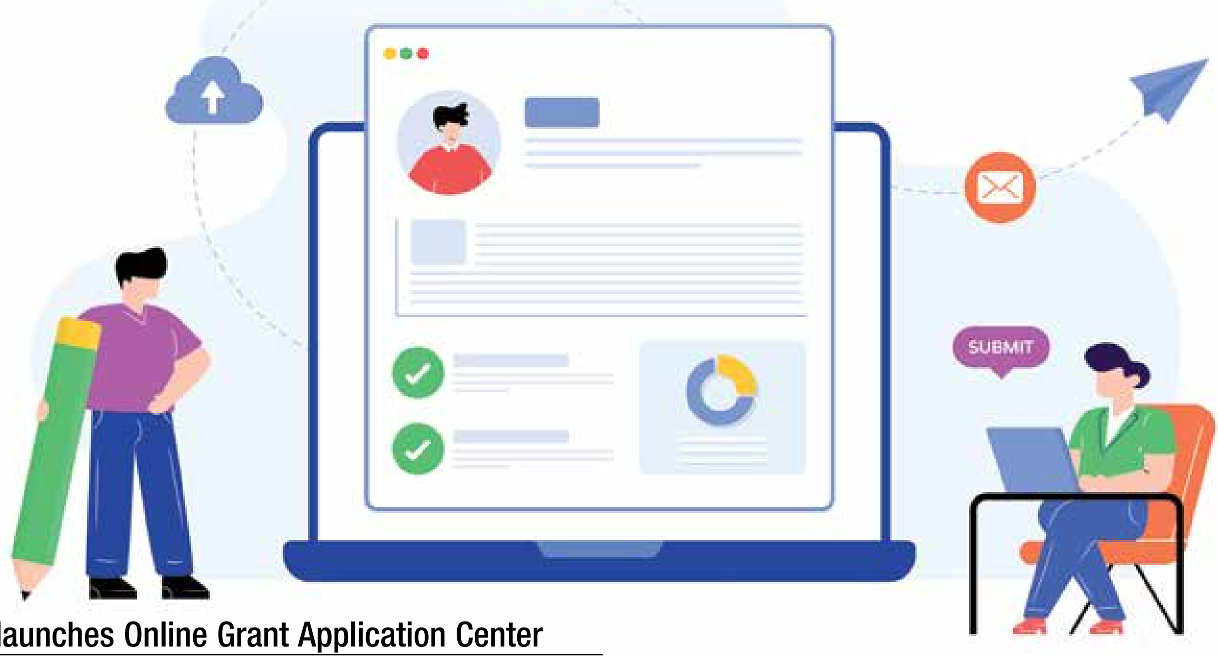
CHECK OUT TWO NEW TITLES FROM ACERS/WILEY

Looking for a new book to read this year? These two new titles by Wiley-ACerS are available on www.wiley.com/ceramics.

3D Printing for Energy Applications, edited by Albert Tarancón and Vincenzo Esposito, delivers an insightful and cutting-edge exploration of the applications of 3D printing to the fabrication of complex devices in the energy sector.

Dynamic Response of Advanced Ceramics, by Ghatu Subhash, Amnaya Awasthi, and Dipankar Ghosh, delivers a comprehensive exploration of foundational and advanced concepts in experimental, analytical, and computational aspects of the dynamic behavior of advanced structural ceramics and transparent materials. ■

CERAMIC AND GLASS INDUSTRY FOUNDATION



CGIF launches Online Grant Application Center

New outreach grant opportunities are now available! Teachers and members of the community can use the new Online Grant Application Center to view and apply for grants that help fund materials science education in the local community and beyond.

THE CERAMIC AND GLASS INDUSTRY FOUNDATION CURRENTLY FEATURES TWO TYPES OF GRANTS.

1. **Kit Grants:** This grant allows applicants to propose outreach or classroom projects focused around CGIF's Materials Science Kits. Applicants can request up to 10 Materials Science Classroom Kits, 50 Mini Kits, or a combination of the two, plus supplementary funding up to $600. Applications are accepted on a rolling basis.

2. **Project Grants:** This grant allows applicants to propose creative projects that expand materials science education projects in their community. Each applicant can request funding for up to $5,000 for their project, which should be directly applicable to expanding materials science education or training the next generation of glass and ceramic professionals. In celebration of the International Year of Glass, special appreciation will be given to applications that incorporate glass. Applications are accepted until **Sept. 2, 2022**.

Apply today at **https://foundation.ceramics.org/grants**.

Questions? Email us at **foundation@ceramics.org**. ■

Intel sets sights on Ohio to drastically expand domestic manufacturing with semiconductor mega-site

On Friday, Jan. 21, a rumor that had been floating around Ohio news outlets for weeks received a very satisfying confirmation—semiconductor chip manufacturer Intel stated that it will commit $20 billion to build a manufacturing mega-site in New Albany, on the outskirts of Columbus, Ohio.

For those outside the industry, the weight of this announcement might not be immediately clear. To clarify its importance, what follows is a look at some of the big events that have affected the semiconductor industry in recent years and how Intel's announcement fits into the narrative.

Semiconductor chips: An essential part of electronics

A semiconductor is a material that has an electrical conductivity value falling between that of a conductor (such as many metals) and an insulator (such as glass). Examples of semiconductor materials include silicon, germanium, gallium arsenide, and elements near the so-called "metalloid staircase" on the periodic table.

In electronics, semiconductor materials are used as the basis for semiconductor chips, i.e., a set of electronic circuits that rest on top of a small flat piece (or "chip") of semiconductor material, usually silicon. These so-called integrated circuits are orders of magnitude smaller, faster, and less expensive than those constructed of discrete electronic components.

There are different ways for industry to categorize types of semiconductor chips. When categorized by functionality, there are memory chips, microprocessors, commodity integrated circuits ("standard chips"), and complex systems-on-a-chip. When categorized by types of integrated circuitry, there are digital, analog, and mixed chips.

The ongoing semiconductor chip shortage and need for domestic manufacturing

When the COVID-19 pandemic started upending everyone's lives in 2020, several factors culminated into

Credit: Yaca2671, Wikimedia (CC BY-SA 3.0)

Example of a microprocessor-type semiconductor chip. Microprocessors contain one or more central processing units (CPUs), which provide the instructions and processing power that a computer needs to do its work.

a global semiconductor chip shortage. The January/February issue of the *ACerS Bulletin* featured a summary of a BCC Research report that looked at these factors, including a sudden demand for consumer electronics, disruption in the supply chain caused by the pandemic, ongoing trade wars between countries, and natural disasters and industrial accidents causing semiconductor fabrication plants to close, among other factors.

This shortage is causing severe problems for industries that rely on electronics. For example, the United States Commerce Department recently issued a report that found manufacturers' median chip inventory levels have plummeted from about 40 days' supply in 2019 to less than five days, according to a survey of 150 companies worldwide.

These tight margins are being reflected in the products available to consumers. The automotive industry is a prime example—General Motors, Honda, Nissan, and Stellantis reported significant declines in sales in later 2021 as chip shortages forced them to idle plants, leaving dealers with few vehicles to offer customers.

As a result, much discussion has turned to bolstering domestic manufacturing of semiconductor chips to avoid such severe shortages in the future. As a recent fact sheet released by the Biden-Harris Administration notes, "The United States used to lead the world in global semiconductor manufacturing. But in recent decades, the U.S. lost its edge—our share of

Credit: Intel Corporation

Renderings showing early plans for the semiconductor fabrication plants.

global semiconductor production has fallen from 37 percent to just 12 percent over the last 30 years."

The Creating Helpful Incentives to Produce Semiconductors for America (CHIPS) Act is one piece of legislation that looks to bolster domestic semiconductor chip production. The act would establish a set of programs to provide incentives and encourage investment in domestic R&D and manufacturing of semiconductor chips.

While the CHIPS Act was approved in principle as part of the fiscal year 2021 National Defense Authorization Act, it did not receive any funding. The Senate included $52 billion in funding for the CHIPS programs in the U.S. Innovation and Competition Act (USICA), which passed in June 2021. On Feb. 4, 2022, the U.S. House of Representatives passed their response to the Senate's USICA, a legislative package called the America COMPETES Act of 2022. The COMPETES Act also directly appropriates $52 billion for the semiconductor production and R&D initiatives that were authorized in CHIPS.

Intel's plans for Ohio

In the midst of the ongoing shortage and funding deliberations, Intel's announcement about building a manufacturing mega-site in New Albany is a major demonstration of the commitment that U.S. companies are making to bringing semiconductor manufacturing stateside.

Intel's immediate plan is to build at least two semiconductor fabrication plants, or fabs, on a 1,000-acre site. These fabs would account for a third of the more than 3,000 acres that the city of New Albany is annexing from Jersey Township in Licking County to Intel.

Intel will use these fabs to research, develop, and manufacture its most cutting-edge computer chips, employing at least 3,000 people. Construction will begin this year, and the plant should be operational by 2025. Intel plans to employ green building principles during construction and hopes to power the new factories with 100% renewable energy and achieve net positive water use.

In addition, Intel says it plans to spend $100 million over the next 10 years to establish the Intel Ohio Semiconductor Center for Innovation, a partnership with universities and community colleges to build semiconductor-specific curricula.

While these initial plans are ambitious, Intel chief executive Pat Gelsinger hinted that the site could eventually grow to accommodate eight chip fabs, with spending potentially reaching around $100 billion over the next decade.

It is believed this mighty goal, though, will rely on Congress funding the programs authorized in the CHIPS Act. Based on the fact both USICA and the COMPETES Act include $52 billion for this purpose, it is likely the final legislative package will as well. ■

Industry survey lays out constraints to rare earth element supply diversification

Renewable energy technologies are a major sector that relies on rare earth elements. Yet as demand for renewable energy increases, manufacturers are growing increasingly concerned about securing enough supply of these elements.

Currently, China holds a monopoly on the world's rare earth mining and refining processes. The possibility of China weaponizing this supply is a concern that became widely recognized in recent years.

Diversifying the supply chain is a main approach that the rare earth industry is taking to ensure adequate supply. However, there are challenges to diversification, and a recent industry survey provides an excellent rundown of these challenges.

An international team of researchers from Monash University Malaysia, University of Moratuwa in Sri Lanka, Imperial College London, and the Rare Earth Industry Association in Belgium conducted the survey. They asked 30 rare earth industry experts to rate and rank 13 factors that hinder rare earth project developments outside of China, which they identified through a detailed literature survey on rare earth elements and the rare earth industry.

The industry experts largely represent rare earth companies outside of China. "This sample size (i.e., 30) is significant as the

An example of a rare earth mining operation. Ever since the possibility of China weaponizing its supply of rare earth elements became a widely recognized concern, countries around the world have looked at ways to diversify the supply chain.

RE [rare earth] industry outside China is relatively small," the researchers write.

Based on the survey, they identified four key constraints to rare earth project development.

Constraint 1: Chinese rare earth supply chain controls and business uncertainties

Constraint 1 is a result of six intercorrelated variables. It primarily addresses two aspects: rare earth business uncertainties outside China, including high capital costs (variables 8, 9, 10, and 13), and Chinese rare earth interests outside China (variables 11 and 12). "The former aspect seems the dominant one due to the high factor loadings assigned to it," the researchers write.

They add that governments should support the companies that are ready to develop rare earth projects and downstream businesses as a risk management strategy.

Constraint 2: Rare earth waste management, recycling, and substitution challenges

Constraint 2 is a result of four intercorrelated variables: rare earth substitution (variable 5) and recycling (variable 4) challenges, costly waste treatment operations (variable 7), and lengthy legislative hurdles to initiate new rare earth operations (variable 3).

"Industrial scale RE recycling is not yet extensively established outside China in order to generate a significant amount of REEs [rare earth elements] from secondary RE resources," the researchers write. Plus, "RE substitution has been applied to a certain extent, though it will not replace the requirement for independent RE supply chains outside China.

They add that government funding will be needed to address this constraint as well, by supporting development of rare earth element extraction, purification, and refining projects at industrial scale.

Constraint 3: Rare earth separation challenges and high investments

Constraint 3 is a result of two variables: high operational costs (variable 2) and complexity of rare earth separation and purification plants (variable 1). The researchers explain that over the last couple of decades, China has developed effective rare earth separation and purification technologies, leading to significant rare earth concentrate imports to China to carry out downstream processes.

"The development of economic RE separation and purification plants outside China would be crucial to address this challenge and establish independent RE supply chains," they write.

Constraint 4: Rare earth ore geology variabilities

Constraint 4 consists only of variable 6, which ascertains how the ore mineralogy of rare earth resources affects development of rare earth mines and separation and purification plants. For example, the researchers note that China possesses ion-adsorption-type rare earth resources, which are much easier to process compared to other rare earth resources.

"Despite the potential availability of ion adsorption type RE ores outside China, the projects are not yet initiated except for the project initiated by Ionic Rare Earths in Uganda," they write.

Among the four constraints, Constraint 1 ranks as the single most important factor dictating development of rare earth projects outside of China according to the statistical analysis. However, "It does not necessarily imply that the other factors are statistically insignificant," the researchers emphasize.

Despite the constraints, the researchers identify several recent developments of rare earth exploration and mining projects outside China, especially in the United States, Canada, Australia, and Europe. They did not account for the project readiness level of each project, though, and they consider this absence the main limitation that future studies should address.

Regardless, "These initiatives will have palpable impacts on the supply diversifications, perhaps in next decades, if new RE mines and their supply chains are connected to such downstream facilities outside China for a sufficiently long time," they conclude.

The paper, published in *Journal of Cleaner Production*, is "Constraints to rare earth elements supply diversification: Evidence from an industry survey" (DOI: 10.1016/j.jclepro.2021.129932). ■

ceramics in biomedicine

Heartening advancements—potential of inhalable particles to treat cardiovascular diseases

In a new open-access paper, researchers from institutions in Italy, Greece, and Malaysia explored the development of inhalable drug-loaded calcium phosphate nanoparticles for treating myocardial cells in the heart.

An inhalable vaccine has several perceived benefits to an injectable vaccine, including halting infection at the body's point of entry; requires lower doses; can be administered through disposable devices; and potentially, when stored in a dry powder form, could be kept stable for much longer than injectable liquid vaccines. While some inhalable medicines such as epinephrine for treating mild symptoms of asthma are well established, researchers continue to investigate what other medicines could be modified for inhalable delivery as well.

Peptide therapeutics is one treatment that is ripe for investigation. Peptides are essentially smaller versions of proteins. They are of particular interest as therapeutic drugs because the body naturally produces many different peptides, thus therapeutic peptides are relatively well-tolerated and have fewer side-effects than other pharmaceutical compounds. However, despite an increasing interest in peptide therapeutics, injection remains the main method for peptide delivery.

In 2018, some of the Italian authors of the recent study published an article that explored whether inhalation could be an effective method for delivering therapeutic peptides to the heart. They specifically looked at using calcium phosphate nanoparticles to carry the peptides because of the material's biocompatibility, biodegradability, and ability to cross the cardiomyocyte cellular membrane, which they demonstrated in a 2016 paper.

The results of the 2018 study were promising—the peptide-loaded calcium phosphate nanoparticles successfully restored cardiac function in a mouse model. However, the researchers identified some limitations that needed to be addressed in future studies. Specifically, they acknowledged difficulties with controlling the size of peptide-loaded calcium phosphate nanoparticles before and after delivery.

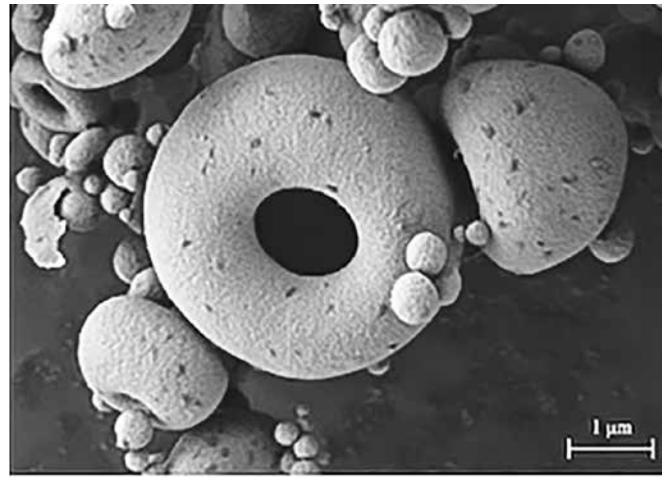
In the new open-access paper, the researchers collaborated with colleagues in Greece and Malaysia to address the transient particle size challenge by turning the nanoparticles into a microparticulate dry powder through spray drying. They chose the diuretic mannitol as a soluble carrier for the calcium phosphate nanoparticles.

A key conclusion of the study was that mannitol protected the size of the released nanoparticles. In addition, increasing the mannitol concentration versus the calcium phosphate amount caused an increase in microparticle respirability, i.e., its ability to be breathed in.

"These quality attributes are crucial for the use of microparticles embedding nanoparticles for targeting the lung first and then the heart," the researchers conclude.

The 2018 paper, published in *Science Translational Medicine*, is "Inhalation of peptide-loaded nanoparticles improves heart failure" (DOI: 10.1126/scitranslmed.aan6205).

The 2021 open-access paper, published in *Pharmaceutics*, is "Inhalable microparticles embedding calcium phosphate nanoparticles for heart targeting: The formulation experimental design" (DOI: 10.3390/pharmaceutics13111825). ■



Scanning electron plan-view micrographs of doughnut-shaped microparticles with a calcium phosphate:mannitol ratio of 14:1.

advances in nanomaterials

Feasibility of nanoceramics as binder in cemented carbide tools

Researchers from Shandong University in China explored the feasibility of using nanoceramics as a binder in cemented carbide tools.

Cemented carbides are metal matrix composites used extensively as cutting tool materials because of their high hardness, wear resistance, and fracture strength. Tungsten carbide–cobalt (WC–Co) cemented carbides, in which cobalt is the cementing phase between the tungsten carbide grains, are one of the main types of cemented carbides used.

The use of cobalt in cemented carbides has some drawbacks, however. For example, the solubility of many workpiece materials in cobalt causes WC–Co to have high sensitivity to crater wear, especially when machining steels. Plus, high-temperature operation of the cobalt-bonded cemented carbide can result in tool failure due to plastic deformation caused by softening of the binder phase.

These drawbacks, in addition to poor corrosion resistance, high cost, and high toxicity of cobalt, have inspired researchers to explore ways to reduce or eliminate the cobalt binder.

Early investigations on alternative binders mainly involved iron, nickel, and their alloys. Intermetallic materials such as titanium aluminide and aluminum nitride were considered as second-generation alternative binders.

Recently, ceramic phases have started attracting significant attention as binders. Studies on several ceramic-bonded tungsten carbides have found they exhibit superior hardness, corrosion/oxidation resistance, and high-temperature performance in comparison with cemented carbides with metal binder or intermetallic binder.

Rapid development of nanopowder technology has led scientists to start researching nanoceramic-bonded cemented carbides as well, following the hypothesis that nanoparticles may improve the densification and properties of cemented carbide.

The authors of the recent study selected nano aluminum oxide (Al_2O_3), yttria-stabilized zirconium dioxide (ZrO_2), and magnesium oxide (MgO) as the binders to investigate. Following microstructural and mechanical analyses of the nanocomposite cemented carbides, which were fabricated through hot-pressing sintering, they determined that all three ceramic binders led to cemented carbides with near-full densification. In addition, the ceramic-bonded cemented carbides achieved excellent comprehensive mechanical properties, specifically

- WC-6Al_2O_3: hardness of 23.5 GPa, flexural strength of 1,173.6 MPa, fracture toughness of 8.13 $MPa{\cdot}m^{1/2}$
- WC-6ZrO_2: hardness of 22.6 GPa, flexural strength of 1,229.7 MPa, fracture toughness of 9.35 $MPa{\cdot}m^{1/2}$
- WC-6MgO: hardness of 21.1 GPa, flexural strength of 906.3 MPa, fracture toughness of 8.62 $MPa{\cdot}m^{1/2}$

Looking closer, the researchers determined that the ceramic-bonded cemented carbides used interlacing distribution of crack deflection, crack bridging, and crack branching as toughening mechanisms. In the case of the zirconia-bonded tungsten carbide, stress-induced transformation toughening significantly enhanced the toughness as well.

Based on these results, "These ceramic bonded WC materials may be promising candidates for high-speed machining tools," they conclude.

The paper, published in *Journal of Alloys and Compounds*, is "Nano-ceramic replacing cobalt in cemented carbide as binder phase: Is it feasible?" (DOI: 10.1016/j.jallcom.2021.162968). ■

Credit: Sandvik Coromant, YouTube

Cobalt is a main material used as the binder in cemented tungsten carbide. A recent study dives further into the feasibility of using nanoceramics as a binder instead.

Cryomilling demonstrates potential to functionalize hexagonal boron nitride

In a recent open-access paper, a group led by researchers at The Pennsylvania State University explored using defect engineering to functionalize hexagonal boron nitride (hBN).

hBN is a layered material that is structurally very similar to graphite. The material is mechanically robust, thermally stable, and chemically inert, and there are several methods to synthesize 2D nanosheets of hBN.

Despite these benefits, researchers are somewhat hindered in applications due to difficulties with functionalizing hBN, or attaching molecules or nanoparticles to the hBN surface to alter its physical or chemical properties. This difficulty stems from the atomic bonds found in hBN. While graphite and hBN are structurally similar, graphite contains nonpolar covalent bonds between the carbon atoms, whereas hBN features highly polar covalent bonds due to the electronegativity difference between the boron and nitrogen atoms.

Researchers have explored different ways to functionalize hBN, such as through reduction reactions, but have faced some challenges using defect engineering. Defect engineering refers to techniques to control defects in a material's structure and/or purposely introducing defects to trigger specific functions. Because of hBN's mechanical robustness, introducing defects into the structure a labor- and/or energy-demanding process.

In the recent study, the researchers suggest that cryomilling, or ball-milling in a cryogenic environment (nitrogen at 77 K), may improve the potential of ball-milling to functionalize hBN.

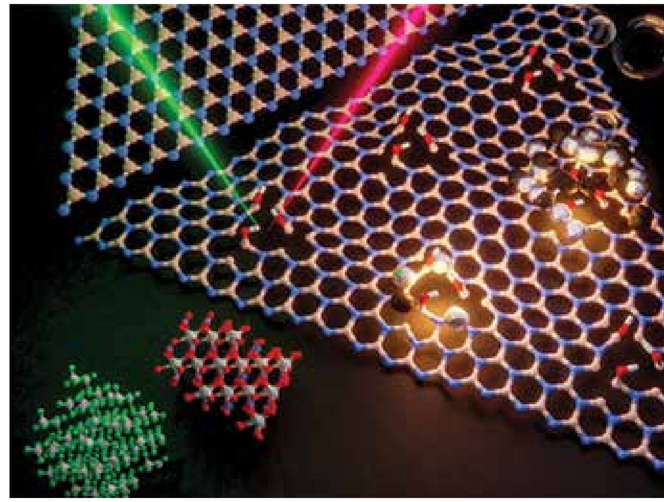
Manufacturers have widely used cryomilling to obtain fine-grained metallic nanostructures with improved mechanical properties. From this application it is known that maintaining the cryogenic environment can significantly suppress undesirable side reactions such as oxidation plus shorten the milling time and lead to a finer grain structure. Researchers have also used cryomilling to unzip carbon nanotubes into graphene, showing the technique's potential to break covalent bonds and create defects in 2D materials.

In their study, the researchers used cryomilling to introduce vacancies into bulk hBN. The vacancies served as reactive sites to reduce metal cations—specifically platinum—on the hBN surface.

Platinum is used as a catalyst in many types of practical chemical reactions. However, the platinum atoms that perform the conversion usually are on the surface, while the ones below serve as structural support. The researchers hoped that by using defective hBN as structural support, it would expose more of the platinum atom to perform chemical reactions.

The researchers reduced bi-metallic silver–platinum sub-nanoclusters on the defective hBN, and the material showed excellent activity when used as a catalyst for the hydrogen evolution reaction, which is used in hydrogen fuel generation.

"This superior performance is attributed to the robust anchoring of atomically dispersed Pt atoms and the synergetic effects among AgPt and d-BN [defective boron nitride]," they write.



Credit: Elizabeth Flores-Gomez Murray, Yu Lei, and Kazunori Fujisawa; The Pennsylvania State University

Researchers led by The Pennsylvania State University showed cryomilling demonstrates potential to functionalize hexagonal boron nitride through defect engineering.

The open-access paper, published in *Materials Today*, is "Low temperature activation of inert hexagonal boron nitride for metal deposition and single atom catalysis" (DOI: 10.1016/j.mattod.2021.09.017). ■

Materials science influences planetary science research

In a recent open-access paper, ACerS Distinguished Life Member Alexandra Navrotsky of Arizona State University and astrophysics graduate research assistant Megan Householder discuss how the study of the geology, physics, atmosphere, and formation of planets shares many of the same analytical and computational frameworks as materials science.

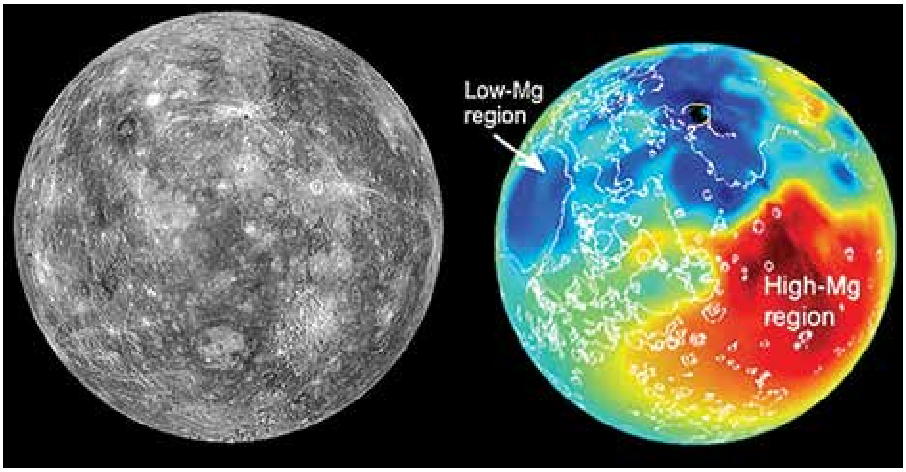
The planets and moons of our solar system have wide ranges of sizes, compositions, atmospheres, and even magnetic field strengths. In their paper, Navrotsky and Householder discuss the interconnections among the history and characteristics of each of the planets. For example, Mars is currently lifeless and has an extremely small magnetic field. Yet explorations of the Martian surface found evidence of water, organic materials, and strong magnetic fields. They posit the question, "If the magnetic field decreases, do processes occur that release, dissociate, and lose the atmosphere and water and make the planet less habitable?"

One clear connection of ceramics to planetary science is the development of materials for space exploration. Not just structural materials, such as rocket nozzles and radiation resistant exteriors, but also advanced sensors, communications devices, and other electronics, and also energy harvesting and storage.

The extreme atmospheres of planets create additional hurdles and scientific possibilities. Venus, for example, has a highly corrosive atmosphere of mainly carbon dioxide and sulfuric acid at extremely high pressures and temperatures. The chemistries occurring in this supercritical environment are yet to be understood. And getting the information has proven to be very challenging because Venus probes to date have survived for mere hours before succumbing to the atmosphere. The researchers at NASA Glenn Research Center constructed a "Venus Chamber" to simulate the atmospheric conditions for development of hardware for future missions.

Even more exciting are the possibilities for solving the "inverse problem in materials science." Throughout history, materials science research has essentially used the "if you build it, they will come" model where materials are discovered and characterized, while applications are built around the unique properties of each discovery. Consider the history of polytetrafluoroethylene (PTFE), commonly called DuPont's trade name Teflon. This material was discovered essentially by accident and is now a ubiquitous part of our lives, particularly in low-friction and weather protection applications.

The future of materials science is rather more deliberate. The inverse problem also can be described as designing and fabricating materials to fit the specific set of criteria for a particular application. In recent years, ACerS has been active in conversations on the data, modeling,



Credit: NASA

Left: Mercury as the human eye sees it through a telescope. Right: chemical mapping obtained by an X-ray spectrometer instrument.

Research News

The puzzle of the 'lost' angular momentum

Researchers led by University of Konstanz investigated the demagnetization of nickel crystals using ultrafast electron diffraction. They showed that the electrons of the crystal transfer their angular momentum to the atoms of the crystal lattice within a few hundred femtoseconds during demagnetization, which sets the atoms in motion on tiny circuits and thus balances the angular momentum. It is only much later and more slowly that the macroscopic rotation effect named after Einstein and de Haas begins, which can be measured mechanically. Such effects might be used to control magnetic materials using laser light. For more information, visit https://www.campus.uni-konstanz.de/en.

The brain's secret to life-long learning can now come as hardware for artificial intelligence

Researchers led by Purdue University created a piece of hardware made of the perovskite nickelate that could dynamically rewire itself to take in new data like the brain does. Applying electrical pulses at different voltages allows the device to shuffle a concentration of hydrogen ions in a matter of nanoseconds, creating states that could be mapped to corresponding brain functions. Through simulations of the experimental data, the researchers showed that the internal physics of this device creates a dynamic structure for an artificial neural network that more efficiently recognizes electrocardiogram patterns and digits compared with static networks. For more information, visit https://www.purdue.edu/newsroom.

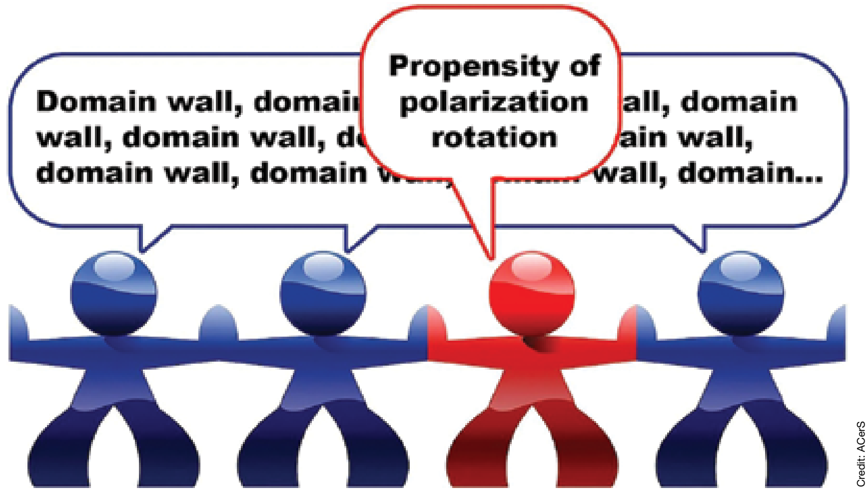
and infrastructure needed to facilitate this paradigm shift in materials science. The challenge is so daunting that many national and multinational "Big Data" projects are underway to develop and deploy tools needed.

Planetary science holds out the prospect of expanding the synthesis and fabrication conditions well beyond those possible on Earth. As Navrotsky and Householder say, understanding the complex dynamics of other planets and moons "liberates our thinking from being bound by one geotherm and one planetary composition." For example, the extreme temperatures and pressures of other celestial bodies extend the realm of ceramic science into regions where entirely new materials and phases can be formed. Imagine the same processes that form diamond from graphite but at more extreme scales.

Navrotsky and Householder explain our current understanding of the geology, atmosphere, size, and other properties of the planets and moons in our solar system as a framework for understanding such bodies orbiting other stars. All the unknowns even within our solar system lead Navrotsky and Householder to conjecture about a range of topics, including the contributions of comets and the possibility of superconductivity within cryogenic planets and how that might affect the magnetic fields and, in turn, the planetary environments.

While there are many challenges to be met—including the development of analytical methods that will enable investigation of other planets at a distance—the answers we will gain about materials, the origins of our universe and terrestrial life, and the possibilities of extraterrestrial life make our research and cross-discipline collaborations so important—and exciting.

The open-access paper, published in *International Journal of Ceramic Engineering & Science*, is "New worlds, new chemistry, new ceramics" (DOI: 10.1002/ces2.10104). ■



In a recent paper, researchers challenge the conventional belief that smaller domain sizes lead to greater piezoelectric properties.

New model for determining piezoelectricity in ferroelectric crystals

In a recent paper, researchers at The Pennsylvania State University and Xi'an Jiaotong University challenge the conventional belief that smaller domain sizes lead to greater piezoelectric properties.

Ferroelectricity is the property of certain materials having spontaneous electric polarization that is reversible through the application of external electric fields. Ferroelectric materials are a subset of piezoelectric materials, which generate an electric charge in response to an applied mechanical stress.

In the 100 years since the first reported discovery of ferroelectricity in 1920, identification and use of ferroelectric materials has proliferated. These materials are now essential components in many advanced technologies, including smartphones, diagnostic ultrasound, energy harvesting and storage, and more.

When designing ferroelectric materials, researchers have long been guided by the belief that smaller domain sizes lead to greater piezoelectric properties. This belief is based on the fact that domain walls have a strong influence on piezoelectricity. Thus, smaller domain sizes equate to a higher density of domain walls, which should give a larger piezoelectric coefficient.

The researchers of the recent paper challenge this belief. They explain that the idea that smaller domains lead to higher piezoelectricity is based on very limited existing data without a solid theoretical foundation, and these studies looked only at the surface of a ferroelectric crystal. So, the authors decided to theoretically examine what happens under the surface of ferroelectric crystals using thermodynamic analysis and phase-field simulations.

They determined that the nature of the domain-size dependence of piezoelectricity is based on the propensity of polarization rotation inside the domains instead of the domain wall contributions. Thus, the inverse domain-size effect—the larger the domain size, the higher the piezoelectricity—is entirely possible and can be just as common.

Based on these findings, the researchers established a new analytical model for predicting the domain-size dependence of piezoelectricity, which "can serve as a guiding tool for optimizing piezoelectricity of ferroelectric materials beyond the 'nanodomain' engineering," they write in the paper.

"We hope that this study allows people to rethink the design principles for piezoelectric materials, perhaps creating better piezoelectric materials in ways that were not thought possible before," Penn State postdoctoral scholar Bo Wang says in a Penn State press release. "This may enable better piezoelectrics made from lower-cost materials, or from materials that are more environmentally friendly."

The paper, published in *Advanced Materials*, is "Inverse domain-size dependence of piezoelectricity in ferroelectric crystals" (DOI: 10.1002/adma.202105071). ■

Refractory issues related to the use of hydrogen as an alternative fuel

By James G. Hemrick

With the increased interest in using hydrogen as an alternative fuel to reduce carbon dioxide emissions, this article looks at some of the effects on refractory ceramic lining systems when industrial furnaces are fired on hydrogen in place of or in addition to traditional fuels.

The United States Department of Energy (DOE) has devoted significant interest and resources to the use of hydrogen as an alternative industrial fuel source because it is known to create only water when combusted and, depending on its production method, generates little or no carbon dioxide.

Yet while much attention is being given to the economics and feasibility of the supply and utilization of hydrogen as an alternative fuel, less consideration is currently aimed at the effects such fuel changes may have on industrial processes where they are implemented.

Industrial processes are currently based largely on the use of fossil fuels, which are responsible for a major portion of industrial emissions. According to a 2019 report by Freidlingstein et al., industrial emissions accounted for 22% of global carbon dioxide emissions, with fuel used for process heating accounting for 42% of industrial emissions globally and 58% in the United States.[1]

Yet, the industrial sector may be more reticent than other sectors (such as electric power or transportation) to invest in alternative fuels that may reduce emissions due to the high capital investments required and long operating lifetimes of equipment, the inability to pass on price premiums to consumers, and the specific technical requirements that limit the options for substituting alternative fuel streams.[2] Such aspects of industrial heating that may be relevant include the absolute temperature, heat flux, heat availability, and heat reliability supplied by the fuel source. All these aspects can be issues when considering using hydrogen as an alternative energy source.

While some work can be found on changes in burner design and implementation when firing hydrogen, less work is available on possible refractory ceramic issues that may occur in furnace lining systems when furnace atmospheres and temperature characteristics are changed by the firing of hydrogen in place of traditional fuels such as natural gas. It is the hypothesis of the author that such changes will influence refractory selection and performance, and the extent of this effect is what will be proposed in the discussion to follow. Although the examples and studies cited in this article are not exhaustive, it is hoped that the issues and experiences summarized will further the discussion of possible issues that may be encountered and whether greater consideration of this topic is warranted.

Effects of the use of hydrogen on burner design

Most relevant work in the literature deals with burner design and alterations needed when burning hydrogen in combination with traditional fuels. These issues are well summarized by Baukal et al.[3] and are described in general below. Some of these effects were also found to be prevalent in applications where hydrogen was used as an alternative fuel in industrial applications, and they will be discussed in greater detail in the section to follow.

Because hydrogen is a light molecule, it has a high heating value on a mass basis and low heating value on a volume basis, leading to higher volumetric flow rates (higher fuel pressures) being required compared to other common fuels. Hydrogen also exhibits a high flame speed and relatively high adiabatic flame temperature compared to other fuels, which can lead to increased NO_x levels during combustion with air and more extreme conditions for burner components. A comparison of hydrogen and other common fuels is given in Figure 1.[4]

Radiation heat transfer from the flame (a function of the fourth power of the absolute temperature) will also be higher with hydrogen, and the combustion product volume flow rate will be reduced compared to more traditional fuels. Additionally, hydrogen produces more water when combusted compared to other hydrocarbon fuels, which may result in water vapor being present in the furnace atmosphere.

Examples of and challenges with using hydrogen as an alternative fuel

As far back as 2013, efforts were made to burn hydrogen-rich tail gases in place of fuel oil to reduce energy consumption and emissions in industrial furnaces.[5] In the study by Hsu et al. (2014), two industrial heating furnaces (11.4 m × 5 m × 10 m) each employing 14 burners (single center nozzle to burn oil and the surrounding nozzles to burn gas) were used. It was found that with the increased use of hydrogen, the volume of resulting flue gas was decreased, reducing the internal furnace pressure. This reduced pressure led to reduced residence time of hot gases in the furnace radiation zone, inefficient heat exchange, and excess heat in the furnace convection zone. Additionally, increased NO_x levels were noted.

Similarly, for the past 10 years, a pulp and paper mill used industrially vented hydrogen from an adjacent chemical process to supplement lime kilns traditionally fired on natural gas and other waste gas.[6] The hydrogen gas was not burned at a constant rate but was used for spot power for several hours a day and up to several weeks as the waste gas was available and based on availability and pricing of primary fuels.

Issues regarding the use of hydrogen in place of traditional fuels have included its higher heat release rate, which can lead to more heat at the front end of the kiln requiring changes to the process air and other parameters. Accelerated wear was also noted in select sections of the kiln due to firing of the hydrogen (seven-foot sections located in regions 50–60 feet and 80–85 feet along the length of the kiln), but it was not clear whether this wear was primarily due to the alternative fuel use or stop/start of the kiln to facilitate fuel changes. Also, discoloration of the refractory lining surface after the use of hydrogen, compared to the firing of traditional fuels, was noted (greenish tinge discoloration). Due to the chemical process resulting in the production of the hydrogen waste gas, it was found to contain chlorides, which are attributed to causing this noted discoloration. Burner issues were also encountered during the initial transition to hydrogen firing.

Heating value		
Gas	Btu/lb	Btu/scf
Methane (CH_4)	21,495	912
Propane (C_3H_8)	19,937	2,385
n-Butane (C_4H_{10})	19,679	3,113
n-Pentane (C5H12)	19,507	3,714
Ethylene (C_2H_4)	20,275	1,512
Propylene (C_3H_6)	19,687	2,185
Hydrogen (H_2)	51,625	274.6
Carbon Monoxide (CO)	4,347	321.9

Flame speed (laminar burning velocity)		
Gas	ft/s	cm/s
Methane (CH_4)	1.37	44.8
Propane (C_3H_8)	1.41	46.2
n-Butane (C_4H_{10})	1.37	44.9
n-Pentane (C5H12)	1.31	43.0
Ethylene (C_2H_4)	2.24	73.5
Propylene (C_3H_6)	1.56	51.2
Hydrogen (H_2)	9.91	325
Carbon Monoxide (CO)	1.58	52.0

Adiabatic flame temperature		
Gas	°F	°C
Methane (CH_4)	3542	1950
Propane (C_3H_8)	3610	1988
n-Butane (C_4H_{10})	3583	1973
Ethylene (C_2H_4)	3790	2088
Propylene (C_3H_6)	3742	2061
Hydrogen (H_2)	3807	2097
Carbon Monoxide (CO)	3826	2108

Credit: *Fuels*, C. Baukal

Figure 1. Properties of hydrogen compared to other common fuels.[4]

Simplification of the burner design was undertaken, along with modifications to accommodate flow rates and fuel properties of the hydrogen waste gas. Currently, a nearby petrochemical plant is being built as well to be exclusively fired on the waste hydrogen fuel and to also use hydrogen produced from new methanol plants being constructed.

Work in Germany in 2018 looked at the hypothetical effects of mixing hydrogen with natural gas for combustion in industrial applications.[7] Issues con-

The H2@Scale initiative at DOE

The H2@Scale initiative at the United States Department of Energy was created to "bring together stakeholders to advance affordable hydrogen production, transport, storage, and utilization to enable decarbonization and revenue opportunities across multiple sectors."[8]

Under this initiative, in October 2021, the DOE announced nearly $8 million in cooperative projects at U.S. national laboratories to support DOE's Hydrogen Shot goal to drive down the cost of clean hydrogen by 80% within the decade.[9] Projects funded under this initiative will be carried out under cooperative research and development agreements (CRADAs) and will leverage the Advanced Research on Intergraded Energy Systems (ARIES) platform to enable the integration of hydrogen technologies in future energy systems, including energy storage and a specific focus on safety and risk mitigation.

A list of funded projects can be found at:

https://www.energy.gov/eere/articles/doe-announces-nearly-8-million-national-laboratory-h2scale-projects-help-reach

Additional information on the H2@Scale initiative and the Hydrogen Shot goal can be found at:

https://www.energy.gov/eere/fuelcells/h2scale

https://www.energy.gov/eere/fuelcells/hydrogen-shot ■

sidered when directly introducing hydrogen into the current industrial gas streams include product quality, process efficiency, and pollutant emissions (NO_x). Both computer simulations (computational fluid dynamics, CFD) and actual experiments were performed using "off-the-shelf" industrial burner systems in a semi-industrial burner rig, with the effects of hydrogen contents of up to 50% by volume considered regarding process efficiency, heat transfer, and pollutant emissions. Three different burner systems were considered: a modular nonpremixed jet burner, a forced-draught burner, and a flameless oxidation burner (firing rates for all burners in the range of 100 kW and air excess ratios of 1.05).

Increased NO_x emissions were noted in the burner testing due to increased local combustion temperatures, but these emissions could be controlled to some degree by adjusting the settings of the individual burners (especially for the flameless oxidation burner). Changes in flame length (decreased with increasing hydrogen content) and shape were also seen in CFD modeling of the burners. Additionally, modeling showed that higher hydrogen concentrations in the fuel impacts the energy balance of the furnace, which could lead to insufficient heat released inside the furnace.

To evaluate changes in furnace efficiency and heat balance, a heat transfer impact factor (HTIF) was developed (Equation 1),[7] where $\dot{Q}_{Load}$ is the heat flux into the furnace load (product), $\dot{Q}_{Load,Reference}$ is the reference case heat flux into the furnace load (product), $\dot{Q}_{Wall}$ is the heat flux into the furnace wall, and $\dot{Q}_{Wall,Reference}$ is the reference case heat flux into the furnace wall.

$$HTIF=\dot{Q}_{Load}/\dot{Q}_{Load,Reference}=\dot{Q}_{Wall}/\dot{Q}_{Wall,Reference}) \quad (1)$$

Using this factor, heat flux within a hypothetical furnace was evaluated using CFD simulations to estimate the heat flux into the product being processed or directly into the furnace walls for various hydrogen concentration levels. An analysis for 20% by volume of hydrogen in natural gas showed reductions of 5–13% in HTIF compared to pure natural gas firing. This finding indicates that more heat is going into the refractory walls of the furnace than into the product when firing hydrogen, thus raising the operating temperatures of the refractory, which accelerate corrosion and wear and require more energy input into the process.

A similar computer simulation analysis was carried out for a regenerative glass melting furnace (for pure natural gas, 10% hydrogen substitution, and 50% hydrogen substitution).[7] Flue gas temperatures were seen to decrease with the introduction of hydrogen, while maximum furnace temperatures within the model tended to increase with hydrogen concentration. This situation resulted in reduced heat transfer to the glass melt and increased heat transfer to the furnace walls, as seen in the earlier simulation described above. Additionally, drastic increases in NO_x emissions were noted. Finally, questions regarding whether hydrogen will chemically interact with the metal and glass products being processed were raised, as well as a need was identified to determine the possible interactions of the hydrogen with the refractory lining materials of the furnace, which could lead to reduced furnace lifetimes and increased maintenance requirements.

A more recent area where hydrogen was considered as an alternative fuel is in industrial boilers.[10] To reduce carbon monoxide and carbon dioxide emissions, along with plant fuel costs, users of industrial boilers are considering alternative fuel sources that they have available to them, such as residual hydrogen left over from reforming and refining processes. Such hydrogen (which is often flared or released) can be injected into a fuel gas stream to supplement normal fuels. However, as noted by users and previously highlighted, the use of this hydrogen can lead to higher flame speeds and firing temperatures, requiring changes in burner construction materials and burner types to facilitate the incorporation of hydrogen into the fuel stream. Additionally, it was noted that some steels used in traditional burner construction could undergo hydrogen embrittlement and attack at elevated temperatures, which can lead to premature failure of the burner.

Due to the burner modifications noted above, impact is also seen in burner emissions and performance.[10] The high flame propagation speed of hydrogen causes the combustion process to occur more rapidly than for natural gas, leading to localized heating near the flame and increased NO_x emission rates. (Field and test facility data have shown that standard low-NO_x burners firing hydrogen typically exhibit an increase in NO_x emission rates by up to a factor of 3.) These phenomena are confirmed in earlier efforts by the petroleum industry to use hydrogen in the firing of process heaters, where a stainless steel burner deflector temperature was seen to increase from 480°F when firing natural gas to 1,300°F when firing 95% hydrogen and NO_x levels increased from just over 40 ppm to nearly 70 ppm, respectively.[11]

These issues were shown to result in higher temperatures, longer heating resident times, and different heat distributions seen by refractory lining materials in service. Additionally, hydrogen produces more water compared to other hydrocarbon fuels and may result in water vapor being present in the furnace atmosphere, which can lead to increased refractory corrosion for certain refractory compositions. All these factors are known to have possibly deleterious effect on refractory materials depending on the compositions employed.[12]

It also has been noted that changes may be seen within the boiler regarding where and how heat transfer occurs, along with increased furnace gas exit temperatures due to the higher flame temperatures. Such changes in boiler performance may require alternative strategies for type and location of refractory materials used.

Hydrogen has been used in combination with natural gas for industrial heat treatment furnaces as well.[13] Natural gas/hydrogen blends were used as alternative fuel due to economic potential for decreasing carbon dioxide emissions. As noted previously, alterations were required to the heating system to account for the differing thermophysical properties of the fuel blends and the corresponding changes to the flue gases (thermodynamic and chemical). In particular, increased NO_x emissions were noted (increases of 10% for air-staged combustion and about 100% for flameless combustion were measured at a 40% hydrogen content in comparison to pure natural gas firing). Again, refractory issues were not noted, but similar issues to those highlighted above are expected with the change in furnace conditions.

In China, hydrogen-rich fuel was injected into a steel blast furnace in place of part of the coke loading to reduce carbon dioxide emissions and energy usage.[14] The effect on refractory performance was not discussed, but the increased hydrogen content of the furnace atmosphere was found to change the thermodynamic and kinetic conditions of the furnace due to altered temperatures (increased flame temperatures) and gas flow (lower gas flow rates). The existence of more water in the furnace was also noted. All these factors lead to reduced efficiency of the blast furnace and would be expected to alter the performance of the furnace lining system. Additionally, the effects of using hydrogen in place of coal will be compounded because the coal not only provides heat but also carbon monoxide and physical structure for the reactions occurring within the blast furnace.[4]

Also for steel production, Tenova S.p.A. introduced a new burner system (TSX Smartburner) for use in steel reheat furnaces in 2020.[15] This megawatt-size flameless combustion system is capable of burning any mixture of natural gas and hydrogen (up to 100% hydrogen) using Tenova's integrated advanced digital control solutions. NO_x emissions are controlled by the flameless combustion technology (releasing < 80 mg/Nm^3 @ 5% of oxygen with furnace at 1,250°C). It also boasts optimal heat transfer uniformity within the furnace with full adaptation of the fuel mixture to balance the available hydrogen stream through the burner control logic. This design is expected to address some of the problems noted previously regarding uneven furnace heating leading to hot spots and to be flexible to varying hydrogen availability, therefore possibly reducing these effects on refractory performance.

Additionally, in Germany, multinational steel producer ArcelorMittal received state funding to implement its plans to invest in a demonstration steel plant using hydrogen produced from renewable electricity.[16] The proposed plant will be a direct reduced iron plant using green hydrogen to reduce iron ore in a carbon-free steelmaking process. Starting in 2025, they plan to produce all "green" steel using clean direct reduced iron (up to 100,000 tons) from a 50 MW electrolyser and melted scrap in a green powered electric arc furnace. The direct reduced iron process is much more amenable to the use of hydrogen as an alternative fuel because it traditionally uses natural gas and generally not coal, as is the case for blast furnaces. Still, changes to the chemistry and thermodynamics of the furnace atmosphere are expected and therefore refractory issues should be a consideration.

The use of hydrogen was also explored in glass melting. Since 1991, numerous container glass furnaces were converted from air-fuel to oxy-fuel firing, where pure oxygen is substituted for part of or all the air mixed with the combustion fuel. Recent advances in this technology have looked at substituting hydrogen in place of oxygen.[17] Such a substitution is hoped to further reduce fuel requirements and emissions while also improving glass quality. It is noted that some batch modification to optimize the glass fining chemistry and control glass foaming may be required, along with further burner improvement. It is therefore expected that reevaluation of the furnace refractory structure may also be required, as was the case when the move to oxy-fuel firing was first undertaken.[18]

Relatedly, in September 2021, NSG Group announced that they successfully manufactured architectural glass at their Greengate location in the United Kingdom using hydrogen in place of natural gas for all power production at the site.[19,20] This demonstration was part of their "HyNet Industrial Fuel Switching" project to prove that hydrogen was as capable as natural gas in achieving excellent melting performance while also reducing carbon emissions by replacing natural gas in the float glass furnace, which accounts for most of the company's overall carbon emissions. Although extended furnace performance was not monitored and therefore the effects on the refractory lining were not evaluated, in this initial short-term three-week trial, a "seamless transition" between fuels was noted.

Examples of the use of hydrogen in cement production were not found, but it is estimated that 30% of high-temperature industrial heat is used in the cement industry and hydrogen should be well suited for use as an alternative fuel.[4] Due to the large carbon footprint of this industry, decarbonization of the fuel source should be attractive. Refractory lined vessels that would be affected include preheating and calcination towers, clinker production kilns, and cooling sections. Additionally, examples of the use of hydrogen in aluminum production were not found, but hydrogen may be a suitable alternative to natural gas used in secondary aluminum production furnaces, which accounts for more than 80% of U.S. aluminum production.[4] Issues concerning mechanical abuse, thermal shock, and metal penetration/reaction already exist in many aluminum reverberatory furnaces, and these issues are expected to be compounded by changes in furnace atmosphere and temperature profiles if hydrogen is introduced.

Conclusions

Significant resources and attention are being devoted to the use of hydrogen as an alternative fuel source to fossil fuels. By doing so, significant reductions in carbon dioxide emissions are possible, but modifications to burner technology and furnace operating procedures will be necessary.

Although much effort has been documented regarding burner design and implementation, less information is available regarding the effects of hydrogen firing on processes and process vessels. In addition, almost no information is available regarding the effects on refractory ceramic materials when hydrogen is used as a part or all of the fuel stream.

Many of the issues associated with the firing of hydrogen in place of traditional fuels such as natural gas result from the properties of the gas itself. Hydrogen is a light molecule with a high heating value on a mass basis but low heating value on a volume basis. This fact leads to higher volumetric flow rates (higher fuel pressures) being required compared to other common fuels. Additionally, hydrogen exhibits high flame speeds and relatively high adiabatic flame temperatures compared to other fuels, leading to higher radiation of heat transfer from the flame and reduced combustion product volume flow rates. This process has been shown in many cases to result in higher temperatures, longer heating resident times, increased NO_x levels, and different heat distributions within furnaces, causing more extreme conditions for burner and correspondingly furnace components.

Examples of hydrogen being used in industrial processes date back over a decade and often involve mixing hydrogen with other traditional fuel sources such as natural gas. Many of these efforts rely on hydrogen from tail gases, vented from chemical processes, or recovered from other processes, while more recent efforts use "blue" or "green" hydrogen production. Regardless of the source, several common issues are prevalent when hydrogen is used as an alternative fuel.

As mentioned above, with increased hydrogen use, the volume and temperature of the furnace flue gas can be decreased, therefore reducing the internal furnace pressure. This reduced pressure leads to reduced residence time of hot gases in the furnace and inefficient heat exchange/transfer, along with excess heat in the furnace convection zone or increased overall furnace temperatures requiring changes to furnace operating parameters. Additionally, increased local combustion temperatures and changes in flame length, speed, and shape can occur, affecting the energy balance of the furnace. Also noted in all cases where hydrogen was used was a significant to extreme increase in NO_x emissions and increased presence of water in the furnace. With the decrease in flue gas temperature and the increase in water content within the furnace, there may also be concern about aqueous condensation and dissolution of NO_x to form an acid compound.

These issues can all have deleterious effects on refractory ceramic lining material performance. Such effects can include accelerated wear, chemical attack, and overheating. For example, it was shown that reactions occur between reducing gas (such as hydrogen) and stable oxides like silica, alumina, and zirconia that make up many refractory ceramic lining materials.[21] This reaction produces gaseous suboxides and water vapor that can be carried downstream to interact with furnace components and the product being processed. Additionally, such reduction of these oxides was shown to accelerate refractory corrosion and deceased refractory strength.[22] Thus, alternative refractory selection may be necessary, or the use of novel lining strategies or configurations may be required to maintain current furnace lifetimes and maintenance schedules.

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Application note

A portable system for melt process optimization and solid waste remediation

By Joseph Purcell

Diversified Controls & Systems, Inc. (East Aurora, N.Y.) was founded in 1977 in response to industry's need for customized process controls for industrial applications. During this more than 40-year journey, we have developed a reliable systems approach to an array of industrial applications, and many of these projects are installed throughout the world.

Our multidecade experience includes designing and building power supplies and supporting equipment for melting furnaces used in the glass and ceramic industry. Through this work we gained an understanding of reliable furnace operation practices, including required power utilization, quality, and throughput to sustain a melt campaign.

Ensuring reliable furnace operation is a continual challenge because furnace operators are not always able to recognize the "cause and effect" regarding production issues. For example, when manufacturing ceramic fiber insulation, one of the goals is maximizing throughput without sacrificing quality. To achieve this goal, the tendency for most furnace operators is to move the electrodes in closer to maximize melt; however, this approach leads to instability in the current due to low resistance. Understanding the melt process in a submerged resistance furnace starts with optimizing the distance between three electrodes to achieve the longest impedance path.

Our field observations led us to question whether there was a creative way to provide a system that harnessed an analytical approach to better understand and optimize the melt process, and thereby improve efficiency, increase melting campaign, and maintain quality. To be valuable in industrial settings, the analytical system needs to integrate multiple systems, including a power regulator system, dust collector, and cooling tower, among others. Additionally, to be fully functional, the analytical system had to meet user expectations for offering various capabilities, such as a better understanding of the melt process through real time data, process for scale-up considerations, and a way to evaluate power quality and efficiency. Finally, what if the system could be truck-mounted and taken to customer locations—basically, a self-contained pilot plant on wheels? Thus was the Melt Mizer conceived.

Designing such a system was the easy part; scaling it onto a platform that worked with limited space and yet remained fully functional proved challenging. After three and a half years of innovation and persistence, the Melt Mizer was built and granted a world patent.

Figure 1. Design of the Melt Mizer portable testing system.

Fig. 2. Melt drops out the bottom-pour electric furnace into collection pots.

The system is designed to be fully transportable on a standard 18-wheeler truck (Figure 1). The self-contained, portable system contains a submerged resistance bottom-pour electric furnace capable of reaching 3,800°F, with its own power supply, dust collection system, and cooling tower. Test melts drop out the bottom of the furnace to pots set underneath the truck's carriage (Figure 2).

After building the system, the next phase was to conduct test runs. Because we lack a ceramic engineer on our staff, we turned to Alfred University to establish data on chemistry and fluxing agents. After a six-month test period and plenty of trial, error, and failure, we finally had an understanding of the dynamics of the system's melting process.

Over two years and 15 melt runs, the Melt Mizer system successfully melted waste and byproducts, such as sludge containing chromium, slag, and contaminant soil. Despite these positive results, the client's decision on what to do next always boils down to cost of remediation vs. revenue generated.

So, our approach for the next design iteration was to review the chemistry and consistency of moisture content and particle size to define temperature vs. resistivity, fluxing agent, and estimate future revenue to justify a test run. We worked with clients to provide data based on test samples to help them determine whether further pilot studies were justified.

We expected the Melt Mizer would be useful to the ceramic, glass, and refractory industries. The next challenge was to identify specific applications that could benefit from using the Melt Mizer. With its high-temperature capability, it is an obvious fit for manufacturing ceramic fiber. We also participated in three pilot programs to evaluate the feasibility of using the Melt Mizer to process fly ash into rockwool insulation or fine aggregate for sandblasting to remove rust or paint (similar, for example, to Black Beauty by Harsco Minerals International).

Diversified Controls also sees a new and important role for Melt Mizer as a strategic player in environmental remediation applications. Presently we have established successful melt runs to remove chromium from toxic sludge waste and to separate iron and toxic waste from soil. Another possible application of Melt Mizer is to establish optimized methods of vitrification of waste streams. For example, the Melt Mizer could establish parameters for designing a production unit that vitrifies fly ash from utilities into large aggregates to reduce erosion along coastlines.

A remaining challenge is to validate the environmental applications based on cost justification and regulatory mandates. Our focus will be on the private sector to harness the capabilities of the Melt Mizer where applications make business sense.

About the author

Joseph Purcell is president of Diversified Controls & Systems (DC&S), a privately held company in Upstate New York. DC&S designs, manufactures, and services custom power supplies and custom control systems for manufacturing industries. Contact Purcell at dcsjp@aol.com or visit www.divconsys.com. ■

THE UNIFIED INTERNATIONAL TECHNICAL CONFERENCE ON REFRACTORIES

17th Biennial Worldwide Congress on Refractories

17TH BIENNIAL WORLDWIDE CONGRESS ON REFRACTORIES
UNITECR 2022
March 15-18, 2022 | Chicago, Ill. USA

UNITECR 2022: Refractories as a global industry

The Unified International Technical Conference on Refractories (UNITECR) is a biennial international conference that contributes to the progress and exchange of industrial knowledge and technologies concerning refractories.

UNITECR 2022 will take place March 15–18, 2022, in Chicago, Ill. Below are abstracts from some of the papers that will be presented at the conference. Find the full papers published in *International Journal of Ceramic Engineering & Science*.

Corrosion of bauxite based refractory castables and matrix components in hydrogen containing atmosphere

By Tim Leber, Sascha Madeo, Thorsten Tonnesen, and Rainer Telle

RWTH Aachen University, Germany

For the transformation to a CO_2 neutral industry, fuel of traditionally fossil-fired furnaces are substituted by the subsequent addition of hydrogen. In these studies, refractory components are identified for the corrosion of refractories in (highly) reducing atmospheres. A bauxite-based refractory castable is set up in diluted, 9Ar 1H2, hydrogen atmosphere. Additionally, a focus is set on the behavior of a common matrix phase, anorthite.

Corrosion experiments up to 1,500°C using a tube furnace with the mentioned atmosphere have been scheduled. Amount and phase stability due to different time and temperature coordinates have been examined by XRD. Furthermore, the microstructure and in particular the bonding phase was observed by means of SEM and EDS. Microstructural components undergoing reaction or loss are identified and explained in regard to complete and incomplete hydrogen combustion. Reduction of impurities such as iron oxides, phosphorus oxides, and titanium oxides are considered in detail.

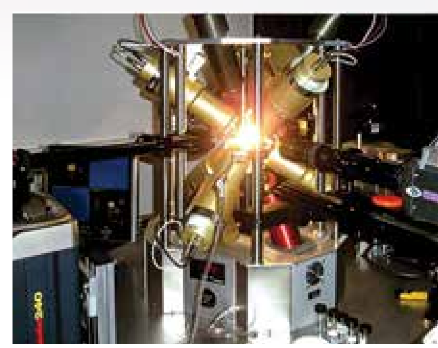
https://doi.org/10.1002/ces2.10111

Examination of the binary system Al_2O_3-ZrO_2 by aero acoustic levitation melting

By Jonas Niessen, Dirk Muehmer, Thorsten Tonnesen, Rainer Telle, and Jesus Gonzalez-Julian

RWTH Aachen University, Germany

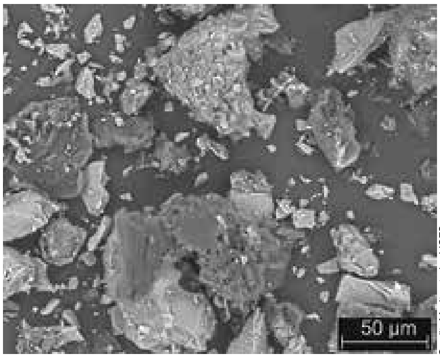
Al_2O_3-ZrO_2 composites exhibit excellent mechanical and high-temperature properties. The solidification of various hypoeutectic compositions has been studied by means of aero-acoustic levitation. A high-speed camera recorded the crystallization, to the correlation of the video stills with the observed microstructures. Solidification takes place by formation of several nuclei and subsequent growth. Nuclei are formed in the supercooled melt, entailing to a fine-grained, simultaneously solidified structure. The remaining melt between the growing nuclei is heated due to recalescence, leading to primary precipitation of zirconia followed by eutectic solidification. A consistent behavior is presented to explain the observed microstructures. Additionally, samples between 40 and 50 mol% ZrO_2 exhibit lamellar areas, which exceed the initial zirconia composition. The observed microstructure strongly indicates the existence of a liquid miscibility gap.



Credit: Niessen et al., IJCES

Aero acoustic levitator in operation.

https://doi.org/10.1002/ces2.10110



Credit: Moritz et al., IJCES

Backscattered electron micrograph of the recyclate R94A1, aggregate size fraction 0–1 mm.

Magnesia-carbon refractories from recycled MgO-C materials

By Kirsten Moritz, Steffen Dudczig, Daniel Veres, and Christos G. Aneziris

Freiberg University of Mining and Technology, Germany

By Hans Georg Endres and Daniel Herzog

Horn & Co. Minerals Recovery GmbH & Co. KG, Germany

By Matthias Schwarz and Leandro Schöttler

Deutsche Edelstahlwerke Specialty Steel GmbH & Co. KG, Germany

Recycling of used refractories—in particular closed-loop recycling—gains in importance because of both ecological and economic benefits, such as the conservation of natural resources, reduced landfilling, and the reduction of greenhouse gases and energy consumption. In this work, the use of a magnesia-carbon (MgO-C) recyclate for the production of MgO-C refractories is investigated. Using fused magnesia, the mentioned MgO-C recyclate, graphite, novolak, and a modified coal tar pitch, test specimens with different recyclate contents (0, 40, 65, and 82 wt%) were prepared on a laboratory scale. The apparent porosity, which is usually higher in recyclate-based refractories than in recyclate-free ones, increased by 14% from the specimens made exclusively from virgin raw materials to those made from the mixture containing 82 wt% recyclate. The dynamic Young's modulus and cold modulus of rupture decreased, but the thermal shock resistance was improved by the use of the recyclate.

https://doi.org/10.1002/ces2.10115 ■

Improved explosion resistance of low cement refractory castables using drying agents

By Hong Peng and Bjørn Myhre

Elkem Silicon Products, Norway

Low cement castables (LCCs) containing different types of drying agents (polymer fibers and EMSIL-DRY) have been studied both in lab- and industrial-scale. Our study shows that the type of drying agent has a profound impact on flow/workability of the fresh castables and that EMSIL-DRY ensures the best workability. Thermal behavior of 300-mm cubes (approximately 80 kg) was studied using a unique macro-thermo-balance (macro-TGA). Compared to the polymer fibers, EMSIL-DRY reduced the temperature level for maximum dewatering rate and will effectively help prevent explosions during heat-up. The LCC with EMSIL-DRY showed excellent explosion resistance, as demonstrated by the production of a perfect 400-kg block that was fired to 850°C at a rate 75°C/hr.

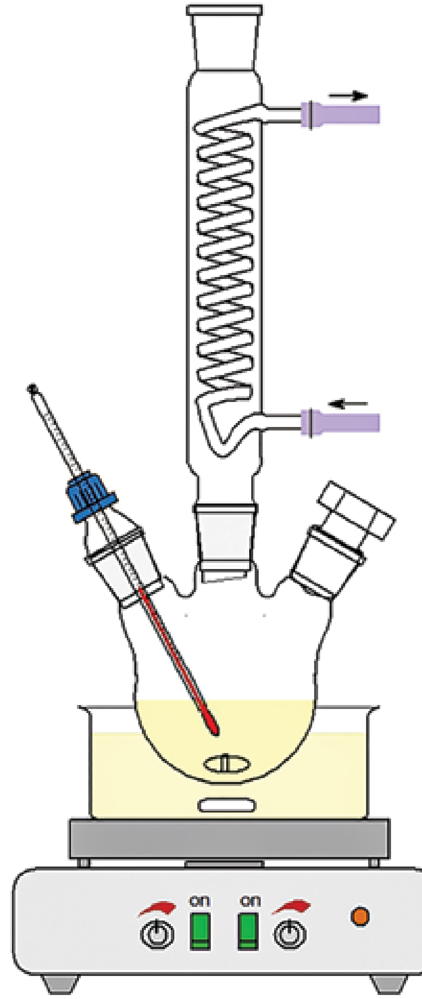
https://doi.org/10.1002/ces2.10118 ■

Iron leaching from nonrefractory grade bauxite: Individual process optimization and prediction by using DOE

By Alena Stein, Almuth Sax, and Peter Quirmbach

University of Koblenz-Landau, Germany

Bauxite is an important raw material for the production of refractories. The availability of refractory grade ore worldwide is limited, and high iron contents in particular reduce the quality of the material. For refractory applications, a maximum iron content of 2% is acceptable. In this study, acid leaching with HCl is used to decrease the iron content in different nonrefractory grade raw bauxites. Computerized design of experiments and statistical methods are used to determine optimum process parameters and influencing factors for different bauxites individually. Compared to previously



Credit: Stein et al., IJCES

Experimental setup of the leaching experiments.

published studies, the applied approach makes it possible to process even very iron-rich bauxites (e.g., 31% Fe_2O_3 in calcined substance) and to lower their Fe_2O_3 contents below the permitted 2%. In addition, larger grain sizes (around 5.5 mm) can be used. Statistical planning and mathematical modeling also allow the prediction of the minimum achievable iron content within the investigated parameter ranges. For selected parameter combinations, the achievable Fe_2O_3 content can be predicted relatively accurately without the requirement for practical testing of the corresponding experimental setup.

https://doi.org/10.1002/ces2.10117 ■

Meeting abstracts: UNITECR 2022: Refractories as a global industry

17TH BIENNIAL WORLDWIDE CONGRESS ON REFRACTORIES
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Study of the addition of a chemical mix additive and curing temperature on the setting time and mechanical properties of no-cement castable

By Ângelo Cristante

Reno Refractories, Inc., USA

Tight installation schedules and economic pressures are potential drawbacks for castable installation and performance. Many factors influence the setting behavior and the properties of no-cement castable refractories, including temperature and chemical composition. In this study, the setting behavior and the mechanical properties of a no-cement castable were analyzed, varying the amount of a chemical additive mix and curing temperature. The chemical additive mix concentration was varied from 0 wt% to 1 wt%. The curing temperature was varied from low (4°C/40°F) to high (40°C/104°F). The mechanical properties were characterized by cold crushing strength (CCS). A variance in the pH level drastically increased the setting time of the castable. Mechanical properties on green samples showed lower strength for castables with a higher concentration of the additive mix. This difference in performance is the result of the lower pH preventing the formation of a chain mechanism in the no-cement castable bonded with colloidal silica.

https://doi.org/10.1002/ces2.10116 ■

Use of dilatometer to screen refractory raw materials

By Somnath Mandal and Manoj K. Mahapatra

University of Alabama at Birmingham, USA

Sudden shortage of a particular raw material due to freight disruptions, competitive market, and COVID-19 restrictions have frequently forced the refractory industry to rapidly develop alternative formulations using available low-cost materials. These alternative ingredients might cursorily appear to have similar total impurity content, but the presence of certain impurity combinations depending on the refractory type can produce more fluid liquid phase at high temperature, thereby drastically reducing hot strength. Undetected by the commonly used X-ray fluorescence (XRF) analysis, the low-cost material might differ in mineral-phase content, whose phase transformations during firing might create excessive expansion, producing warpage of the refractory along with a high porosity that reduces strength and corrosion resistance. Finally, those cheap raw materials might have similar sieve analysis to that of the standard ingredient but might have much lower tapped density, which would introduce detrimental porosity into the resulting refractory. Hence, time-consuming trials are often performed. Dilatometer studies on pressed or cast samples in a single test can identify reaction temperatures of spinel or mullite formation, which expand during firing, along with the amount of expansion and exact times at which firing needs to be done. It can also compare relative shrinkage due to liquid-phase formation among impure raw materials like recycled grogs or low-grade ores. Finally, dilatometric step scan is shown as a fast technique to prepare in-house, low-cost reactive spinel powder, which can also work for mullite.

https://doi.org/10.1002/ces2.10113 ■

Refractories from fire to FIRE

By Michel Rigaud and Jacques Poirier

Emeritus Professors from Polytechnique Montréal, Canada

A brief description of the evolution of the making and usage of crucible and heat containing linings to the development of today's eco-designed refractories materials is offered to illustrate the gigantic steps the refractory constituency has accomplished. Eco for Ecological, Economical, Eco-Energetical. That is fire to FIRE.

To prolong Professor T. Planje's vision, the research and education needs are to be secured. This will require unified efforts of all stakeholders of our brotherhood. A brief description of FIRE's role for such a purpose is hence recalled, insisting on the implementation of the conception, design, implementation, organization (CDIO) approach to support the refractory industry needs for young innovators.

https://doi.org/10.1002/ces2.10121 ■

John S. McCloy
Guest columnist

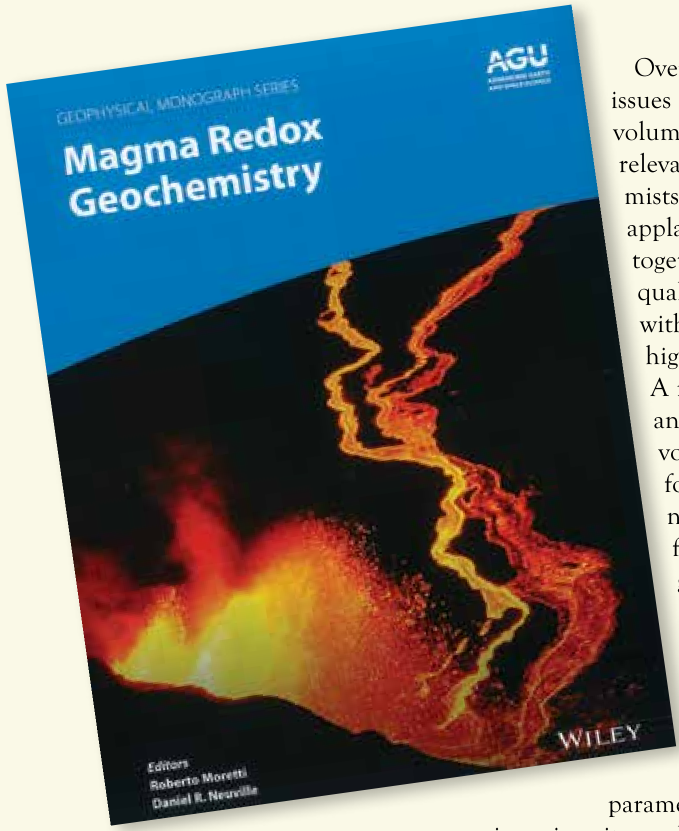
Review of "*Magma Redox Geochemistry*"

In their recent book "Magma Redox Geochemistry," editors R. Moretti and D. Neuville have compiled a timely and useful set of scholarship focused on various aspects of inorganic chemistry and oxidation-reduction reactions as they apply to chemical, physical, and geological processes affecting magma, the lifeblood of the Earth.

The book, which brings together 32 authors from France, Germany, Italy, Switzerland, Australia, the United States, and Canada, offers 19 chapters separated into three parts: "Redox from the Earth's Accretion to Global Geodynamics," "Redox at Work: From Magma Sources to Volcanic Phenomena," and "Tools and Techniques to Characterize the Redox and its Effect on Isotope Partitioning."

Though targeted at the earth sciences communities working on understanding Earth's dynamic processes, there is much here of interest to ceramic and glass scientists and engineers. For example, in industrial glass-melting and fining, redox effects of sulfur and iron are equally as important as they are in influencing outgassing, magma rise, and volcano eruptive character. Likewise, the behavior of volatiles such as halogens and water influence melting in earth systems as well as nuclear waste vitrification. The effect of redox on melt-crystal partitioning permits establishing oxygen fugacity in natural systems and also effects glass melt interaction with melter refractory, specifically for transition metals in spinel crystals, as well as phases produced in technical glass-ceramics.

The techniques for measuring oxidation state summarized in this volume are equally useful for many in the technical ceramics and glass communities. While the most important redox sensitive elements in natural systems may be carbon/carbonate, hydrogen/water, iron, and sulfur, other transition metals (titanium, vanadium, chromium, tungsten, molybdenum, rhenium, palladium), lanthanides (cerium, europium), and actinides (uranium) play a forensic and a dynamic role in both natural systems and complex systems, such as nuclear waste glass melts. Natural processes discussed here, including mixing of aqueous fluids and silicate melts, degassing, fractionation, and crystallization, all have analogues in controlled technical processes. Additionally, the consequences of Earth's natural processes involving redox are the distribution of metals in ore bodies used as raw materials in ceramic products.



Overall, the technical issues described in this volume have very strong relevance to many ceramists, and the editors are applauded for putting together such a high-quality volume complete with varied chapters and high-quality illustrations. A mix of fundamental and applied studies, this volume offers much for our community, as nearly all structural and functional ceramic and glass materials contain at least one redox sensitive element, influencing optical, electrical, and magnetic properties, as well as processing parameters such as foaming, viscosity, and crystallization that we seek to control. Whether you deal with electrochemistry and batteries or crystal chemistry and thermodynamics, this volume will provide both excellent method summaries directly applicable as well as an introduction to fascinating adjacent areas of scientific inquiry.

Book info

Magma Redox Geochemistry, edited by R. Moretti and D. Neuville, Geophysical Monograph 266, American Geophysical Union and Wiley, 2021.

John S. McCloy is Lindholm, Herman & Brita Endowed Chair in Materials Engineering and director of the Institute of Materials Research at Washington State University. ■

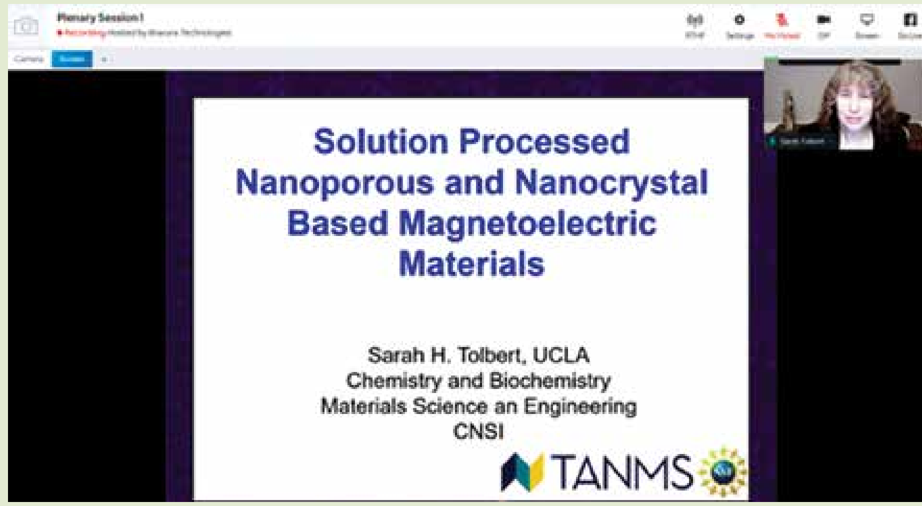
Omicron does not stop success of EMA 2022

For the second consecutive year, the annual Electronic Materials and Applications Conference (EMA) was held as a virtual meeting due to the COVID-19 pandemic.

EMA is an international meeting focused on electroceramic materials and their applications in numerous and varied components, devices, and systems. Jointly programmed by the ACerS Electronics and Basic Science Divisions, EMA 2022 was scheduled to take place in Orlando, Fla., from Jan. 19–21, 2022.

However, the expectation of an in-person meeting was dashed with the surge of the new Omicron variant that swept the United States and countries around the world in December and January. As a result, the ACerS Executive Committee along with the meeting organizers made the decision to pivot EMA 2022 to a fully virtual conference just weeks before the scheduled start date.

The fact that EMA 2022 was pivoted to a fully virtual event did not hamper the exchange of quality technical content. Nearly 300 attendees from 22 countries logged in to view the more than 300 oral and poster presentations. Although virtual networking is challenging, EMA 2022 provided multiple opportunities for attendees to connect with each other through events such as an industrial panel for students and young professionals, Networking with a Pro, *Publishing for Impact* workshop, the 2nd Annual EMA Pub Quiz, and the student award and networking session to end the meeting.



Credit: ACerS

Sarah Tolbert, professor in the chemistry & biochemistry and materials science & engineering departments at the University of California, Los Angeles, kicked off EMA 2022 with her plenary talk on "Solution processed nanoporous and nanocrystal based magnetoelectric materials."

"I think it is a testament to the electroceramics community that so many joined us in a successful pivot to a virtual meeting, especially when so many of us were looking forward to meeting in person. We had three days filled with outstanding presentations, including two great plenary speakers, along with outstanding invited and contributed talks and posters. I am so pleased that our community was able to come together in a virtual format for a productive and engaging meeting," says Jennifer Andrew, Electronics Division co-chair and professor at the University of Florida.

The meeting concluded on the evening of Friday, Jan. 21, with the announcement of the winners of the student poster and oral competitions. The first-place winner for best poster went to Christoph Riedle, TU Wien, Austria, for his presentation titled "Surface decoration of $Pr_{0.1}Ce_{0.9}O_{2-\delta}$ electrodes with binary oxides measured by in-situ PLD technique."

For the oral presentation competition, Bryan Conry of the University of Florida and Luis Ortiz of the University of Connecticut shared in first place honors for their presentations titled "Engineering grain boundary anisotropy to suppress abnormal grain growth in alumina" and "Grain and grain boundary photoconduction in perovskite solar cells with tomographic AFM," respectively.

EMA 2023 will take place in Orlando, Fla., Jan. 17–20, 2023.

EMA 2022 program chair Amanda Krause introduces Thursday's plenary speaker, Bilge Yildiz. Yildiz is the Breene M. Kerr Professor in the nuclear science & engineering and the materials science & engineering departments at the Massachusetts Institute of Technology. Her presentation was titled "Energy-efficient hardware and intelligent materials for brain-inspired computing: Artificial synapses based on proton and oxygen motion."

Credit: ACerS

The 46th ICACC perseveres despite pivot to virtual meeting for second straight year

For the second consecutive year, the International Conference on Advanced Ceramics and Composites was held as a virtual, live meeting from Jan. 24–28, 2022, due to the COVID-19 pandemic.

ICACC is an annual meeting organized by ACerS Engineering Ceramics Division (ECD). This year marked the conference's 46th occurrence, but the expectation of meeting in Daytona Beach, Fla., was halted due to the surge of the new Omicron variant that swept the United States and countries around the world in December and January. As a result, the ACerS Executive Committee along with the ECD meeting organizers made the decision to pivot to a fully virtual conference just weeks before the schedule start date.

"Despite the hard decision to pivot ICACC 2022 from hybrid to a fully virtual event, I am amazed with the splendid response by the ceramic community for their active participation," says program chair Palani Balaya of the National University of Singapore. The conference featured 158 sessions and welcomed nearly 700 participants from 37 countries, including 123 students.

Balaya says he received positive feedback from participants about the high quality of research work shared during the conference. Below are highlights from the week-long meeting.

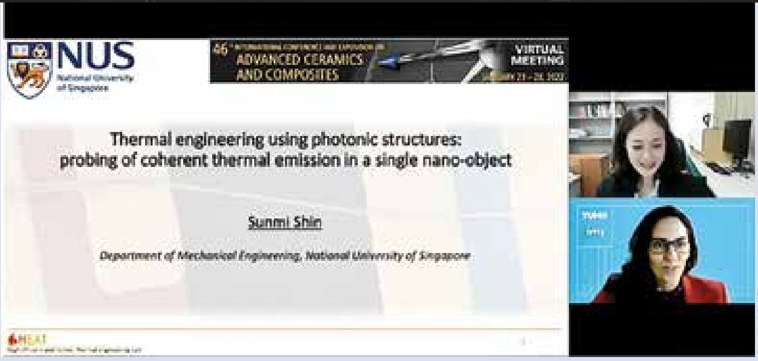
Opening award session

Balaya and ECD chair Hisayuki Suematsu of Nagaoka University of Technology partnered in leading the opening award session on Monday, Jan. 24. The session included plenary talks by Y. Shirley Meng of UC San Diego and Thomas Speck of University of Freiburg, as well as award presentations by Richard Sisson of Worcester Polytechnic Institute (James I. Mueller Memorial Award) and Jingyang Wang of Shenyang National Laboratory for Materials Science (ECD Bridge Building Award).

Five ECD members were also honored during the opening session with ECD's Global Star Award for their great support to the success of ICACC 2022. This year's recipients included Olivier Guillon, Forschungszentrum Jülich, Germany; Valerie L. Wiesner, NASA Langley Research Center; Emanuel Ionescu, Technische Universität Darmstadt; Bai Cui, University of Nebraska-Lincoln; and Amjad A. Almansour, NASA Glenn Research Center.

Student and young professional events

Three posters were awarded first place for the ICACC 2021 student poster contest, which was announced during the opening award session of ICACC 2022.



Credit: ACerS

Sunmi Shin, ECD Global Young Investigator Awardee, is introduced by session moderator Kaline Furlan of Hamburg University of Technology.

Sunmi Shin, assistant professor of mechanical engineering at the National University of Singapore, was presented with the ECD Global Young Investigator Award on Tuesday. The tile of Shin's presentation was "Thermal engineering using infrared photonic structures: probing coherent thermal emission in a single nano-object."

ECD Jubilee Global Diversity Award

Each year, three early/mid-career women and minority professionals are selected for the ECD Jubilee Global Diversity Award. This year's recipients of the Jubilee Global Diversity Award were Cristina Balagna, assistant professor of materials science and technology at Politecnico di Torino, Italy; Zhaoju Yu, professor in the College of Materials at Xiamen University, China; and Tyrone Jones, advanced body armor consultant for Inventor, USA.

NIST discussion panel

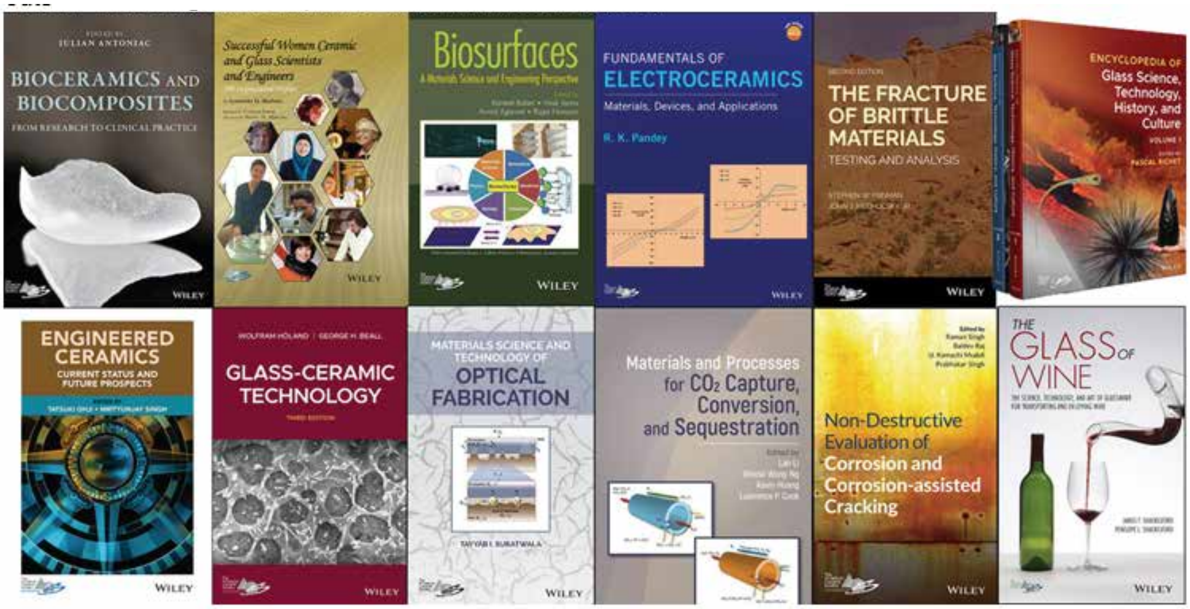
As part of the 6th International Symposium on Additive Manufacturing and 3D Printing Technologies symposium, Igor Levin and Andrew Allen of NIST organized a discussion panel on direct ink writing of ceramic materials. This special session continued a series of NIST-led discussion events on ceramics additive manufacturing that aim to identify measurement, standards, and data needs hindering the commercialization of ceramics additive manufacturing and facilitate collaborative efforts within the ceramics additive manufacturing community.

Organizer appreciation session

Approximately 50 people encompassing ECD leadership, ICACC symposium organizers, and ACerS staff joined together on Wednesday, Jan. 26, to review ICACC 2022 and look forward to ICACC 2023. The session concluded with the presentation of the ECD Staff Appreciation Award, which this year went to Jonathon Foreman, managing editor of the ACerS journals, and Cathy O'Toole, customer service specialist.

ICACC 2023 will take place in Dayton Beach, Fla., Jan. 22–27, 2023. ■

ACerS-Wiley Books



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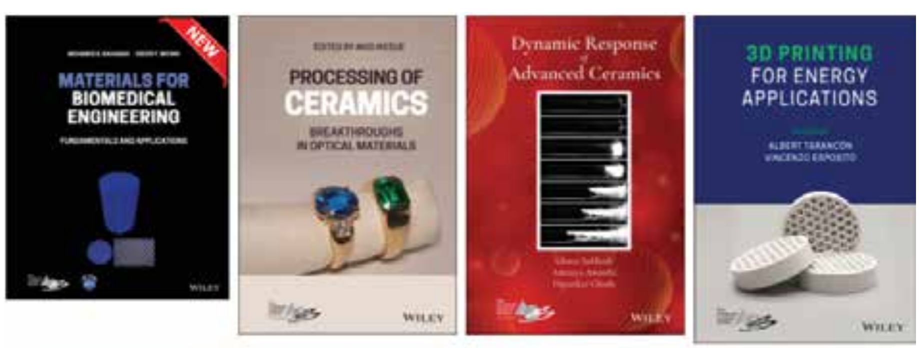

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2022 GLASS & OPTICAL MATERIALS DIVISION ANNUAL MEETING

MAY 22–26, 2022

https://ceramics.org/gomd2022

HYATT REGENCY BALTIMORE | BALTIMORE, MD., USA

*Join the **Glass & Optical Materials Division (GOMD)** for its annual meeting May 22–26, 2022, in Baltimore, Md. The 2022 GOMD meeting is special because the United Nations declared 2022 the "International Year of Glass." We will have a number of special events to commemorate this occasion as we meet together in-person for the first time since 2019.*

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

Technical leaders from industry, national laboratories, and academia will lead technical sessions featuring oral and poster presentations that provide an open forum for glass scientists and engineers worldwide to present and exchange findings on recent advances in various aspects related to glass science and technology.

Students are encouraged to enter their presentations in the annual poster competition for professional recognition and cash awards. Students attending the 2022 GOMD meeting are invited to attend a career roundtable discussion with scientists from industry, national laboratories, and academia about career opportunities and other topics in a casual environment. This 2022 GOMD meeting will provide a unique opportunity for students to learn, interact, and win.

Nestled in the heart of downtown, the Hyatt Regency Baltimore Inner Harbor hotel offers a luxury gateway to the enchanting waterfront town. The conference venue is only 12 miles from Baltimore/Washington International Thurgood Marshall Airport (BWI) and within walking distance to museums, historic landmarks, restaurants, and attractions like the National Aquarium and Camden Yards.

On behalf of the GOMD executive committee and volunteer organizers, we sincerely hope you will join us at the 2022 GOMD meeting to find new collaborative opportunities and to exchange ideas in the international glass community.

2022 PROGRAM CHAIRS

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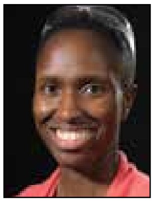

Charmayne Lonergan
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SPECIAL SESSION

Remembering Ted Day

This session is dedicated to the memory of our friend and colleague, Ted Day, who passed away in Sept. 2020. Speakers will review Ted's many contributions to our glass and bioceramics communities, as an entrepreneur, a philanthropist, and a dedicated member of The American Ceramic Society. If you would like to contribute to this session, share a memory, or offer a story, please contact Richard Brow (brow@mst.edu) or Julian Jones (julian.r.jones@imperial.ac.uk).

TECHNICAL PROGRAM

S1: FUNDAMENTALS OF THE GLASSY STATE
- Glass Formation and Structural Relaxation
- Glass Crystallization and Glass-ceramics
- Structural Characterizations of Glasses
- Topology and Rigidity
- Atomistic Simulation and Predictive Modeling of Glasses
- Data-based Modeling and Machine Learning for Glass Science
- Mechanical Properties of Glasses
- Non-Oxide Glasses and Glass-ceramics
- Glass Under Extreme Conditions

S2: GLASS AND INTERACTIONS WITH ITS ENVIRONMENT — FUNDAMENTALS AND APPLICATIONS
- Glasses and Glass-ceramics for Healthcare
- Nuclear Waste Immobilization
- Dissolution and Interfacial Reactions
- Surfaces and Coatings

S3: OPTICAL AND ELECTRONIC MATERIALS AND DEVICES — FUNDAMENTALS AND APPLICATIONS
- Laser Interactions with Glasses
- Charge and Energy Transport in Disordered Materials
- Optical Fibers and Waveguides
- Glass-based Optical Devices and Detector Applications
- Optical and Photonic Glass and Glass-ceramics

S4: GLASS TECHNOLOGY AND CROSS-CUTTING TOPICS
- Sol-gel Processing of Glasses and Ceramic Materials
- Challenges in Glass Manufacturing
- 3D-printing of Glass

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

ceramics.org/PACCFMAs

Organized by

The American Ceramic Society www.ceramics.org

Panama FMAs 2022

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

Not ready to commit to an in-person event? PACC-FMA 2022 will run as a hybrid meeting and offers a virtual option for those not ready to meet in person. You can submit your abstract now and decide later whether you'll present in-person or virtually.

The technical program will consist of invited and contributed talks and poster sessions important to ceramic and glass professionals who live or do business in the Americas. It will provide an information exchange on the latest emerging technologies and facilitate open dialogue and discussion with leading experts from around the globe.

PAN AMERICAN CERAMICS CONGRESS TECHNICAL PROGRAM CHAIRS

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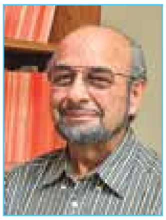
FERROELECTRICS MEETING OF AMERICAS CHAIR



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Mexican program chair: **Barbara Bermudez Reyes**, barbara.bermudezry@uanl.edu.mx

Peruvian program chair: **Jhon Hartley**, jhartley@celima.com.pe

Tentative Schedule of Events

Tentative Schedule of Events	
Sunday, July 24, 2022	
Conference registration	3:30–7 p.m.
Welcome reception	5:30–7 p.m.
Monday, July 25, 2022	
Conference registration	7 a.m. – 5 p.m.
Opening awards ceremony & plenary session	8:30–11:30 a.m.
Lunch/Technology fair	11:30 a.m. – 1 p.m.
Concurrent technical sessions	1–5 p.m.
Coffee break	3–3:20 p.m.
Technology fair and poster session, including reception	5:30–7 p.m.
Tuesday, July 26, 2022	
Conference registration	7 a.m. – 5 p.m.
Concurrent technical sessions	8:30–11:30 a.m.
Lunch/Technology fair	11:30 a.m. – 1 p.m.
Concurrent technical sessions	1–5 p.m.
Coffee break	3–3:20 p.m.
Wednesday, July 27, 2022	
Conference registration	7:30 a.m. – Noon
Concurrent technical sessions	8:30 a.m. – Noon
Technology fair	8:30 a.m. – Noon
Afternoon on own	Noon – 5 p.m.
Conference dinner	7–9 p.m.
Thursday, July 28, 2022	
Conference registration	8:00 a.m. – Noon
Concurrent technical sessions	8:30 a.m. – Noon

Calendar of events

March 2022

9–10 Sustainable Industrial Manufacturing (SIM) – Brussels, Belgium; https://sustainableindustrialmanufacturing.com/europe

15–18 17th Biennial Worldwide Congress Unified International Technical Conference on Refractories – Hilton Chicago, Chicago, Ill.; https://ceramics.org/unitecr2022

May 2022

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

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

June 2022

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

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

28–30 2022 FIRE-ECerS Summer School: Eco-Design of Refractories – RWTH Aachen University, Germany; https://ecers.org/news/146/419/0622-FIRE-ECerS-SUMMER-SCHOOL/d,ceramic_details_conferences

July 2022

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

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

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

August 2022

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

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

September 2022

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

October 2022

9–13 ACerS 124th Annual Meeting with Materials Science & Technology 2022 – David L. Lawrence Convention Center, Pittsburgh, Pa.; https://ceramics.org/event/acers-124th-annual-meeting-with-materials-science-technology-2022

January 2023

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

22–27 47th International Conference and Expo on Advanced Ceramics and Composites (ICACC2023) – Hilton Daytona Beach Oceanfront Resort, Daytona, Fla; https://ceramics.org/event/46th-international-conference-and-expo-on-advanced-ceramics-and-composites-icacc2023

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

July 2024

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

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

Entries in **BLUE** denote ACerS events.

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

denotes International Year of Glass event

denotes virtual meeting

Career Opportunities

Business Services

custom finishing/machining

custom/toll processing services

firing/melting/drying

laboratory/testing services

liquidations/used equipment

maintenance/repair services

ADINDEX

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MARCH 2022

AMERICAN CERAMIC SOCIETY **bulletin**

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Tony Wetzig
Guest columnist

Novel approaches for steel melt filtration in continuous casting of steel

Due to its availability and versatile applicability, steel is one of the most important materials in the modern global economy. The ever-increasing quality and efficiency of steelmaking processes enables new possibilities across many industries.

The purity of steel melts plays a major role in its application. Excessive amounts of nonmetallic inclusions or the presence of macro inclusions or clusters with critical size restrict important mechanical properties and increase the tool wear during processing, ultimately leading to reduced reliability of the final product and causing higher scrap rates.

Steel melt filtration is a popular approach to remove residual nonmetallic inclusions prior to casting, especially in the foundry industry. However, the application of filters in the continuous casting of steel bears the risk of premature clogging of the filter due to the limited filter capacity.

To overcome this limitation, a novel approach based on the immersion of filters in the industrial tundish was adopted and tested in the framework of the Collaborative Research Center (CRC) 920.[1] The immersion of components into the tundish during the continuous casting procedure allows for the exchange of clogged filters without interrupting the underlying process.

To implement the novel filtration process, the conventional replica technique provided a good basis for manufacturing the cellular components.[2] The conventional replica technique involves coating reticulated polymer foam templates with a ceramic suspension and subsequently drying and firing the filter material.

Carbon-bonded alumina was used as filter material due to its favorable behavior in contact with molten steel and low shrinkage during firing. The cylindrical foam templates were coated via impregnation and centrifugation, and a secondary dip coating and spray coating provided structural reinforcement to ensure sufficient mechanical strength. The filters were then immersed for over 40 minutes in an industrial tundish at temperatures above 1,550°C, which equates to the casting of one batch comprising approximately 400 tons of steel melt (Figure 1).

Filters with full-cylindrical geometry showed no critical damage after removal from the steel melt despite severe thermal shock and slag contact.[3] However, the lateral filter struts were covered with dense clogging layers, and the filter bottom exhibited pronounced clusters of plate-like inclusions.

The dense clogging layers were analyzed by means of scanning electron microscopy, energy-dispersive X-ray spectroscopy, and electron backscatter diffraction.[3] The clogging layers exhibited an increased aluminum/calcium ratio, which could not be explained solely by the filter base material or the slag. It is assumed that a thin layer of slag covered the filter surface during the immersion of the filter and acted as the basis for the removal of alumina micro inclusions by reactive filtration mechanisms, resulting in the formation of a dense clogging layer.

These investigations provided the first proof of concept for the application of exchangeable filter systems in continuous steel casting. In the framework of future investigations, fluid dynamics simulations could provide the information required for adaptions of the tundish design, the filter geometry, and the immersion apparatus. A stack of exchangeable filters could be applied in combination with flow control devices such as dams and weirs to allow for effective filtration of the cast melt.

Credit: Tony Wetzig

Figure 1. Carbon-bonded alumina filter after application in the industrial tundish.

References

[1]Baaske A, Karrasch S, Schnitzer H, Aneziris CG, Dudczig S, Gehre P, and Schwarze R, "Ceramic filters and filter systems for continuous metal melt filtration," United States Patent US20170292173A1, 2017.

[2]Wetzig T, Luchini B, Dudczig S, Hubálková J, and Aneziris CG, "Development and testing of carbon-bonded alumina foam filters for continuous casting of steel," *Ceramics International* 2018, 44(15):18143–18155.

[3]Wetzig T, Baaske A, Karrasch S, Brachhold N, Rudolph M, and Aneziris CG, "Application of exchangeable carbon-bonded alumina foam filters in an industrial tundish for the continuous casting of steel," *Ceramics International* 2018, 44(18): 23024–23034.

Tony Wetzig is a research associate in the Institute of Ceramics, Refractories, and Composite Materials at TU Bergakademie Freiberg. His research focus is on refractory ceramics, specifically those used for steel casting. He enjoys climbing in his free time.

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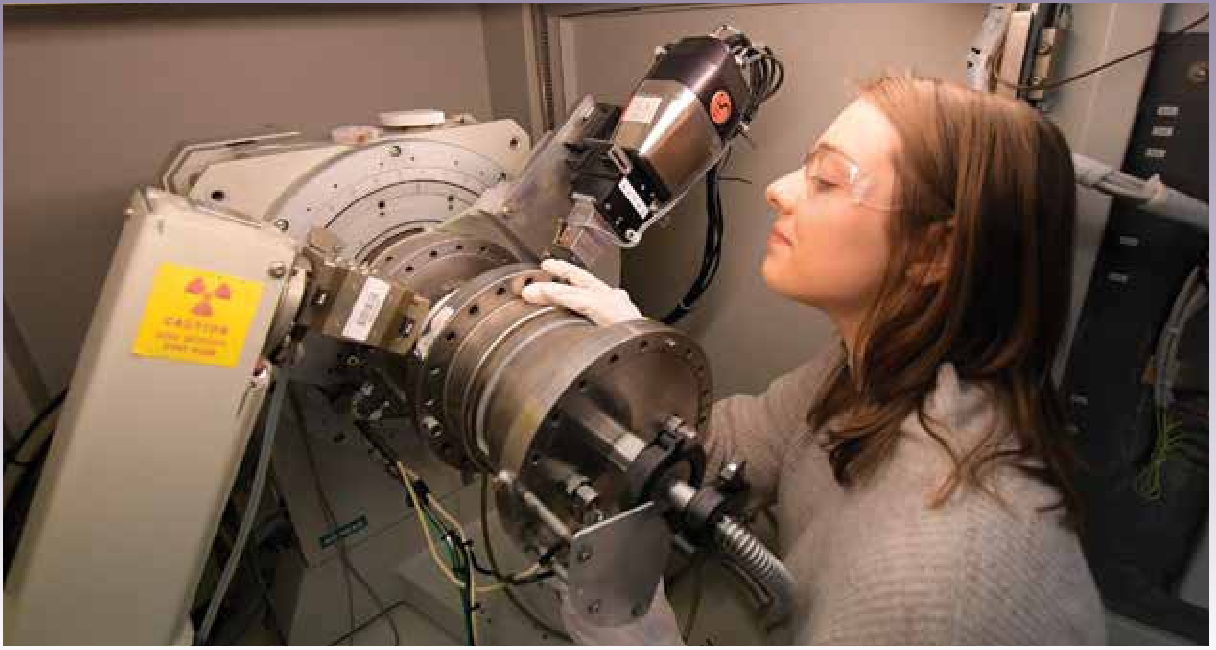

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