Fusion cast refractories: Roles of containment
A BROAD RANGE OF SPECIALTY ALUMINAS DESIGNED FOR DEMANDING APPLICATIONS

With 120 years of expertise, ALTEO is a world leading fully-integrated supplier of specialty aluminas for various markets such as ceramics (technical and tiles), refractories, special glass, flame retardant, etc.

Our comprehensive product range incorporates hydrates, calcined aluminas, low soda aluminas as well as other high performance specialties.

To ensure the best quality of products and services, ALTEO continuously invests in the latest production equipment, local storage and logistics, applied research and technical expertise.

To know more, meet us at CERAMITEC - hall A6, stand 410

www.alteo-alumina.com
feature articles

21 Fusion cast refractories: Roles of containment
Refractory linings in glass furnaces are a critical component of glass-based applications, including encapsulation of nuclear waste through vitrification. Careful design of these lining materials can ensure safe and long-lasting methods of nuclear waste storage.
by Kevin Selkregg

29 World Materials Research Institutes Forum addresses global materials science challenges
Collaboration and cooperation in materials R&D of leading international laboratories enhances rapid employment of new ceramic and glass material technology solutions and products.
by Nicholas Barbosa, Stephen Freiman, and Michael Fasolka

30 Micromilling of uniform nanoparticles for space applications
Fritsch micromills have enhanced one NASA lab’s ability to develop optimized ceramic nanoparticulate materials for demanding research projects, including energy storage and thermoelectric device applications.
by Curtis W. Hill and Lee Allen

32 National Science Foundation awards in the Ceramics Program starting in 2017
In FY 2017, the NSF Ceramics Program recommended support for 19 awards, 13 supplemental awards, two workshops/conferences, and cofunding of a Solid-State and Materials Research project.
by Lynnette D. Madsen

34 Ceramics Expo—A significant meeting of minds, materials, machines, and markets
Ceramics Expo—May 1-3, 2018, at the I-X Center in Cleveland, Ohio—champions an industry that continues to make its mark in the enrichment of an array of engineering, manufacturing, scientific, and research communities.
The American Ceramic Society is excited to announce that the entire ACerS Bulletin library—all 96 volumes, dating back to 1922—is now available online.

With more than 1,100 fully searchable and downloadable issue PDFs, the Bulletin Archive Online is a vast resource for all things ceramic and glass, from slip casting to sanitaryware to superconductors.

Explore this vast resource today—access is free for ACerS members!
Dear Editor,

The title of the article "Special benefits of bauxite for a stable porcelain microstructure..." (J. Liebermann, ACerS Bulletin, 96 [7]) is misleading because it implies that porcelain is intrinsically unstable in service. This implication is false and could be detrimental to the porcelain insulator industry. Porcelain has been the industry standard for electrical power insulation for over 100 years and there are well-documented examples of insulators that have been in continuous service for over 50 years.

There are several issues that challenge the legitimacy of this article:

- Liebermann’s assertion that crack extension from embedded quartz particles in porcelain is the cause of strength reduction is unsupported. The microstructures he presents are over-etched accentuating quartz-matrix cracking (and the magnification differences cause additional confusion). Evidence for microcrack growth is not presented and has never appeared in the literature—likely because it does not exist. A cursory review of residual stress conditions would demonstrate that crack extension is not expected.¹

- Liebermann misused Ref. 5 to support his argument and changed the figure captions (Figs. 3 & 4 in both articles). Fig. 3 is data from a single manufacturer (not “various producers” as indicated in his text) and the data in Fig. 4 is from several manufacturers from the same study (not “alumina porcelain,” as indicated—see Table 1). His conclusions are also inconsistent with the results presented in Fig. 4:
  - Manufacturer “C” in Liebermann (“D” in Ref. 5 and in Fig. 3) extrapolates to ~50-year service lifetime; and
  - “A” and “B” extrapolate to over 100 years.
  - A service lifetime of 50–100 years is certainly “stable.” Frese and Pohlmann concluded that their results confirmed the assumption of long service life and reliability. (The incorporation of bauxite to fix porcelain is unnecessary.)

- What causes the reported decrease in strength with time? Any hypothesis must be able to explain the differences between manufacturers and the strength distribution broadening. Degradation due to thermal cycling is impossible as the quartz inversion temperature is >500K above ambient. Ultrasonic velocity results (Ref. 5) stated no discernable differences between the insulators removed from service. This indicates no significant changes in the bulk microstructure.

There is one plausible scenario: The glaze chemistry, and thus the chemical durability and resistance to weathering, differed between manufacturers when the insulators were produced (1964–1966—the “new” data in Fig. 3). Glaze weathering would account for a decrease in strength and a broadening of the distribution, by the migration of the fracture origin from the body to the glaze. Small differences in glaze thickness—the new “critical” flaw—broadens the strength distribution.

This seemingly innocent but ill-informed article could severely damage the electrical porcelain industry by the suggestion of poor performance and instability. It is understood that there is no peer review process, but poor science cannot be justified. How to address these potential issues in the future likely requires an open discussion.

Reference:

William M. Carty, Ph.D.
John F. McMahon Professor
Chair of Ceramic Engineering and Glass Engineering Science
New York State College of Ceramics at Alfred University

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>New</th>
<th>20 years</th>
<th>35 years</th>
<th>Translated Comments (Original German text)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>242.9</td>
<td>220.6</td>
<td>224.7</td>
<td>Pure alumina (reine Tonerde)</td>
</tr>
<tr>
<td>B</td>
<td>180.5</td>
<td>167.1</td>
<td>176.3</td>
<td>Quartz porcelain w/aluminosilicate (Quarzporzellan mit Tonerdeanteil)</td>
</tr>
<tr>
<td>C</td>
<td>184.5</td>
<td>186.0</td>
<td>217.5</td>
<td>Pure alumina (reine Tonerde)</td>
</tr>
<tr>
<td>D</td>
<td>182.9</td>
<td>161.0</td>
<td>150.0</td>
<td>Alumina with quartz (Tonerde mit Quarzanteil)</td>
</tr>
<tr>
<td>E</td>
<td>183.0</td>
<td>178.0</td>
<td>158.7</td>
<td>Pure quartz porcelain (reines Quartzporzellan)</td>
</tr>
</tbody>
</table>
Dear Editor,

Prof. Carty imputes a statement that was not made and would not be correct, if made. Nowhere in the article is there any hint that the alumina porcelain currently used in high-voltage engineering would be unsuitable, not matching the demands of application. On the contrary, in the introduction it was emphasized that with the transition from quartz to alumina porcelain a material was developed, which from the viewpoint of its initial and long-term strength guarantees the performance of high-voltage insulators on a new level, as required in use.

However, this does not rule out the option to purposefully improve the material. It was the only goal and result of the work done to provide such a technical and economical optimization of this material type by use of bauxite, as alumina carrier. The options of optimization were demonstrated and proved.

The first of these options consists of further improvement of the body microstructure to reduce the microstructure stresses. They occur in all ceramic materials with a multiphase microstructure containing crystalline and vitreous phases that differ in their coefficient of expansion. Additional external mechanical and thermal loads can increase the microstructure stresses, leading to microstructure damage—by growth of microcracks, especially. This in turn may result in losses of strength. These phenomena quite undoubtedly appear in ceramics.

Quartz particles are characterized by expansion values and expansion anomalies, which both considerably differ from the other phases. Therefore, in particular, they cause higher microstructure stresses, which have a very negative impact on the long-term behaviour of quartz porcelain, as demonstrated on Fig. 3. This is the only conclusion to be made from Fig. 3. On the contrary, Fig. 4 shows that alumina porcelains provide clearly better initial and, especially, long-term strength values. This gives a mechanical guarantee for their good performance in high-voltage insulation.

This does not mean, however, that no improvement of mechanical properties can be achieved by further purposeful reduction of the portion of free quartz crystals in the microstructure.

As shown by the data of Fig. 3, the use of bauxite as alumina carrier may perhaps be a way to achieve this goal.

Furthermore, it was proved that the use of bauxite can give benefits for the firing process and a more economical utilization of raw materials.

Thus, it will meet the intention of the paper that from mechanical and economical points of view it seems possible to still improve the properties of alumina porcelain by the purposeful use of bauxite.

This was the sole goal and result of the work done.


Johannes Liebermann
Lichtenfels, Germany
New process, new product? Old kiln no longer fits? When you outgrow your current kiln, call Harrop. Like a fine suit, Harrop kilns are made-to-measure so that they fit your exact needs. Harrop kilns are built to last so that you will enjoy “wearing” them for years to come. And like a fine tailor, Harrop can often alter your old kiln so that it fits your current needs.

Harrop kilns are designed and built at our facility in Columbus, OH. We can install your kiln at your site and provide commissioning and operator training – a true turnkey supplier.

Contact Harrop when an “off-the-rack” kiln won’t do.
President’s executive order could mean less dependence on critical mineral imports

The United States Geological Survey recently identified 23 minerals, including rare earths, that are essential to the U.S. economy and national security and have the potential to pose a supply risk to the U.S. A quick look at highlights from ACerS Bulletin’s recent annual commodity summary indicates that eight minerals related to the ceramic and glass industries are on the USGS list—and none are produced in the U.S., with the exception of lithium.

But there may be some light at the end of the mineral mine tunnel. Just before Christmas, U.S. President Donald Trump signed an executive order to “reduce the nation’s vulnerability to disruptions in the supply of critical minerals, which constitutes a strategic vulnerability for the security and prosperity of the United States.”

Examples of rare-earth oxides: (clockwise from top center) praseodymium, cerium, lanthanum, neodymium, samarium, and gadolinium.

BIOACTIVE GLASSES have the ability to bond to soft and/or hard tissue and are biodegradable in the body. Our staff of glass engineers and technicians can research, develop, and produce glass which is custom-made to fit your particular application.

Contact us today to discuss your next project.

www.mo-sci.com • 573.364.2338
ISO 9001:2008 • AS9100C
according to section 3 of the executive order.

“The United States must not remain reliant on foreign competitors like Russia and China for the critical minerals needed to keep our economy strong and our country safe,” Trump said in a statement reported in The Washington Post.

The executive order has four initiatives:

- Identifying new sources of critical materials;
- Increasing supply chain activity—starting with exploration and mining to the end result of reprocessing and recycling;
- Ensuring that miners and producers have access to advanced geological and topographical data for the U.S.; and
- Streamlining leasing and permit processes to accelerate exploration, production, processing, reprocessing, recycling, and refining of critical minerals in the U.S.

China currently leads the world in the production of 20 out of the 23 critical minerals identified in the USGS list—and that includes rare earth production.

“It is time for the U.S. to take a leading position,” Interior Secretary Ryan Zinke says in The Washington Post article, referring to the production of minerals.

“And it’s not that we don’t have the minerals in the U.S. It’s likely we do.”

The president asked the secretaries of several departments to provide a strategy for reducing U.S. reliance on critical materials, which includes assessing progress toward developing recycling and reprocessing technologies and creating technological alternatives to critical minerals.

Although the federal government wants to do everything it can to increase production of critical minerals in the U.S., there may be hurdles to overcome—including limited availability of domestic reserves of a few minerals, according to commodities reporter William Clarke of Industrial Minerals. And Mountain Pass, the last U.S.-owned rare earth mine, purchased by a Chinese consortium last year, still has not reopened.

**CES 2018 unveils latest tech to the world, from voice assist toilets to ceramic 3-D printers**

In mid-January, some of the world’s most innovative, influential, and forward-thinking technology companies showcased their latest developments at the Consumer Electronics Show 2018 in Las Vegas, Nevada.

With more than 180,000 attendees and 4,000+ exhibitors, CES is one of the largest tech shows in the world—which also means it is a prime place for companies to unveil their newest concepts, gadgets, devices, ideas, and prototypes to try to wow consumers.

As far as tech goes, CES has it all—from totally useful to completely impractical, from low tech to extravagantly engineered, from affordable to exorbitant, from real science to pseudoscience, from startups to multinational-dollar corporations.

One of the biggest trends on the 2018 show floor was, not surprisingly, that nearly everything is connected—whether the insole of your shoe, your ukele, or nearly any aspect of your home. Any task that can be automated probably already is, and nearly anything that you would want—or not want—to connect to voice assistance probably does. And that includes your toilet.

Of course, ceramic and glass materials were pervasively present in the tech on the CES 2018 show floor, although most companies were not focused on the materials themselves.

There were exceptions, however, including Kwambio, a company that specializes in 3-D printing user-designed ceramic products. Kwambio just developed their own in-house 3-D printer, called Ceramo One, after several years of development. Kwambio says its binder jet ceramic printer serves the arts, design,
aerospace, energy, healthcare, and defense industries through its ability to additively manufacture a variety of ceramic materials for both printed objects and industrial molds. The company is now accepting pre-orders for Ceramo One, which will ship in the summertime.

**Major spark plug maker plans to shift focus towards solid-state batteries**

NGK Spark Plugs, the Japanese company that leads the global spark plug market, is turning its focus away from spark plugs and instead concentrating its efforts to develop solid-state batteries for electric vehicles, according to a recent Reuters article.

“We realized that it was inevitable that the industry would at some point shift from the internal combustion engine to battery electric vehicles, and that ultimately this could make our spark plug and oxygen sensor businesses obsolete,” Takio Kojima, senior general manager of engineering and R&D at NGK Spark Plug, says in the Reuters story. “Our expertise is in advanced ceramics, and so we have decided to pursue all solid-state batteries.”

NGK says it is working on a solid oxide-based ceramic electrolyte battery technology that can be scaled up into larger formats that would support electric vehicles.

“It’s relatively easy to work in smaller sizes, but when you get to larger sizes it gets very difficult to assemble each layer because it’s difficult to make each layer the same thickness,” Hideaki Hikosaka, a member of NGK Spark Plug’s solid state battery R&D team, says in the article.

So NGK has engineered an additional material into the battery to offset those problems. The undisclosed material “makes the electrolyte easier to process into larger, thin layers which are compressed, making them easier to stack with anodes and cathodes.”

“It’s because of the addition of that material that we’re able to process layers using compression (rather than sintering) to make a bigger, oxide-based battery cell,” Hikosaka explains in the story.

So far, NGK says it has made a battery cell that is 10 cm x 10 cm, but the company is still developing ways to boost the battery’s energy density to sufficiently enhance performance, with a target of having a more powerful, lighter, competitively price battery within the next few years.
Radioactive waste management technologies and services projected to reach $21.3 billion by 2020

By Nikos Thomopoulos

Macroeconomic and statistical data from various organizations estimate that total radioactive waste produced in 2015 reached around 42.4 million cubic meters. Quantities are expected to continue their positive growth rate at a projected five-year compound annual growth rate (CAGR) of 3.4%, reaching 50 million cubic meters by the end of year 2020.

The global market for radioactive waste management technologies and services was worth an estimated $18.8 billion in 2015. This figure is expected to continue rising up to nearly $21.3 billion by the end of 2020 at a projected CAGR of 2.5%.

The global radioactive waste market is segmented on the basis of technologies and services, including transportation and disposal services, remediation, containment, size reduction, decontamination and decommissioning services, stabilization and encapsulation technologies, and physical, chemical, and thermal technologies. Transportation and disposal services dominate the market at almost $3.2 billion, or 17% of total sales in 2015, and is projected to increase at a CAGR of 2.9% through 2020 (Table 1).

Physical treatment technologies accounted for the second largest share of the market in 2015 at almost $3.0 billion (16%) due to simplicity of operation and low investment and operational cost. Containment and storage technologies, including traditional and well-known methods for radioactive waste treatment, accounted for the third largest share of the market at $2.4 billion (12.8%). The projection for this market share segment is to remain almost constant until the end of 2020.

Chemical treatment, decontamination and decommissioning, and thermal destruction and encapsulation technologies together accounted for more than 40% of the global market sales for 2015. Size reduction technologies and remediation technologies, although offering high efficiency, account for 13.4% of global market sales for 2015.

Remediation technologies for radioactive waste treatment include six main categories of technologies: in-situ and ex-situ biological treatment, in-situ and ex-situ thermal technology treatment, and finally in-situ and ex-situ physical and chemical technology treatments. The global remediation technology industry reached almost $1.2 billion in 2015.

From 2015 through 2020, the remediation technology market is expected to see a moderate growth of 2.4% CAGR, reaching $1.3 billion in 2020, because this type of technology will continue to be used for radioactive waste treatment mainly in Europe and North America due to low cost of operational and environmental protection.

In-situ thermal treatment is the third largest market of remediation technologies used for radioactive waste treatment. Two main technologies are grouped under the in-situ thermal treatment classification: thermally enhanced soil vapor extraction and vitrification. The global market for in-situ vitrification, which converts contaminated soil to stable glass and crystalline solids, was expected to reach $98.5 million by the end of 2015 (Table 2). An estimated CAGR of 2.6% will bring the value of this market to about $112 million by the end of 2020.

About the author

Nikos Thomopoulos is a project analyst for BCC Research. Contact Thomopoulos at analysts@bccresearch.com.

Resource


Table 1. Global market for radioactive waste management by type of technology, through 2020 ($ millions)

<table>
<thead>
<tr>
<th>Type of technology</th>
<th>2015</th>
<th>2020</th>
<th>CAGR% 2015-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation and disposal services</td>
<td>3,199.0</td>
<td>3,683.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Physical treatment</td>
<td>2,996.0</td>
<td>3,455.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Containment and storage</td>
<td>2,406.0</td>
<td>2,742.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Chemical treatment</td>
<td>2,226.0</td>
<td>2,504.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Decontamination and decommissioning</td>
<td>2,053.0</td>
<td>2,321.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Thermal destruction</td>
<td>1,821.0</td>
<td>2,014.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Stabilization and encapsulation</td>
<td>1,593.0</td>
<td>1,775.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Size reduction</td>
<td>1,307.0</td>
<td>1,446.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Remediation technologies</td>
<td>1,195.0</td>
<td>1,345.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Total</td>
<td>18,796.0</td>
<td>21,285.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Table 2. Global market for radioactive waste in-situ thermal treatment technologies through 2020 ($ millions)

<table>
<thead>
<tr>
<th>Type of technology</th>
<th>2015</th>
<th>2020</th>
<th>CAGR % 2015-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermally enhanced soil vapor extraction</td>
<td>129.5</td>
<td>146.0</td>
<td>2.4</td>
</tr>
<tr>
<td>In-situ vitrification</td>
<td>98.5</td>
<td>112.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Total</td>
<td>228.0</td>
<td>258.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>
St. Louis Section/RCD 54th Symposium hotel reservation deadline is March 1

“Refractories for the Cement, Glass, and Minerals Manufacturing Industry,” is the theme of the 54th Annual Symposium on Refractories, sponsored by ACerS St. Louis Section and the Refractory Ceramics Division, which is set for March 21–22 at the Hilton St. Louis Airport Hotel in St. Louis, Mo. A kickoff event—a night of food, drinks and games—will be held at the 99 Hops House at the Hollywood Casino on March 20. Program cochairs are Andrew Domann (Bucher Emhart Glass) and Steven Ashlock (Kyanite Mining Corporation).

You can book your hotel room at a special rate of $111 (March 19–23) by mentioning the group code “SCS.” Call (314) 426-5500 or visit http://bit.ly/54thRCDHotel to make a reservation before March 1, 2018.

For details about the event, visit http://bit.ly/54thRCDSymposium. Questions? Contact Patty Smith, psmith@mst.edu or (573) 341-6265.
Society and Division news (continued)

Theodore J. Planje Award
Nancy Bunt, senior market manager and global marketing manager of Kerneos Aluminate Technologies, a Division of Imerys, will receive the 2018 Theodore J. Planje-St. Louis Refractories Award. Bunt has held several leadership roles in ACerS Refractory Ceramics Division, including chair. She served on ACerS nominating committee and the Corporate Environmental Achievement Awards committee.

Western New York Section chapter meeting is March 1
ACerS Western New York Section’s first meeting of 2018 is scheduled for Thursday March 1, 2:45–7:00 p.m. at the Innovation Center at Praxair Technology Center, Tonawanda, N.Y. The meeting includes two presentations, an infrastructure tour, and buffet dinner. RSVP for the meeting by emailing Victoria Willard, VW2@alfred.edu before February 21.

Names in the news
Day presented with lifetime achievement award
Marquis Who’s Who presented ACerS past president and Distinguished Life Member Delbert Edwin Day with the Albert Nelson Marquis Lifetime Achievement Award. The award recognizes individuals for leadership qualities, outstanding achievements, career success, and noteworthy accomplishments. Day is Curators’ Professor Emeritus of Materials Science and Engineering at Missouri University of Science and Technology and co-founder of Mo-Sci Corporation.

Petrucci appointed director of business development
EBL Products Inc. has appointed Russell Petrucci director of business development. His 34 years of experience includes design and manufacturing of A-scan and B-scan transducers for medical imaging and industrial NDT applications, as well as growing new global business opportunities for several leading industry piezomaterials manufacturers and suppliers.

Lawson appointed general manager of Edward Orton Jr. Ceramic Foundation
Mark Lawson replaces Gary Childress as general manager of the Edward Orton Jr. Ceramic Foundation as Childress retires. Lawson brings more than 20 years of senior management experience with Elkay Manufacturing, Trigon International, and Tervis.

Amine named to Web of Science Highly Cited List
Khalil Amine, materials scientist at the U.S. Department of Energy’s Argonne National Laboratory, has been named to the Web of Science’s Highly Cited List of 2017, ranking in the top one percent of his peers by citations and subject area.

In memoriam
Carlos Frick
Joseph E. Neely
David Griffith Wirth Jr.
Some detailed obituaries can also be found on the ACerS website, www.ceramics.org/in-memoriam.

Awards and deadlines
Congrats to winners of best student oral presentations and best student posters of EAM 2018!

**Poster competition**

**First place**
Freeze casting of LAGP for 3D textured solid-state structured electrolytes, William Huddleston, Case Western Reserve University
**Second place**
Shape and size dependent phase transformations and field-induced behavior in ferroelectric nanoparticles, Krishna Chaitanya Pitike, University of Connecticut
**Third place**
Mesoscale modeling of stress induced bandgap attenuation in ZnO nanowires, Lukasz Kuna, University of Connecticut
Awards and deadlines (continued)

Oral presentation competition

First place

The influence of electrode geometry on the average and local electrical responses of electroceramics, Richard Veazey, University of Sheffield

Second place

Understanding electrochemical and structural behaviors of irradiation induced defects in TiO₂, Kassiopeia Smith, Boise State University

Third place

Exploring the rich defect chemistry of amorphous carbon using a combination of experiments and theory, Wesley Surta, Oregon State University

Basic Science GEMS Awards deadline is March 15

Sponsored by ACerS Basic Science Division, the annual Graduate Excellence in Materials Science (GEMS) Awards recognize outstanding achievements of up to 10 graduate students in materials science and engineering. The award is open to graduate students making oral presentations in any symposium at MS&T 18. If interested, visit matscitech.org and submit your paper by March 15, 2018.

Three awards have May 15 deadline

Three prestigious Division awards have a May 15, 2018 nomination deadline. Award eligibility for each can be found at ceramics.org/awards.

Glass & Optical Materials: Alfred R. Cooper Scholars Award

This award recognizes undergraduate students who have demonstrated excellence in research, engineering, and/or study in glass science or technology. The recipient receives a plaque, $500, and free MS&T registration.

Electronics: Edward C. Henry Award

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

Electronics: Lewis C. Hoffman Scholarship

This $2,000 tuition award encourages academic interest and excellence among undergraduate students in the area of ceramics/materials science and engineering. The 2018 essay topic is "Tailoring Material Properties through Defect Engineering for Electronic Ceramics."

Visit www.ceramics.org/awards for nomination forms. Contact Erica Zimmerman at ezimmerman@ceramics.org with any questions.

Member spotlight

ACerS Fellow continues to learn at age 100

By Faye Oney

ACerS Fellow Ralph Rose may have reached a milestone birthday, but that has not slowed down his memory or curtailed his desire to continue his education. He recently turned 100 years old and was happy to talk about his career, achievements, and especially his time at ACerS.

Rose entered Ohio State University during the Depression, and was required to complete four years of ROTC. His interests and strengths lied in physics, chemistry, and math, so he enrolled in the engineering college, initially without a specific major.

After exploring job opportunities, Rose chose ceramic engineering. “We all had to take an introductory course, which was a synopsis of what engineering consisted of,” Rose recalls. “I was interested in chemical engineering.” But before he decided to choose that path, he researched the job market for chemical engineering graduates.

Starbar® and Moly-D® elements are made in the U.S.A. with a focus on providing the highest quality heating elements and service to the global market.
Member spotlight (continued)

“I found out that not all of the chemical engineering graduates had been placed in jobs,” he says. “So I checked out ceramics, and found out that by September after [the previous] graduation year, everyone had a job. So I went into ceramics without knowing much about it.”

Rose remembers there were only three professors in the entire department. “In those days they educated us to be engineers working in small ceramic companies, where there would be one engineer on staff,” he explains.

After serving in WWII from 1942–1945, Rose’s first professional job was as a research engineer for Battelle in Columbus, Ohio, working on sponsored research projects for commercial companies. Since then he’s held several jobs, but he says his most rewarding was at H.K. Porter and Company, where he was involved in helping to build a plant that extracted magnesia from seawater. “Process design of the plant and products was the job I enjoyed the most,” he says.

ACerS involvement included promoting abstracts

Wanting to get more involved in his field, Rose joined ACerS in 1940 as a student, and was a member of the Refractories Division. During his time at Battelle, he became chairman of the Central Ohio Section. When he moved to Philadelphia for a new job, he became chairman of the Philadelphia Section. Although he attended national meetings on a regular basis, he enjoyed being more involved in the local sections. Rose even worked as a paid employee for ACerS between 1946–1951, putting together a column in the ACerS Bulletin to promote abstracts. “The purpose was to give members information on abstracts from technical presentations in local and national meetings,” he explains. “I wanted to bring attention to the various projects in different fields.”

Rose holds several patents, including one for development of a glass polishing compound and one for a method of metal cladding for basic refractories. He was married for 72 years until his wife Ruth passed away in 2013. They have five children, seven grandchildren, and five great grandchildren. Today, Rose lives outside of Harrisburg, Pa., where his favorite pastime is listening to nonfiction books on tape. “I’ve been reading about astrophysics, medicine, and archaeology,” he says jokingly. “I’m getting my Ph.D. at the age of 100!”

Rose reflects on his life and career with fond memories, knowing it has been one of hard work, family love, striving for education and the American dream, service to his community, and professional achievement.

“All of the jobs I held amounted to problem-solving jobs,” he says. “I found it to be a very interesting career.”

New Corporate Partner program enjoys successful first year

ACerS Corporate Partner program, launched in January 2017, completed its first successful year. The new program, designed to increase member company engagement and exposure in Society activities, provides added value in three key areas: marketing and business development, professional development, and technical resources. Rather than a membership dues structure based on staff size, the new program is based on each company’s desired level of engagement. “One of our goals is to build stronger partnerships with member companies,” director of membership Kevin Thompson explains. “The response has been very positive. We thank all our partners who made the transition from the old program.”

Three levels of corporate partnership include Corporate Partner, Sapphire Partner, and Diamond Partner. Following are Diamond and Sapphire partners, with a complete corporate partner roster on ACerS website, including contact information and company description. To learn more about ACerS Corporate Partnership program, visit http://bit.ly/CorpPartnership.

Diamond Partners
ALTEO Gardanne
Harrop Industries
Morgan Advanced Materials
Mo-Sci Corp.
National Center for Manufacturing Sciences
Saint-Gobain
SCHOTT North America Inc.
Superior Technical Ceramics

Sapphire Partners
II-VI Optical Systems
Central Glass & Ceramic Research Institute
CeramTec GmbH
CoorsTek
Kyocera
McDanel Advanced Ceramic Technologies
Specialty Glass Inc.
Trans-Tech
Unimin
Zircar Ceramics

Welcome receptions introduce new members to ACerS

ACerS Member Services Committee introduced new receptions at EAM 2018 and ICACC18 to welcome new ACerS members at each conference. More than 30 new members gathered at EAM 2018 for afternoon refreshments and dessert, while more than 150 were welcomed at ICACC18 with complimentary beverages and appetizers following Monday’s technical sessions. The receptions gave new members the opportunity to meet and network with one another while learning about ACerS and the many benefits of membership. “This was a big hit,” Member Services Committee chair Kristin Breder exclaimed. “We scheduled it for just one hour, but people stayed for more than 1.5 hours because they were having so much fun meeting and mingling with other new members.” Based on their successful debut, new member receptions will be a part of future conferences.
Sharon Uwanyuze and Mark K. King Jr., both from the University of Alabama, won the first Student Industry Failure Trial (SIFT) competition at ICACC18, hosted by ACerS President’s Council of Student Advisors. Materials data were collected for previously failed ceramic parts from industry, which participants analyzed to determine the material and how the parts failed. Students then suggested possibilities for material improvement. Congratulations Sharon and Mark!

Show your expertise in ACerS Next Top Demo competition

Show off your demonstration skills! Get a group of fellow students together and submit a video of a ceramic or glass outreach demonstration. ACerS Next Top Demo is a virtual competition organized by ACerS President’s Council of Student Advisors to help educate the public while advertising the community outreach that you and your university/group already perform. Visit www.ceramics.org/pcsademo to find out how to compete and send video submissions. Deadline is April 27, 2018.
Ceramic and glass students from around the world had an opportunity to learn, share knowledge, hone professional development skills, and network at ACerS Winter Workshop at ICACC18, January 19–23 at the Hilton Daytona Beach Oceanfront Resort in Daytona Beach, Fla.

This year, the European Ceramic Society (ECerS) provided 16 travel grants for international students. A total of 52 students participated in the event.

The Winter Workshop featured experts on the topics of:
- Advanced ceramics—Victoria Blair, Army Research Lab;
- Armor ceramics—Lionel Vargas-Gonzalez, Army Research Lab;
- Bioceramics—Marta Cerruti, McGill University; and
- Ceramic coatings—Bryan Harder, NASA Glenn Research Center

Clive Randall of Penn State University delivered a special presentation, “Humanitarian materials engineering.”

Another session featured speakers and activities on professional development. Ceramics career panelists, ranging from academia to industry, led interactive discussions on career paths taken by successful members of the ceramics field.

Participants also enjoyed a tour of the Kennedy Space Center.

Winter Workshop participants could attend all ICACC events, which showcased cutting-edge research and product developments in all aspects of ceramics.

The Winter Workshop was made possible through the support of the Ceramic and Glass Industry Foundation, ACerS President’s Council of Student Advisors, Young Professionals Network, and ECerS.

Mark your calendars for next year’s Winter Workshop, held in conjunction with ICACC19 at Daytona Beach, Fla., January 27–31, 2019.
Rethinking optical fiber glasses and what it will take to pump more data into our phones

Light is a $7.5 trillion industry driven largely by demand for information transmission and storage, with an estimated contribution of $19 billion from the United States-based photonics industry in 2014.

Statistica reports that in 2015, for the first time, the number of cell-phone-only American households exceeded the number of homes with landlines. The trend of trading landlines for wireless phones shows no sign of stopping.

However, growing market demand for wireless service and faster transmission of more data is bumping up against the limits of the material properties of optical fibers.

“Present fiber-based communication and high-energy laser systems are limited in the level of optical power that can be propagated,” says Clemson professor John Ballato in the introduction of a new paper. Limitations in power scaling—pushing more light/data through a fiber—arise from optical phenomena such as stimulated Brillouin scattering, stimulated Raman scattering, transverse mode instabilities, nonlinear refractive index, and other phenomena related to wave mixing.

Manufacturing porous silicon carbide

Researchers at Technische Universität Wien (Vienna, Austria) have succeeded in developing a method for controlled manufacture of porous silicon carbide. To demonstrate the potential of this new technology, the researchers integrated a special mirror that selectively reflects different colors of light into a silicon carbide wafer by creating thin layers with different degrees of porosity. The technique makes it possible to produce a complex structure of silicon carbide layers with higher and lower levels of porosity, which is finally separated from the bulk material by applying a high voltage pulse. The thickness of individual layers can be selected to reflect certain light wavelengths particularly well, resulting in an integrated, color-selective mirror. For more information, visit www.tuwien.ac.at.

This collection of “nonlinearities” creates problems for optical engineers. Thus far, optical engineers have gotten around these materials limitations by manipulating the signals or by distributing light intensity across a larger cross-section to keep intensity below the threshold that stimulates nonlinearities.

However, these tactics do not address the root cause of limitations of silica-based optical fibers. Ballato and his team are taking a different approach—searching for new materials and processes to fabricate fibers with intrinsically low optical nonlinearities. “A materials approach is arguably the more direct and efficient route since the interaction of the light with the material is where the nonlinearities fundamentally originate,” he says in a new paper.

The paper is the first of four new papers in an open-access “trilogy” by Ballato and collaborators on their work developing a unified approach to mitigating optical nonlinearities in optical fibers. The four-article series communicates a trilogy of ideas. The first paper evaluates the nonlinearities problem by describing thermodynamics of optical scattering. The second and third papers (part 2 of the trilogy) dive into glass science and additivity models that determine properties and nonlinearities. The fourth paper offers a path forward with examples and a materials roadmap.

In the course of the trilogy, Ballato et al. conclude that silica-based glasses still are the best materials for efficient optical transmission. However, the compositional adjustments needed are not compatible with traditional CVD preform processing. Instead, the team proposes a “molten core” fabrication process, where a molten core glass surrounded by a clad glass are pulled directly into a fiber. Because the core is molten and quenches so quickly during fiber fabrication, compositions can result that are not feasible using conventional methods.

“The papers are, perhaps not surprisingly, somewhat provocative. For our industry friends, where transitions to new systems/methods is not feasible (or desired), we plan another paper that is more tailored to your processes. That said, the trends discussed, even taken in small increments, could still have beneficial impacts,” Ballato writes in an email.

The sheer size of the optical fiber industry means change will be challenging and costly. But which change is more likely—that the market will cease to demand more data transmission, or that industry will change to meet market demand?

The articles are all open-access in the *International Journal of Applied Glass Science*.


**Nanoindentation experiments reveal porous particle size matters for assembled material toughness**

Porous particles are important in a host of materials and applications, including drug delivery, insulation, catalysis, chromatography, filler materials, construction materials, and ceramics. But, despite their importance and potential applications, the mechanical properties of such porous particles are often ignored.

Now, after collecting extensive data, researchers at Rice University (Houston, Texas) can definitively say that, when it comes to porous nanoparticles, size matters—and, in the process, they have made some surprising discoveries about how size affects the materials’ intrinsic properties.

Using uniformly porous calcium-silicate nanoparticles with diameters ranging 150–550 nm and pore sizes of 2–4 nm, the scientists found that larger particles behave differently under pressure than smaller ones. Using a nanoindenter, they tested...
how assembled films and compacted pellets of the various-diameter nanoparticles held up under pressure.

The data, the result of more than 900 nanoindentation experiments, shows that self-assembled films of larger calcium-silicate nanoparticles are 120% tougher than those assembled from smaller particles of the same composition and porousness.

“This means that larger submicron calcium-silicate particles are tougher and more flexible compared with smaller ones, making them more damage-tolerant,” senior researcher Rouzbeh Shahsavari says in a Rice University news release.

Shahsavari completed the study with graduate student Sung Hoon Hwang, who together also recently wrote an interesting article about innovative concretes in the January/February 2018 issue of the ACerS Bulletin.

“Usually the common perception in nanomaterials is that smaller is better (such as in metallic systems), but our results were the opposite,” Shahsavari explains in an email. “This new knowledge can help to better create and use either individual version of these particles, for example for drug delivery—or their collected behavior, such as in self-healing applications and bone-tissue engineering.”

In addition to size, however, the scientists also showed that assembly of those nanoparticles matters, too.

The nanoparticle size effect they measured with self-assembled films disappeared when the researchers tested compacted samples of the nanoparticles, highlighting important intrinsic differences depending on how a material is prepared—even when it is prepared from the same starting nanomaterial. That is an important point for ceramic materials, which are often compacted from small porous particles.

“The results can be helpful in generalizing to any porous particles materials where the relationship between three factors—particle size, pore size, and mechanical properties—are often not intuitive but very important,” Shahsavari writes in an email. “This interrelationship we found is akin to the role of ‘structure-property’ design maps in metallic systems or other material classes. Overall, what we found paves the path for discovering composition-structure-property design maps for porous inorganic materials and ceramics.”

The paper, published in ACS Applied Materials & Interfaces, is “Intrinsic size effect in scaffolded porous calcium silicate particles and mechanical behavior of their self-assembled ensembles” (DOI: 10.1021/acsami.7b15803).
2018: Year of the Dog likely to live up to its name for Chinese mineral consumers

We are entering the Chinese New Year of 2018—the Year of the Dog—a festival that officially lasts February 16–March 2, 2018.

Many Chinese ceramic mineral consumers in the West also hope that it will be a time to take stock and perhaps see what might be in store regarding China’s mineral supply outlook for the rest of the year.

Since the mid-1980s, China has been the world’s dominant supplier of a range of important ceramic, abrasive, and refractory minerals, such as bauxite, fused alumina, fluorspar, kaolin, graphite, magnesia, refractory clays, silicon carbide, talc, and wollastonite. All that may be about to change.

The closing months of 2017 witnessed an unprecedented period in Chinese mineral trade, particularly regarding refractory and abrasive export minerals—Chinese producers were struggling to reassure customers that they could maintain future supplies of grades in demand.

The problem remains that they cannot—and even the few in a position to continue supply for export markets were having a challenging time trying to fix prices into 2018. This is a nightmare for western traders and consumers, whose normal practice of fixing annual forward contracts simply dissolved as 2017 wore on. Few were lucky to get Q1 2018 contracts concluded.

There are three primary causes for this extraordinary state of affairs, driven by the strategy of China’s president Xi Jinping (who was recently rebooted for another five years by the October 2017 Congress). The situation evolved in early 2017 and climaxed towards the year’s end: a countrywide and robust program of anti-pollution control on industrial plants; a ban on normal provision of dynamite; and an across the board clean-up of illegal and unlicensed operations.

The net effect has significantly hit the mineral and ceramics industries, with plant closures (a few refractory mineral plants have reopened since they met environmental standards, but there have been province-wide closures in Shanxi and Henan, which host most bauxite and alumina calcination and fusion plants) and reduced primary raw material availability owing to little or no drilling and blasting at mines. In addition, certain suppliers lacking correct documents, licenses, and tax payments are facing business closure.

The upshot has been acute shortages in supply and soaring prices for export minerals, causing panic among traders and consumers.

As January 2018 came around, refractory-grade brown fused alumina was pushing through $800/tonne free on board (FOB), with abrasive grades priced at $850/tonne FOB. Calcined bauxite 86–88% Al₂O₃ ranged $470–500+/tonne. Fused magnesia remained at >$1,000/tonne FOB.

Some fusion plants have reportedly resumed production in January 2018, but the brown fused alumina shortage is expected to last another two or three months at least.

Unlike past cycles of Chinese mineral supply ups and downs, which were relatively short-lived, this time is different—forces impacting the mineral industry are driven by the central government and appear to have long-lasting intent. January 2018 witnessed the implementation of a new environmental tax penalizing plant emissions, a new cost input to the complex and unpredictable anatomy of Chinese mineral pricing.

End of year feedback suggested that perhaps by the end of the Chinese New Year, or maybe mid-2018, some of the dust may settle and things can clear somewhat. However, others are bracing themselves for a long haul of short supply and high prices through 2018 and into 2019.

Indeed, for western Chinese ceramic mineral consumers, the Year of the Dog may seem an apt description for the next 12 months.

About the author

Mike O’Driscoll is director of IMFORMED and has over 30 years of experience in the industrial minerals business. IMFORMED has conferences this year covering mineral recycling, magnesia, fluorspar, and China’s abrasives and refractory minerals—see www.imformed.com for more information. Contact O’Driscoll at mike@imformed.com.
The role of glass in modern society is evident everywhere—from windows and wine bottles to car windshields and durable device touchscreens.

Industrial glass manufacturers require highly engineered high-temperature furnaces to contain glass in its molten state (3,000°F–3,200°F, or 1,600°C–1,800°C) so that convections in the melter allow proper mixing as well as melting of incoming raw batch materials. After the refining process, in which dissolved gases are allowed to escape, the glass has a chemical homogeneity ready for formation of the final article. This molten glass must be contained by a refractory lining in the furnace to allow safe operation over an extended time period to economically and efficiently manufacture high-quality glass products.

Evolution of glass furnace refractory linings

Toward the end of the 19th century, fireclay, a bonded alumina refractory, was the glass furnace refractory lining of choice. This progressed to a better quality of fireclay, and later, the refractory lining package included bonded silica brick, which easily dissolved but did not affect glass quality. However, the furnace life of glass-contact silica refractory was only 8–12 months.

In the early 20th century, sillimanite (Al$_2$O$_3$·SiO$_2$) and then mullite (3Al$_2$O$_3$·2SiO$_2$) found their way into use as bonded refractory materials that performed better than fireclay and silica bricks.$^{1,2}$ Typically, these refractory materials are pressed with binders to maintain geometry and fired at high temperatures to create a bonding phase for strength. These refractory bonded shapes typically have a porosity (~10–15%) that will severely reduce corrosion resistance in contact with a slag or glass at high temperatures, not to mention high solubility of their components.

Enter the advent of a refractory manufactured by fusing molten oxide powders at high temperatures (~3,800°F–4,000°F). The process of fusion casting bypasses conventional bonding of refractory bodies mentioned earlier by developing crystalline intergrowths capable of exceptional corrosion resistance due to high density of the body. The batch, after dry blending, is fed to an electric arc furnace for fusion by energy released in arc-resistance paths. The furnace melting the material tilts to pour this liquid into molds designed for final applications. Monofrax LLC pioneered this technology in the late 1930s with high-alumina fused cast refractory materials and, later, many compositional evolutions.
After the Second World War, the refractory of choice for lining glass furnaces soon became a material called AZS, an acronym for a composition consisting of alumina, zirconia, and silica. Manufacture of fusion-cast AZS resulted in a refractory material with low porosity (~1%), high density, and good corrosion resistance—critical factors to extend life of the glass furnace. The material increased furnace life from ~18 months to 3–5 years, allowing furnaces to operate at higher temperatures and at greater throughput.1,2

Corrosion resistance of AZS results from its low porosity and high density, as well as the presence of zirconia, a highly insoluble phase. Even though the AZS refractory lining in contact with glass extends high-temperature glass furnace life dramatically over bonded refractory materials, furnace life cannot continue indefinitely. Corrosion and erosion of the lining will occur, eventually curtailing furnace operation until the lining is repaired or replaced. Figure 1A shows a new AZS furnace lining before delivery and installation, contrasted with a corroded AZS furnace lining after 6.5 years of service in a soda-lime glass furnace in Figures 1B and 1C.

Glass quality in soda-lime, borosilicate, and high alumina–silica glass compositions is critical to achieve clarity and strength because, without these properties, the items of interest will fail in their designed applications. This places high demand for quality refractories in contact with glass to not alter critical properties of the glass by refractory defects and dissolved refractory components. The images in Figure 1 of corroded AZS fused cast refractory lining are a revealing testament to the erosion of refractory linings during a glass furnace campaign.

The final glass article, be it a bottle or window, will actually have some trace of the refractory components (e.g., ~0.07% ZrO₂) dissolved in its structure, although at a level that does not affect required glass clarity and strength. Refractory lining in a typical glass furnace is designed to account for the types of corrosion encountered at molten glass contact or by corrosive vapor species in non-glass contact regions at temperatures of ≥2,700°F (1,500°C).

The philosophy in glass furnace refractory design is to ensure corrosion equivalency of differing refractory materials in the whole furnace, so the term of the campaign is not prematurely interrupted due to a single refractory region failure.

There are many compositional varieties of fusion-cast refractories available beyond AZS, such as high zirconia, high alumina, magnesium spinel, and chrome–magnesium–aluminate castings. Monofrax LLC supplies several compositional groups (~12 currently) to diverse glass manufacturing industries, including flat glass, containers, fiberglass, and, more recently, tough, thin glass touchscreen surfaces for electronic devices.

AZS fused cast materials such as Monofrax CS-3 and CS-5 are typical glass contact and non-glass contact mate...

Capsule summary

CONTAINMENT
Disposal of nuclear waste is a complex problem—one solution is vitrification, in which glass is used as a containment medium to stabilize radioactive waste.

DESIGN
As with industrial glass furnaces, refractory designs for nuclear waste vitrification melters call for a variety of refractories that corrode equivalently. Refractory linings in the glass furnace are a critical component of molten glass containment for glass articles.

LONGEVITY
Nuclear applications have already generated thousands of tons of nuclear waste, and that amount will continue to increase. Although operational challenges still exist in melters, vitrification provides a proven method of nuclear waste storage.
materials, while high-alumina materials such as Monofrax M and H are used in lower temperature glass contact refiner and distributor regions. Chrome/alumina/magnesia-bearing materials, such as Monofrax K-3 and E, are often used in weir walls and throat cover blocks, which require the highest level of corrosion resistance and can tolerate potential chrome coloration.

**Clarity to containment**

On December 2, 1942, a team of 49 scientists, led by Enrico Fermi, proved that a self-sustaining nuclear chain reaction could be initiated. Conducted under Stagg Field of the University of Chicago, this experiment, called the Chicago Pile-1 reactor, became the integral first step of the Manhattan Project to develop the atomic bomb.4

In the midst of this dash to successfully create a controlled nuclear chain reaction, there is no known reference that any of these scientists foresaw the immensity of the amount of nuclear waste that harnessing such energy in weaponry and power generation would create.

However, as of January 2009, the amount of spent nuclear fuel from the 104 nuclear reactors operating within the United States alone reached 64,000 metric tons.5 In the U.S., defense and weapon-related activities are another source of waste, with the largest quantities created in the early days of nuclear weapon development and testing.

The U.S. Department of Energy officially discontinued reprocessing spent nuclear fuel in 1992, although the U.S. has generated 347,300 m³ of waste incidental to reprocessing.6 Most of this liquid high-level waste (HLW) is stored in underground tanks at the Hanford site in Richland, Wash., and the Savannah River site in Aiken, S.C. Another portion of HLW was calcined to a dry powder and is stored at the Idaho National Laboratory in Idaho Falls, Idaho.

Weapons-grade plutonium production stopped in the 1980s. However, the consequence of this material lingers on in the form of waste. The current emphasis of nuclear fission is electricity generation in the U.S., but not to the extent of its role in other countries, such as Canada and China.

In the public sector, developing uranium fuel to produce power from nuclear plants generates different forms of waste (e.g., mine mill tailings, conversion, enrichment)—which all will need disposal. Rod Ewing7 states that “...the complexity of the nuclear waste disposal problem has delayed final choices of waste disposal sites in most countries that have nuclear waste inventories. So much so that, there are, at present, no operating [geologic] nuclear waste repositories for spent nuclear fuel from commercial nuclear power plants or for HLW from the reprocessing of spent fuel.”

Complexity in the disposal of nuclear waste is partially due to the variety of waste compositions that ultimately drive the need for different glass containment formulations. Waste containment plant designs are dictated by radioactive loads, which may require fully remote designs or permit a hands-on approach. At the Hanford and Savannah River sites, HLW is further separated into a smaller volume containing most of the radioactivity and a larger volume of contaminated liquid with much lower radioactivity (low activity waste, or LAW), which has a different disposal strategy. However, each facility treats LAW differently—Savannah River grouts LAW, while Hanford vitrifies it. Regardless of the means, nuclear waste must be reduced to a solid form before disposal and must resist leaching.

**Vitrification**

The term vitrification connotes involvement of glass, which serves as a host medium to stabilize radioactive waste. Durability is the top priority for containing radioactive waste for thousands of years. This contrasts with other applications, such as commercial glasses designed for optical clarity.

<table>
<thead>
<tr>
<th>Table 1. Soda-lime glass composition typical for flat glass and examples of vitrification melter glass chemistries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt%</td>
</tr>
<tr>
<td>SiO₂</td>
</tr>
<tr>
<td>Al₂O₃</td>
</tr>
<tr>
<td>CaO</td>
</tr>
<tr>
<td>MgO</td>
</tr>
<tr>
<td>Na₂O</td>
</tr>
<tr>
<td>K₂O</td>
</tr>
<tr>
<td>B₂O₃</td>
</tr>
<tr>
<td>Li₂O</td>
</tr>
<tr>
<td>BeO</td>
</tr>
<tr>
<td>MnO</td>
</tr>
<tr>
<td>V₂O₅</td>
</tr>
<tr>
<td>Fe₂O₃</td>
</tr>
<tr>
<td>CoO</td>
</tr>
<tr>
<td>Cr₂O₃</td>
</tr>
<tr>
<td>SO₃</td>
</tr>
<tr>
<td>NiO</td>
</tr>
<tr>
<td>Sb₂O₅</td>
</tr>
<tr>
<td>P₂O₅</td>
</tr>
<tr>
<td>ZrO₂</td>
</tr>
<tr>
<td>TiO₂</td>
</tr>
<tr>
<td>ZnO</td>
</tr>
<tr>
<td>La₂O₃</td>
</tr>
<tr>
<td>Nd₂O₃</td>
</tr>
<tr>
<td>CdO</td>
</tr>
<tr>
<td>SnO₂</td>
</tr>
<tr>
<td>CeO₂</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>99.85</td>
</tr>
</tbody>
</table>

*Flat glass industrial furnace, Glaverbel S.A. Belgium.*

*China simulated HLW waste, Karlsruhe Nuclear Research Center, Germany.*

*West Valley, NY.*

*Savannah River, EA Glass.*

*Savannah River Activity Waste Vitrification Project, 2002.*

*PNNL glass for research scale melter test.*
Fusion cast refractories: Roles of containment

At Savannah River and Hanford sites, radioactive waste is transitioned into a molten borosilicate glass through a variety of steps involving a liquid slurry with dry additives that form a blanket on the glass called a cold cap. The bottom portion of this cold cap melts into a foamy glass and ultimately melts into the pool, which is poured into a robust stainless steel canister (~1–3 m high) and allowed to cool, forming a solid matrix.

Containers are welded shut, ready for storage and final disposal. This encapsulation in molten glass and solidification in final storage containers is called vitrification and is a suitable and adequate process for management of ILW and HLW.

Figure 2A shows a K-3 melter box in the setup area at Monofrax with a similar layout to soda-lime industrial glass tanks. The melter box contains glass slurry as nuclear waste is encapsulated within the glass. This box is a portion of the larger unit at the Hanford site (Figure 2B).

Refractory design experience, philosophy, and technology for melting of industrial commercial glasses (e.g., soda-lime, borosilicate, and high-alumina cover glasses) has been transferred in a similar fashion when designing the nuclear waste vitrification melter. In this case, the design uses another property of glass.

Unlike the clarity and strength necessary in soda-lime and borosilicate glass, the chemistry of encapsulating glass in nuclear waste treatments is unique in its ability to immobilize radionuclides. Specific oxides determine various properties in soda-lime glass, such as melting point, mechanical properties, or color. For example, iron is incorporated at low levels (0.1–2.0% iron oxide) in soda-lime glass to reduce the effect of harmful UV rays for construction glass.8

Design of the glass composition necessary for nuclear waste encapsulation involves a complicated selection process with non-radioactive glass-forming additives. These chemistries are tailored to create a favorable viscosity-temperature relation, meaning radionuclide volatilities are not in play.9 In this case, boron has an important role in reducing glass viscosity at temperatures below radionuclide volatility temperatures of >1,200°C.

Vitrification is a particularly attractive immobilization route because the glassy product has high chemical durability.10 Borosilicate glass contains waste material through direct chemical incorporation into the glass structure (i.e., dissolution), although some studies also have evaluated the feasibility of physically encapsulating solid wastes. The durability of borosilicate glass allows storage for thousands of years, even under conditions of irradiation by incorporated radioactive materials, which do not crystallize the oxide glass.

The temperatures encountered in vitrification melters (~1,050°C–1,200°C) are considerably lower than in commercial soda-lime glass tanks (~1,500°C–1,600°C). Table 1 lists soda-lime glass compositions typical for flat glass, alongside some examples of vitrification melter glass chemistries.

There are numerous critical components of the vitrification melter used to heat glass to 1,050°C–1,150°C, not the least of which is the refractory lining. Monofrax has manufactured a chrome-bearing fused cast refractory designed for this lining for over 30 years, since the beginning of the process of encapsulating nuclear wastes. In one instance at Savannah River National Laboratory, the designed life of this lining was estimated to be 2–6 years.11 However, in actual practice at SRNL, the life of Melter #1 was 8.5 years and Melter #2 was >14 years, eventually shutting down due to mechanical failures that were not refractory related.12

Corrosion in soda-lime glass tanks

Corrosion kinetics and byproducts of fused cast refractories in contact with soda-lime glasses of the container and flat glass industries are well known. AZS refractories have three microstructural components: zirconia dendrites, a coprecipitate component of zirconia and corundum, and a high-alumina glass.

When the AZS lining interacts with molten glass, there is typically a corrosion reaction layer at glass contact that remains attached to the lining. Continued corrosion takes place by erosion of this layer and, in some cases, may “peel” off, creating some glass quality problems.

Types of nuclear waste

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLW</td>
<td>High level waste—highly radioactive due to reprocessed nuclear fuel</td>
</tr>
<tr>
<td>ILW</td>
<td>Intermediate level waste—requires shielding when handling</td>
</tr>
<tr>
<td>LLW</td>
<td>Low level waste—contaminated by radioactive materials, but not inherently radioactive</td>
</tr>
</tbody>
</table>
This thin reaction layer, often called the passivation layer ("G" in Figures 3A and 3B) because it serves to “passivate” further corrosion, is a byproduct of incongruent dissolution into the tank glass. Alumina in the coprecipitate alumina–zirconia component of AZS goes into solution at the glass–refractory interface, creating a layer of highly aluminous glass with undissolved zirconia (Figure 3 and Table 2).

Corrosion with soda-lime glass is not restricted to the immediate glass contact, however, as the glass phase component of AZS provides a pathway for diffusing alkali and alkaline earth species, such as potassium, sodium, magnesium, and calcium. Alkalis are more rapid diffusers than alkaline earths, as observed by Kasselouri et al.13 as well as others—potassium and sodium species migrate to deeper depths than magnesium and calcium. Consequently, alkalis such as potassium and sodium promote corrosion of the corundum primary phase at depths into the AZS body beyond the immediate glass–refractory contact.

Corrosion in vitrification melters

Facilities active in vitrification of nuclear waste cannot afford failure of the melter due to refractory lining failure either by excessive corrosion or spalling. During the life of the melter, different glasses formulated due to differing waste compositions can have a variable impact on the refractory corrosion rate. Care must be taken to not formulate glasses that will be highly aggressive to the refractory.

Some of the most corrosion-resistant refractory materials available contain chromium oxide as a major component (e.g., Monofrax K-3 and E). Since the beginning of vitrification of nuclear waste, Monofrax K-3 chrome refractory has been a refractory of choice for lining melters in the U.S. and, in later years, Japan.

Chromium oxide is more insoluble than even zirconia in most glasses, making it a desirable component of refractory lining. Potential coloration of the glass by chrome refractories is a concern in soda-lime container and flatglass industries, but is not an issue for nuclear waste glass.

What are the chemical and microstructural factors that make a chrome refractory, such as Monofrax K-3, perform so well as the glass contact refractory liner in vitrification reactors?

As aforementioned, fused cast materials such as K-3 have low porosity and an interlocking, tight microstructure. The typical microstructure of Monofrax K-3 is a binary phase assemblage primarily of an (Mg,Fe)O\(\cdot\)Cr\(_2\)O\(_3\) spinel, and an \(R_2O_3\) (Cr\(_2\)O\(_3\)-Al\(_2\)O\(_3\) solid solution) phase, with minor glassy phase and low level reduced iron as free metal at grain boundaries. Further, the \(R_2O_3\) phase is present as chemically inhomogeneous cored grains, with relatively Cr\(_2\)O\(_3\)-rich centers and relatively Cr\(_2\)O\(_3\)-poor rims (Figure 4).

When in contact with melt glass, Monofrax fused cast chrome materials (K-3 and E) react with glass in an incongruent fashion (as in AZS in contact with soda-lime glass), leaving a byproduct at the glass–refractory interface. Magnesium and aluminum are the most soluble components of K-3, generally leaving the most insoluble component, Cr\(_2\)O\(_3\), behind at the corrosion interface.

Monofrax K-3 in contact with waste glass simulant at the SRNL melter was characterized after service in 1984.14 Nickel and iron in the glass chemically behaved as a spinel former at the interface to create a nickel–iron–chrome spinel layer, somewhat metastable in the melter environment. This layer also inhibits further reaction at the interface by “passivating” corrosion rate at the glass contact. This chromium-rich spinel “skin” containing nickel is thermodynamically more stable.

Table 2. Chemistry of glass in the AZS glass phase, soda-lime tank glass, and passivation layer

<table>
<thead>
<tr>
<th>Wt%</th>
<th>AZS glass phase</th>
<th>Passivation layer</th>
<th>Soda-lime tank glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Al_2O_3)</td>
<td>23.2</td>
<td>32.0</td>
<td>1.2</td>
</tr>
<tr>
<td>(SiO_2)</td>
<td>68.0</td>
<td>46.0</td>
<td>74.0</td>
</tr>
<tr>
<td>(CaO)</td>
<td>0.2</td>
<td>3.3</td>
<td>10.0</td>
</tr>
<tr>
<td>(Na_2O)</td>
<td>6.5</td>
<td>15.5</td>
<td>14.0</td>
</tr>
<tr>
<td>(Fe_2O_3)</td>
<td>0.3</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>(K_2O)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>(MgO)</td>
<td>1.0</td>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>(ZrO_2)</td>
<td>1.8</td>
<td>1.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>99.5</td>
</tr>
</tbody>
</table>

Figure 3. Electron micrographs of (A) virgin AZS and (B) corroded AZS.
West Valley, NY case study

West Valley Demonstration Project in western New York was a site for private reprocessing of spent nuclear fuel as part of a program to make this a commercialized enterprise in the 1960s. This business venture was set up under a private company called Nuclear Fuel Services Inc., with construction beginning in 1963 and completed in 1966. From 1966–1971, 640 metric tons of fuel from defense and commercial power reactors were reprocessed, more than half of which came from the Hanford nuclear reactor.

When operations at this facility halted in 1972 for modifications to increase reprocessing capacity and efficiency, the Atomic Energy Commission at the same time established new regulations for reprocessing spent nuclear fuel. These new regulations affected the West Valley facility by dramatically increasing operational costs, making it too costly to continue under its design.

Nuclear Fuel Services withdrew from this business in 1977 and turned it over to the state of New York to deal with the site. Eventually it took an “act of Congress” in 1980 to create the West Valley Demonstration Project (WVDP) Act to deal with what now became a “clean-up,” rather than a business venture of reprocessing spent nuclear fuels.

A key requirement and high priority of the WVDP Act was solidification of HLW, because LLW could be dealt with by incorporation into grout and disposal at the Nevada Test Site, which contains 20,000 71-gallon drums. The consequence of reprocessing 640 metric tons of fuel during its short business operation was to create 600,000 gallons of liquid HLW. Higher-activity waste was mixed with a borosilicate glass frit, melted, poured into 275 stainless steel canisters, and solidified—i.e., vitrified—which continued during 1996–2002.

The melter, shaped like an inverted prism, was 6 feet deep and continuously received a water-saturated feed slurry at a rate of 20 gallons/hour. Wastes and glass formers melted into the glass pool, where they mixed by natural convection at 1,050ºC–1,150ºC, with a 2–3 day residence time before being transferred to stainless steel canisters. The melt was slowly poured into these ten-foot canisters over a period of 63 hours.

The lining in that melter cavity consisted of Monofrax K-3 fused cast chrome refractory—the first of many applications of Monofrax K-3 in vessels vitrifying radioactive HLW. However, even though most of the lining consisted of K-3, other portions contained other Monofrax fused cast material. Monofrax E (78% Cr₂O₃) composed two riser blocks of the overflow chambers because of its higher thermal conductivity to maintain a high glass temperature in the externally heated riser. Non-glass contact regions of the plenum area of the melter cavity consisted of high-alumina Monofrax H fused cast material because of its resistance to vapor corrosion and thermal shock.

Therefore Monofrax’s involvement in vitrification of ILW and HLW began in the mid-1980s—currently reflecting more than 30 years of refractory experience in this application. During this period, additional facilities have adopted Monofrax K-3 in melters, including the following, some of which are not yet operational:

- Savannah River Site’s Defense Waste Processing Facility and the Duratek Duramelter 5000 unit M-Area facility in South Carolina
- HLW and LAW treatment melters in Hanford, Wash.
- Japan Nuclear Fuels Limited HLW melters in Rokkasho, Japan

---


Spinel layer byproduct evolution path formation is as follows.

\[(\text{Mg,Fe})\text{O} \cdot (\text{AlCr})_2\text{O}_3 \rightarrow (\text{Ni,Fe})\text{O} \cdot (\text{Cr, Fe, Al})_2\text{O}_3\]

Work by Jantzen\textsuperscript{15} at Savannah River Technology Center on the corrosion of K-3 by reducing and oxidizing feeds also found a highly insoluble protective layer of nickel spinel \((\text{Ni(Cr}_{0.8}\text{Fe}_{0.2})_2\text{O}_4)\) at the K-3–glass interface.

Additional characterization of K-3 involved a research scale melter (RSM) from the Pacific Northwest National Laboratory (PNNL) that consisted of a small Monofrax K-3 cylindrical chamber with a 6-inch diameter melt pool. A test with this melter consisted of eleven weeks at temperatures of 1,050°C–1,150°C to observe the behavior of crystals precipitating out of the melt, which potentially can clog the outlet feeder to the holding cylinder.

Glass used in the test was a high nickel–iron–borosilicate glass (see Table 1) that resulted from a feed of the simulant liquid slurry mixed with glass formers (referred to as AZ-101 simulant). The scanning electron micrograph in Figure 5 is from the glass–K-3 interface bottom of the melter, revealing secondary phase formation at the reaction layer. Phases 1 and 2 are spinel and \(\text{R}_2\text{O}_3\) solid solution, respectively, with chemistries slightly altered from typical K-3 (Table 3).

Moving closer to the glass–K-3 interface, the \(\text{R}_2\text{O}_3\) phase dissociates by giving up its alumina portion. The spinel phase experiences oxidation with the FeO component going to \(\text{Fe}_2\text{O}_3\), MgO, and FeO replaced by NiO, and alumina dissociating out to the glass as in the \(\text{R}_2\text{O}_3\) phase (spinel phases 3, 4, and 5). The spinel stable phase at the glass–K-3 contact is a nickel spinel in the form: Ni\(_{0.9} \text{(Fe}_{1.9}\text{Cr}_{0.1}\text{Al}_{0.5})_2\text{O}_4\). Well-formed crystals in the waste glass simulant above the reaction layer are nickel spinel precipitates, which form in the glass and accumulate on the bottom.

The chart in Figure 6 tracks the chemical trend of magnesium, aluminum, and nickel from the glass–K-3 interface region towards the interior. This shows nickel replacing magnesium in the spinel phase, with a concomitant decrease in alumina as it migrates to the glass. The “normal” spinel composition for K-3 is found ~1 mm deep, keeping alteration of K-3 within a restricted zone at the glass–K-3 contact.

The major phases of Monofrax K-3, spinel, and \(\text{R}_2\text{O}_3\) are both solid solution phases and demonstrate the ability to adapt to transition metal levels in the waste glass. The consequence of this adaptability is formation of a secondary protective spinel layer reflecting the glass chemistry and oxidation state. In the PNNL melter, nickel replaces magnesium and reduced iron in the primary spinel of K-3, and ferric iron replaces alumina.

![Figure 4. Electron micrograph of Monofrax K-3 showing (Mg,Fe)O • (AlCr)\textsubscript{2}O\textsubscript{3} spinel phase and the \(\text{R}_2\text{O}_3\) (Cr\textsubscript{2}O\textsubscript{3}-Al\textsubscript{2}O\textsubscript{3} solid solution) phase. The \(\text{R}_2\text{O}_3\) phase is present as chemically inhomogeneous cored grains.](credit: Monofrax)

![Figure 5. Scanning electron micrograph of the glass–K-3 interface at the bottom of the melter, revealing secondary phase formation at the reaction layer. Phases 1 and 2 are spinel and \(\text{R}_2\text{O}_3\) solid solution, respectively. Phases 3, 4 and 5 are spinels with increasing nickel content and oxidized iron closer to the glass.](credit: Monofrax)

### Table 3. Phase compositions present in the glass–K-3 interface at the bottom of the melter

<table>
<thead>
<tr>
<th>Wt%</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgO</td>
<td>10.3</td>
<td>6.4</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FeO</td>
<td>18.2</td>
<td>19.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe(_2\text{O}_3)</td>
<td></td>
<td></td>
<td>39.6</td>
<td>65.7</td>
<td></td>
</tr>
<tr>
<td>Al(_2\text{O}_3)</td>
<td>44.1</td>
<td>81.5</td>
<td>41.4</td>
<td>15.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Cr(_2\text{O}_3)</td>
<td>27.4</td>
<td>18.5</td>
<td>26.5</td>
<td>25.0</td>
<td>4.1</td>
</tr>
<tr>
<td>NiO</td>
<td>6.4</td>
<td>16.9</td>
<td>28.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MnO</td>
<td>1.0</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Future challenges of nuclear waste containment in glass**

Operational challenges still exist in melters, specifically involving phase separations in the melter feed. Precipitation of a nephi-

---

27
elkreg@monofrax.com.

Acknowledgements

The author thanks the following reviewers of the manuscript for their comments and suggested modifications: William Eaton and Mark Hall, Pacific Northwest National Laboratory; Donna Post Guillen, Idaho National Laboratory; and Kai Xu, Wuhan University of Technology. The sample from the PNNL research scale melter was kindly provided by William Eaton and Mark Hall, Pacific Northwest National Laboratory at Monofrax LLC. Contact Selkregg at kevin.

References

The World Materials Research Institutes Forum (www.wmrif.org), established at the National Institute for Materials Science in Japan in 2005, is comprised of directors and executives of over 50 materials research institutes from around the world. WMRIF’s composition positions it to identify and define worldwide grand challenges in materials science, to establish collaborative research efforts to address global challenges, and to provide premier materials education and training to young scientists to enable sustained innovation in materials sciences.

WMRIF members meet in a biennial general assembly at one of the participating materials research institutes. The 7th WMRIF Symposium and General Assembly took place June 19–22, 2017, at the National Science and Technology Development Agency in Bangkok, Thailand, hosted by the National Metal and Materials Technology Center (Figure 1). Michael Fasolka of the National Institute of Standards and Technology (NIST), the current WMRIF president, led the 7th WMRIF along with current WMRIF secretary general Nick Barbosa, also of NIST. The symposium, which took place prior to the general assembly, brought together more than 170 participants, including leaders and technical staff from 16 world materials research institutes. The main theme of the symposium was advances in materials for renewing and protecting critical infrastructure and resources.

At the general assembly, discussion focused on WMRIF priority areas and opportunities to collaboratively leverage resources to address priority materials needs. For example, a discussion of materials-related data needs revealed that while efforts to increase international awareness and coordination in the development of data tools and resources has been valuable, WMRIF should continue to drive interactions to reach a larger audience.

WMRIF also fulfills its mission through four task groups.

**Outreach to underrepresented regional laboratories**

This task group seeks to identify and support laboratories around the globe that are underrepresented in the international materials science community or would benefit from access to resources available at other national materials research institutes. The immediate focus is on material science and engineering laboratories in countries throughout Africa, with an emphasis on assisting early career scientists.

**Early career scientists**

Biannual international technical workshops for early-career material scientists and engineers—the leaders of tomorrow—focus on important materials science topics. As part of these workshops, young scientist attendees present recent work on a small group of topics and then discuss strategies to address challenges in these areas. In addition to promoting continued interactions among attendees, senior scientists select top presenters who are awarded stays at WMRIF laboratories of their choice, including all travel and living expenses. The 5th International Workshop for Early Career Scientists was held November 2017 in Tsukuba, Japan, and the next early career scientist meeting will be held at the National Physical Laboratory in Teddington, England, June 18–22, 2018.

**Databases and data quality**

In an era of open data, this working group aims for WMRIF member organizations to lead the international measurement society by providing high-quality data based on best practices (e.g., calibrated equipment, standardized methods, and multisite data of known precision). WMRIF will be collaborating with the Versailles Project on Advanced Materials and Standards (VAMAS) pre-normalization initiative, a liaison partner.

**Ten materials needs for the future**

This task group has identified and continues to update the ten most important topics in materials science and engineering for future economic, environmental, and social needs. A synopsis of the current challenges requiring materials innovations can be found at www.ceramics.org/WMRIF.

**About WMRIF and the authors**

Find more information about WMRIF at www.wmrif.org. Nicholas Barbosa, Stephen Freiman, and Michael Fasolka are all with NIST. Contact Freiman at steve.freiman@comcast.net.
Micromilling of uniform nanoparticles for space applications

By Curtis W. Hill and Lee Allen

Our laboratory at NASA Marshall Space Flight Center (Huntsville, Ala.) develops materials and processes for NASA’s exploration missions and the International Space Station. This involves developing and optimizing materials properties for very demanding applications in energy storage, power generation, and other advanced application areas.

The challenge of developing new materials and processes demands laboratory equipment with advanced capabilities. For instance, the ability to produce uniform nanoparticles is critical for our development of advanced ultracapacitors for energy storage, thermoelectric devices with high figure-of-merit, and materials for NASA’s Nuclear Thermal Propulsion system.

However, ceramic powder as-received from suppliers typically has a fairly wide range of particle sizes and is not consistent enough for our high-performance materials research. We have investigated and tested various milling machines and processes, including ball mills and vibratory mills. Although these techniques help reduce D50 particle size as well as improve particle size distribution, the resulting powders are still of insufficient quality for our demanding research.

We have been working with Fritsch’s Pulversette line of micromills for the past couple of years to develop much smaller and more uniform particles, as these micromills are capable of ultrafine grinding results down into the nanometer particle size range (Figure 1). The laboratory-size mills use smaller, very hard media to achieve extraordinary milling energy.

We use stainless-steel milling bowls lined with zirconia, although mills are available in several other materials and capacities depending upon the materials to be milled. The micromill uses rotation speeds of up to 1,100 rpm and an acceleration force of 95 g for a resulting energy application roughly 150% greater than that of classic planetary mills. This extraordinary milling energy results in more economical and efficient milling of particles, providing us with considerably finer grinding results in shorter times.

Although grinding media is available in different sizes and materials, we use hardened ZrO₂ media with diameters of 0.5–2.0 mm. We have reduced milling times by an order of magnitude when using these micromills compared with traditional planetary milling techniques.

Fritsch micromills have enhanced one NASA lab’s ability to develop optimized ceramic nanoparticulate materials for demanding research projects, including energy storage and thermoelectric device applications.

Figure 1. Fritsch’s Pulversette line of micromills are capable of ultrafine grinding results down into the nanometer particle size range.
of magnitude, and the resulting powders are much higher quality in terms of reduced particle sizes and improved particle size distribution. These high-quality ceramic powders have enabled several trajectories of research applications, a couple of which are highlighted below.

Ultracapacitor research

Our ultracapacitor development has focused on optimizing dielectric properties of perovskite ceramic powders for ultrahigh permittivity, low dielectric loss, and high dielectric breakdown. The resultant materials can be used as solid-state energy storage devices to replace electrochemical batteries, and they can be used as very high-voltage triggers for propulsion systems.

We have been developing processes to increase grain boundary characteristics of these materials to store charge and to significantly increase sintered density of the devices. The ability to micromill ceramic particles into low nanometer particle sizes, with corresponding improvement of D10 to D90 particle size distribution and particle distribution curve (Figure 2), has allowed us to optimize these processes, resulting in ultracapacitor devices with good sintered density resulting from the uniform particle size (Figure 3).

Thermoelectric research

We also develop thermoelectric materials that can be used for power generation subsystems on long-range missions and habitats. This research involves optimizing sintering of various doped ceramic nanopowders to increase electrical conductivity and reduce thermal conductivity.

Our ability to micromill powders with <50 nm particle sizes has enhanced these research efforts in allowing us to investigate the effect of substantially increased grain boundary surface area, and the effects of the various materials and dopant modifiers at these extremely small particle sizes. Figure 4 shows the microstructure of a sintered doped ZnO thermoelectric device.

About the authors

Curtis W. Hill is senior materials engineer with NASA Marshall Space Flight Center’s Engineering and Science Services and Skills Augmentation (ESSSA). Contact Hill at curtis.w.hill@nasa.gov. Lee Allen is materials engineer with NASA Marshall Space Flight Center. Contact Allen at lee.r.allen@nasa.gov. Marshall Space Flight Center is located on Redstone Arsenal in Huntsville, Ala. ■

Figure 2. Particle size distribution curve of as-received and milled barium titanate nanopowders.

Figure 3. Scanning electron micrograph of a sintered ultracapacitor device, showing good sintered density resulting from uniform particle size.

Figure 4. Scanning electron micrograph of sintered doped ZnO thermoelectric device.
National Science Foundation awards in the Ceramics Program starting in 2017

By Lynnette D. Madsen

The U.S. National Science Foundation is an independent federal agency that serves as a funding source for basic research conducted at America's colleges and universities. NSF has seven science and engineering research and education directorates. The Ceramics Program within the Division of Materials Research (DMR) is located in the Mathematical and Physical Sciences Directorate.

The Ceramics Program's mission is to support fundamental scientific research in ceramics (e.g., oxides, carbides, nitrides, and borides), glass-ceramics, inorganic glasses, ceramic-based composites, and inorganic carbon-based materials. The majority of the proposals received continue to be focused on oxides. The overall objective of the program is to increase fundamental understanding and to develop predictive capabilities for relating synthesis, processing, and microstructure of these materials to their properties and ultimate performance in various environments and applications. Discovery or creation of new ceramic materials is welcome as is the development of new experimental techniques or novel approaches.

At the end of August 2016, the Ceramics Program embarked on a pilot (alongside the Condensed Matter and Materials Theory Program, also in DMR) to permit proposals to be submitted at any time, with a few restrictions (NSF 16-597). This approach is not unique—it is used in the Geosciences, Engineering, and Biological Sciences Directorates at NSF and by some German and United Kingdom agencies. NSF undertook this change to better accommodate the schedules of principal investigators (PIs) and encourage submission of emerging ideas. In addition, NSF hopes the change will increase proposal quality and spread workflow (for reviewers and NSF staff) more evenly throughout the year. Additionally, PIs submitting to the Ceramics Program must suggest reviewers, and annual budget requests cannot exceed $160,000.

During fiscal year (FY) 2017, the number of full proposals received by the Ceramics Program dropped to below 80—in contrast to the past decade, when the program received 110 to nearly 160 proposals annually. Supplemental proposal requests to support new international collaborations or the addition of veteran and underrepresented minority graduate students to projects (through MPS-GRSV: NSF 15-024 and AGEP-GRS: NSF 16-125) slightly increased. Although the Ceramics Program has funded Career-Life Balance supplements (for leaves of absence for dependent care responsibilities) in the past, no requests were received during FY 2017. Supplemental proposals are best submitted in February. PIs should bear in mind that full proposal submissions to NSF are best made 9–12 months before the funds are needed, to allow time...
for review and award processes and to circumvent the non-award zone (August–September due to FY cycles).

In FY 2017, the Ceramics Program recommended support for 19 awards, 13 supplemental awards, two workshops/conferences, and cofunding of a Solid-State and Materials Research project. The awards are listed in Table 1; more information on any NSF award is available by adding the 7-digit award number to the end of www.nsf.gov/awardsearch/showAward?AWD_ID= or by searching the NSF awards database. Additional ceramics research is supported through centers, group grants, and other programs focused on one or two investigators (e.g., in the Engineering Directorate).

FY 2018 began on October 1, 2017—the first awards are likely to appear in late winter or early spring.

At any given time, a map or list of active awards can be generated near the bottom of the Ceramics Program homepage at www.nsf.gov/funding/pgm_summ.jsp?pims_id=5352.

About the author
Lynnette D. Madsen has been the program director, Ceramics, at NSF since 2000. Contact her at Imadsen@nsf.gov.

Table 1. NSF Ceramics Program awards made during FY 2017

<table>
<thead>
<tr>
<th>Title (award no.)</th>
<th>Principal investigator (PI), organization; co-PIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 Professional Development Workshop in Ceramics (1734055)</td>
<td>Geoff Brennecke, Colorado School of Mines</td>
</tr>
<tr>
<td>Conference support for the Fourteenth International Meeting on Ferroelectricity (1742945)</td>
<td>Amar Bhalla, University of Texas at San Antonio; co-PI: Ruyan Guo</td>
</tr>
<tr>
<td>CAREER: Interfacial transformations in ceramic ion conductors for solid-state batteries (1652471)</td>
<td>Matthew McDowell, Georgia Tech Research Corporation</td>
</tr>
<tr>
<td>CAREER: Towards engineering electronic defects in inorganic luminescent materials (1653016)</td>
<td>Luiz Jacobsohn, Clemson University</td>
</tr>
<tr>
<td>CAREER: Enhanced ferroelastic toughening in electroceramic composites through microstructural coupling (1654182)</td>
<td>Jessica Krogstad, University of Illinois at Urbana-Champaign</td>
</tr>
<tr>
<td>GOALI: Fundamental investigations of nucleation processes in silicate liquids and glasses with a goal of developing predictive models for glass formation and crystallization (1720296)</td>
<td>Kenneth Kelton, Washington University; co-PI: Randall Youngman; former co-PI: John Mauro</td>
</tr>
<tr>
<td>NSF/DMR-BSF: Ceramic electrode/electrolyte interface fundamentals in all solid state Li-ion batteries (1794763)</td>
<td>R. Edwin Garcia, Purdue University; co-PI: Lia Stanciu</td>
</tr>
<tr>
<td>Design of ceramics with isotropic superionic conductivity (1708749) (Solid State &amp; Materials Chemistry lead; Ceramics secondary)</td>
<td>Peter Khalilah, SUNY at Stony Brook</td>
</tr>
<tr>
<td>Nanofiber-based ceramic structures: The roles of initial phases and microarchitecture (1708600)</td>
<td>Andrei Stanishevsky, University of Alabama at Birmingham</td>
</tr>
<tr>
<td>Beyond binary: Understanding multi-state stability in ferroelectrics (1708615)</td>
<td>Lane Martin, University of California-Berkeley</td>
</tr>
<tr>
<td>Surface-based point defect manipulation in semiconducting oxides (1709927)</td>
<td>Edmund Seebauer, University of Illinois at Urbana-Champaign; co-PI: Efthimios Galiotis</td>
</tr>
<tr>
<td>Metal-insulator transitions in 2D and 3D refractory nitrides (1712752)</td>
<td>Daniel Gall, Rensselaer Polytechnic Institute</td>
</tr>
<tr>
<td>Surface stress relaxation: Science and effects on glass properties (1713670)</td>
<td>Minoru Tomozawa, Rensselaer Polytechnic Institute; co-PI: Thierry Blanchet</td>
</tr>
<tr>
<td>Ultrasonic assisted cold sintering: Kinetics of densification and grain growth study in binary oxide ceramics (1728634)</td>
<td>Clive Randall, Pennsylvania State University</td>
</tr>
<tr>
<td>Direct conversion of carbon into Q-carbon and diamond and fabrication of novel nanostructures (1735695)</td>
<td>Jagdish Narayan, North Carolina State University</td>
</tr>
<tr>
<td>Fundamental study of ordered MXenes and their defects (1740795)</td>
<td>Michel W. Barsoum, Drexel University; co-PI: Yury Gogotsi</td>
</tr>
<tr>
<td>Understanding and controlling defects, disorder and electronic transport in high mobility perovskite oxides (1741801)</td>
<td>Bharat Jalan, University of Minnesota-Twin Cities</td>
</tr>
<tr>
<td>Intrinsic properties of zirconium carbide ceramics (1742086)</td>
<td>William Fahrenholtz, Missouri University of Science and Technology; co-PIs: Joseph Graham, Gregory Hillmas</td>
</tr>
<tr>
<td>Electrochemically-induced fracture of ionic conductors: Electrolyzers and batteries (1742696)</td>
<td>Anil Virkar, University of Utah</td>
</tr>
<tr>
<td>Highly thermally conductive and mechanically strong graphene fibers: From molecular orientation to macroscopic ordering (1742806)</td>
<td>Jie Lian, Rensselaer Polytechnic Institute</td>
</tr>
<tr>
<td>Electron-rich oxide surfaces (1742807)</td>
<td>Michele Pavanello, Rutgers University Newark; co-PI: Huixin He</td>
</tr>
<tr>
<td>Effect of doping and nanostructuring on properties of perovskite oxide catalysts for oxygen evolution (1742828)</td>
<td>Meilin Liu, Georgia Tech Research Corporation</td>
</tr>
</tbody>
</table>
TUESDAY, MAY 1, 2018

PLENARY
10:20 a.m. Welcome address
10:30 a.m. Leadership Panel: Forecasting the Future of Advanced Ceramic Materials
Noon Lunch

TRACK 1: MATERIALS MARKETPLACE
1 p.m. Mapping the Materials Market: Outlining Availability, Cost and Quality of Raw Material Supply
2:15 p.m. Break & industry trails
2:45 p.m. Industry Update—Reviewing the Status of Ceramic Matrix Composites (CMCs) Production and Application

TRACK 2: SLURRY PREPARATION, POWDER DISPERSION, PARTICLE SIZE DISTRIBUTION, AND RHEOLOGY
1 p.m. Controlling Viscosity, Density, and Particle Size Distribution of Ceramic Slurry to Optimize Rheology in Ceramic Processing
2:15 p.m. Break & industry trails
2:45 p.m. Reviewing the Function of Polymeric Additives in Conventional Processing and Additive Manufacturing of Ceramics to Optimize Structure of the Final Part

WEDNESDAY, MAY 2, 2018

TRACK 1: CERAMIC MATERIAL PROPERTIES AND APPLICATION
10:30 a.m. Reviewing Innovations in Zirconia for Dental Applications
11:00 a.m. Examining the Application of Electroceramics
Noon Lunch
1 p.m. Industry Focus: Examining the Potential for Advanced Ceramic Materials in Battery Technology
2:15 p.m. Break & industry trails
2:45 p.m. Promoting the Adoption of Advanced Ceramic Materials as an Alternative to Traditional Materials
The fourth Ceramics Expo, North America’s leading annual supply chain exhibition for advanced ceramic and glass materials, manufacturing, and technologies, will take place at the Cleveland International Exposition Center in Ohio on May 1–3, 2018. More than 330 companies will present in the exhibit area; about 4,000 visitors are expected; and around 60 industry experts will speak at the concurrently held conference.

Ceramics Expo aims to champion an industry that continues to make its mark in the enrichment of an array of engineering, manufacturing, scientific, and research communities. “Visitors across the industrial spectrum—from experimental to full production environments—will be keen once more to see firsthand all the latest innovations, meet the movers and shakers, and find solutions to myriad manufacturing challenges,” exhibition director Danny Scott comments.

One fundamental goal driving efforts of the organizer, Smarter Shows, is to create a fully inclusive environment for representatives from all key end-user industries: automotive, space/aerospace, medical, electronics, energy, heat treatment, optical, and defense. Getting this right pays dividends, making this show a forum of choice. “We value the ability to meet so many of our customers in one location,” Robert Antolik, vice president of sales at Applied Test Systems (Butler, Pa.), says. “Our business is not just about sales—it is a relationship that we want to build on and develop. We look forward to meeting old and new customers each year, and appreciate the diversity of industry contacts that attend Ceramics Expo.”

Crucially, Ceramics Expo remains a totally free-to-attend opportunity. Not in the habit of letting grass grow under their feet, show organizers are rolling out brand new attractions this year to further enhance the visitor experience. These program additions embrace increased interaction, knowledge-sharing, and structured planning.

NEW THIS YEAR
The first is the Ceramic Industry BenchPress, a live polling experience that centers on the industry’s hottest topics. The format will combine expert analysis and a complimentary networking breakfast. This will provide a stimulating start to the final day of the event and offer a fantastic chance for...
attendees to network with fellow professionals, while benchmarking their industry knowledge against peers and counterparts.

The second is the Product Showcase—attendees get to see the latest developments in ceramic materials and technologies, explained to them via a series of 15-minute live demonstrations taking place at exhibitor stands throughout the hall. These presentations will highlight novel developments in the technical ceramics sector.

B2B Matching is the third concept added for 2018. This has been designed as a quick and easy solution for participants to meet new potential customers, suppliers, and cooperation partners—one-to-one—right at exhibitor booths. This platform is ideal for industry end-users to use their time at the event to meet with ceramic manufacturers to discuss product developments, design challenges, and potential advantages of using technical ceramics as a material solution. As Gregg Shemanski, president at Custom Processing Services (Reading, Pa.), summarizes, “It’s not giving customers what we have, it is understanding what they want.”

NANOMECHANICAL CHARACTERIZATION TOOLS
Keysight Technologies (Santa Rosa, Calif.) will show its G200 nanoindenter and the latest released high-temperature nanoindentation system, the laser heater. Nannan Tian, product manager of Nano Measurement Operations, explains, “At Ceramics Expo 2017, the researchers, lab managers, and quality assurance engineers who stopped at our booth were amazed by the advanced capabilities and flexibility of the G200. There were a lot of great discussions about how the G200 could help and accelerate their study and work. The outstanding features of the laser heater were really popular and attracted lots of attention from the attendees. Precise, ultra-fast control of temperature and minimized thermal drift with the G200 laser heater are key desirable features that people have been pursuing in the past decade. Therefore, we are expecting even more interest and quality leads from a broader audience this year.”

TRANSPARENT CERAMIC, ALTERNATIVE TO GLASS
CeramTec (Plochingen, Germany) will unveil its high-purity Perlucor ceramic material. Its extraordinary properties are what make Perlucor a game-changing material with near universal application potential. The material is a mechanically, chemically, thermally, and optically perfected solution for transparent applications in extreme conditions. The transparent ceramic is resistant to highly concentrated acids and lyes. With a relative transparency of more than 90%, Perlucor is an attractive alternative to glass when the latter reaches its limits in specific applications. The material is distinguished by its pronounced strength and wear resistance and exhibits three to four times the hardness and strength of conventional glass. It has a Mohs hardness of 9, surpassed only by diamond or ruby. This makes Perlucor particularly resistant to mechanical stress and scratches and prevents Perlucor panes from clouding or corroding. The technical ceramic also has three times the thermal resistance of glass, enabling it to be used in temperatures of up to 1,600°C (2,910°F). A high refractive index of 1.72 makes it possible to miniaturize optical lenses and elements.

3-D PRINTING CONTINUES UPWARD TREND
Saint-Gobain High Performance Refractories (Worcester, Mass.) will showcase products from its recent acquisition, Pennsylvania-based Spin-Works™ International Corporation. Spin-Works is an innovative producer of highly complex ceramic burner components. Designed for end-users, a SpyroCor™ Insett is placed in a radiant tube to capture and re-radiate exhaust gas energy into furnaces. Spin-Works also partners with furnace and burner system manufacturers to integrate its patented Helical Channel Heat Exchanger into burner systems for even greater performance. Both products significantly improve the efficiency of industrial heating processes and deliver double-digit energy savings and nitrogen oxide emission reductions. The innovative AmaSiC-3D™ manufacturing platform achieves savings by enabling geometries previously impossible with ceramic materials.

Meanwhile, giving ceramics manufacturers the freedom to create ceramic parts with the most complex geometries and without compromising quality, additive manufacturing company XJet (Rehovot, Israel) will showcase its breakthrough NanoParticle jetting technology. Comprising the Carmel 1400 and Carmel 700 additive manufacturing systems, XJet’s Carmel product portfolio represents a transformation in the ceramic additive manufacturing industry by printing ultrafine layers of NanoParticle ‘inks’. The technology uses nanolevel dispersion to simultaneously print build and support materials, achieving freedom of design for the most complex shapes. Ceramic parts produced on this system enjoy superfine details, smooth surfaces, and high accuracy due to the unique printing process. The whole process offers operational advantages as it is productive, efficient, safe, and simple to use. Visitors at Ceramics Expo can meet the XJet team, feel the quality of samples, and find out more about XJet’s additive manufacturing technology and its first North American customer installation.

PULSE-JET FILTER CLEANING
Efficient removal of ceramic dust and other particulate matter is vital, and Models 40008, 40012, and 40013 compressed-air powered vacuums from VAC-U-MAX (Belleville, N.J.) are the first-line offerings for Class II, Division 2 environments due to their bumper-to-bumper grounded and bonded design and reasonable cost and availability. The vacuums meet NFPA 77 requirements for grounding and bonding and also meet the definition of an ‘intrinsically-safe system’. These air-powered vacuums do not use electricity and do not generate any heat from operation. They are presented as a complete system, comprising vacuum cover, drum, dolly, vacuum hose and cleaning tools, compressed air hose with quick-disconnect fittings, and polybag drum liners—the customer supplies no components.
Anyone interested in participating should contact the Ceramics Expo team as soon as possible.

The ability to extract maximum value from time spent at the expo is paramount to the introduction of Innovation Trail—a concept that will allow visitors to be guided around the expo area, physically demonstrating which companies are at the forefront of R&D, developing cutting-edge materials, technologies, and solutions for a range of ceramic applications. These are all designed to smooth the way and help everyone meet their prime business objectives.

Not only are these new features taking the event forward in terms of experience and value, but the exhibit profile promises to be broader than ever. “As part of our important work over the past year, we have cast the net wider, and we feel we have successfully strengthened our value proposition while increasing global resonance,” Scott says. “We have a larger contingent from China, particularly strong in technical ceramic raw materials and finished components, and we also welcome new companies from Europe, South-East Asia, India, Japan, and Korea.”

Below, we take a look at just a few of the developments to be featured in May 2018.

REACHING NEW HEIGHTS IN THE AMERICAS

The Nutec Bickley Ceramics Division (Santa Catarina, Mexico) has continued its development of kilns for all ceramic sectors, but the last few years have seen highly successful outcomes for sanitaryware tunnel and shuttle kilns—especially in the American markets—and these currently account for almost 50% of turnover. These kilns offer low fuel consumption, great temperature uniformity, and improved yields. New shuttle and tunnel kilns have also been successfully installed in the ceramic colors field, providing users with flexibility while significantly improving fuel consumption. Users have also seen improvements in temperature uniformity and product consistency with continued use of the company’s advanced pulse firing technology. Technical ceramic kilns have always been a core strength for Nutec Bickley—the company again ued its development of a wide variety of shapes and sizes. This offers the customer an attractive mix of design flexibility and high-temperature capability. Cordierite products are fired close to 1,400°C (2,550°F) to give a material that is volume-stable in service (temperatures up to 1,300°C/2,370°F). Products are thermally and electrically insulating and are often used as lead-in tubes or as supports for wire heating coils. The ever-widening IPS portfolio finds applications across many end-use industries, so the display will also feature recently introduced silicon carbide tubes, beams, and rollers; small burner nozzles; and cast setters.

COMBINED REVENUES EXCEEDING $63B

The breadth and depth of the overall technical ceramic offering in Cleveland is impressive, with recognized leaders—such as Saint-Gobain, Corning, Kyocera, Schott, CoorsTek, Morgan Advanced Materials, CeramTec, Blasch, Materion, Ceramco, McDanel, Bakony, POCO, and Shovia Denka—already all committed to exhibiting. These companies are together responsible for revenues in excess of $63 billion.

The discussions set to take place with these preeminent manufacturers will surely lead to an ever-expanding range of applications for this extraordinary family of materials. “We expect to see continued acceptance and use of ceramics in many growing markets—particularly in alternative energy (solar, wind, and fuel cells), medical, automotive, aerospace, and water treatment businesses; and second-tier companies supplying those businesses,” comments John Dodsworth, vice president of Materials Technology, McDanel Advanced Ceramic Technologies (Beaver Falls, Pa.). Greg Sherman at Custom Processing identifies other growth centers, too. “A key trend in the next five years will be the demand for smaller and smaller particles with higher and higher purities. These trends also showcase themselves in revolutionizing the additive manufacturing arena, the battery industry, as well as the medical industry.”

CONFERENCE

Held concurrently with the expo, and also free-to-attend, show organizers present the 4th Annual Conference @ Ceramics Expo: Enabling the Adoption of Advanced Ceramic Materials & Processing Technologies.

This well established and highly valued series of presentations provides a great opportunity to hear about the latest advancements in ceramic materials, technologies, and manufacturing and to gain an in-depth view of the ceramic materials markets, the latest innovations and R&D for commercialization, manufacturing, and technological solutions, plus a look at industry challenges and future requirements.

The conference is specially designed for engineers and decision makers from original equipment manufacturers and first-tiers in all industries that rely on technical ceramics to drive manufacturing excellence. To create the most accessible event, twin-track forums are positioned right alongside the exhibit area—enabling delegates to choose exactly which sessions to attend and to be back amongst the booths afterwards in a matter of seconds.

The roster of speakers features leading expert voices from manufacturing, engineering design, project management, research, development, and academia. This includes senior personnel from the likes of Nabaltex, Morgan Advanced Materials, Corning, Toshiba, GE Aviation, HRL Labs, Lear Corp, Aerojet Rocketdyne, Medtronic, U.S. Naval Research Lab, and—for the very first time—CoorsTek, Kyocera, Schott, and Lucideon.

The conference begins at 10:30 a.m. on May 1 with a traditional plenary session keynote address that will offer a realistic picture of the potential and barriers to success for the ceramic industry within the next 5–20 years. The aim will be to share insights on the status of advanced ceramic and glass sectors and to review areas of growth and what is needed to achieve these goals and enable technologies of the future. This will be followed by a panel discussion among ceramic manufacturers, end users, and material suppliers, who will provide their visions on key issues driving the industry.
The Conference on Electronic and Advanced Materials wrapped up on Friday, January 19 in Orlando, Fla., after three days of stimulating sessions. The weather cooperated and was unusually chilly, which safeguarded attendees from sunshine distraction!

Nearly 345 people from about 22 countries, including about 85 students, attended the conference, coorganized by ACerS Electronics and Basic Science Divisions.

Both plenary sessions were exceptional and set the stage for an unexpected theme around the idea of making peace—if not friends—with defects.

Roger de Souza, professor at RWTH Aachen University (Germany), opened the conference by suggesting that we need to learn to live with and take advantage of defects in crystalline structures.

Later, in a breakout session, Lane Martin, professor at University of California, Berkeley, and coauthor of the cover story in last month’s ACerS Bulletin, suggested a new appreciation of defects is emerging.

This theme emerged again in Thursday’s plenary session talk by Judith MacManus-Driscoll, professor at University of Cambridge (England), who discussed application opportunities for oxide thin-film devices and the challenges to overcome.

Pennsylvania State University professor Clive Randall and his group presented several talks on cold sintering.

Lenny Koh’s group at the University of Sheffield in England used an analytical modeling tool, SCEAnTi, to consider whether KNN is more environmentally damaging than PZT—which it was.

EAM continued its tradition of offering a tutorial session for graduate students, a host of networking receptions, poster session, and a conference banquet. Wrapping up the conference was the Failure Symposium. The “lessons learned” were entertaining but genuine reminders that success comes with difficulty, even for the most successful researchers in the field.

ICACC 2018—Never a dull moment between sessions, networking, and government shutdown

ICACC in Daytona Beach, Fla., never disappoints in terms of quality, size, and the unexpected. Usually, weather serves as the wildcard, but this year it was the shutdown of the United States federal government. The three-day shutdown overlapped with the first day of the conference, forcing federal employees to cancel their travel plans. By Tuesday the government was open again, and many federal government employees resurrected plans and came to Florida.

More than 1,100 attendees came, with more than half coming from 37 countries outside the United States. ICACC18 offered about 1,000 presentations in 17 symposia, three focus sessions, two poster sessions, and two special symposia—the Global Young Investigators Forum and the Mrityunjay Singh Honorary Symposium.

ACerS Engineering Ceramics Division (ECD) organizes the conference and also holds its annual business meeting at ICACC. ECD included many opportunities for students to present their work, engage with peers, and learn more about their chosen professions.

“The number of young people is increasing,” conference program chair Manabu Fukushi-ma says. “A young woman from Nigeria, attending for the first time, told us that coming to the conference was her dream.”

ECD helped support her trip to participate in the Global Young Investigators Forum.

ICACC opened Monday with its traditional plenary session with ECD’s Mueller Award lecture, Bridge Builder Award, and two plenary talks. ACerS past president and Distinguished Life Member, George Wicks, delivered the Mueller Award lecture on the topic of porous wall hollow glass microspheres.

Yanchun Zhou reported on his group’s work on MAX phases and some interesting new compositions based on borides instead of carbides.

Plenary speaker Frank Muecklich’s talk focused on deep learning and “fully convolutional neural networks” to interpret microstructure, especially in three dimensions.

Least technical but most provocative was a talk by Oxford professor Richard Brooks on research motivations, of which he suggests three: catastrophe avoidance, curiosity/adventure, and engineering/technology.

Much effort goes into making ICACC conducive to making friends. Events included networking events for new ACerS members, young professionals, Corporate Partners, and students.

The accompanying exposition provided a forum for 32 exhibitors to present their products and services and for the conference poster session. An interesting mix of familiar companies as well as newcomers exhibited.

Mark your calendars for next year’s ICACC, January 27–February 1, 2019, in Daytona Beach. And let’s hope we can avoid stormy weather and politics!

2018 GLASS & OPTICAL MATERIALS DIVISION ANNUAL MEETING

May 20 – 24, 2018 | Hilton Palacio del Rio | San Antonio, Texas

The Glass & Optical Materials Division (GOMD) builds its annual meeting around emerging trends in glass science and technology. Join technical leaders from industry, national laboratories, and academia May 20–24, 2018, in San Antonio, Texas, to share your research and lessons learned with colleagues from around the world.

TECHNICAL PROGRAM

S1: Fundamentals of the glassy state
- Session 1: Glass formation and structural relaxation
- Session 2: Crystallization in glass and its application
- Session 3: Structural characterizations of glasses
- Session 4: Topology and rigidity
- Session 5: Computer simulation and predictive modeling of glasses
- Session 6: Mechanical properties of glasses
- Session 7: Non-oxide glasses
- Session 8: Glass under extreme conditions

S2: Glasses in healthcare—fundamentals and application

S3: Optical and electronic materials and devices — fundamentals and applications
- Session 1: Laser interactions with glasses
- Session 2: Charge and energy transport in disordered materials
- Session 3: Optical fibers and waveguides
- Session 4: Glass-based optical devices
- Session 5: Optical ceramics and glass-ceramics
- Session 6: Glasses and glass-ceramics in detector applications
- Session 7: Rare-earth and transition metal-doped glasses and ceramics for photonic applications

S4: Glass technology and cross-cutting topics
- Session 1: Glass surfaces and functional coatings
- Session 2: Sol-gel processing of glasses and ceramic materials
- Session 3: Challenges in glass manufacturing
- Session 4: Waste immobilization—waste form development: processing and performance
- Session 5: Optical fabrication science and technology

S5: Dawn of the Glass Age: New horizons in glass science, engineering, and applications
- Symposium to honor Professor L. David Pye—Glass scholar and ambassador

For more information and to register, go to www.ceramics.org/gomd2018

SPECIAL THANKS TO OUR CONFERENCE SPONSORS

HOTEL INFORMATION

Hilton Palacio Del Rio
Ph: 210-270-0752 | Fax: 210-270-0761
200 S Alamo | San Antonio, TX 78205

Based on availability:
- Single/double $189 plus tax
- Triple/quad $209 plus tax
- Prevailing government rate

Reserve your room by April 24, 2018, to secure the negotiated conference rate.

www.ceramics.org/gomd2018
If you are involved in the structural clay industry—and that includes manufacturing, sales and marketing, consultants, and material or equipment suppliers—then join us June 6–8, 2018, at the Hilton Columbia Center in Columbia, S.C. This is the second year for combined meetings with ACerS Structural Clay Products, its Southwest Section, and the National Brick Research Center that better meet the needs of the structural clay industry.

The event will feature meetings, two technical sessions, a suppliers’ mixer, and two plant tours at Carolina Ceramics in Columbia, S.C., and at Meridian Brick.

www.ceramics.org/scpd2018

Registration is now open!

MATERIALS CHALLENGES IN ALTERNATIVE AND RENEWABLE ENERGY (MCARE 2018)

August 20 – 23, 2018
Sheraton Vancouver Wall Centre Hotel | Vancouver, BC, Canada

TECHNICAL PROGRAM

– MATERIALS FOR SOLAR FUEL PRODUCTION AND APPLICATIONS
– ADVANCED ELECTROCHEMICAL MATERIALS FOR ENERGY STORAGE
– MATERIALS CHALLENGES IN PEROVSKITE AND NEXT GENERATION SOLAR CELLS
– FERROELECTRICS AND MULTIFERROICS FOR ENERGY GENERATION, CONVERSION, AND STORAGE
– MATERIALS CHALLENGES IN DIRECT THERMAL-TO-ELECTRICAL ENERGY CONVERSION AND THERMAL ENERGY HARNESSING FOR EFFICIENT INNOVATIVE APPLICATIONS
– MATERIALS FOR SPECTRAL ENERGY CONVERSION
– ADVANCED MATERIALS FOR SOLID OXIDE FUEL CELLS AND HIGH TEMPERATURE ELECTROLYSIS
– LIFECYCLE CONSIDERATIONS FOR ENERGY MATERIALS
– CRITICAL MATERIALS FOR ENERGY
– MATERIALS AND PROCESS CHALLENGES FOR SUSTAINABLE NUCLEAR ENERGY
– SUSTAINABLE, ECO-FRIENDLY ADVANCED MATERIALS AND NANODEVICES
– YOUNG SCIENTISTS FORUM ON FUTURE ENERGY MATERIALS AND DEVICES
– SYMPOSIUM ON MATERIALS FOR SUPER ULTRA LOW ENERGY AND EMISSION VEHICLE

www.ceramics.org/mcare2018
new products

Composite materials handbook

SAE International has a new book that offers technical guidance and properties on ceramic matrix composite material systems. “Composite Materials Handbook Volume 5: Ceramic Matrix Composites” is the fifth volume of the six-volume Composite Materials Handbook. This book helps standardize engineering methodologies related to testing, data reduction, and reporting of property data for current and emerging composite materials. Selected guidance includes material selection, processing, characterization, testing, data reduction, design, analysis, quality control, and more.

SAE International (Warrendale, Pa.)
http://books.sae.org/r-426
888-875-3976

World’s smallest multilayer ceramic capacitors

Kyocera Corporation has developed new multilayer ceramic capacitors (MLCCs) for mobile device applications in the world’s smallest case sizes. Measuring just 0.25 x 0.125 x 0.125 mm, the new CM01 series reduce space requirements by 60% in surface area and 75% in total volume as compared to conventional products. The new MLCCs feature tight tolerances on key specifications, with an industry-leading Q value that is 20% higher than conventional MLCCs to meet the rising demand for highly efficient power amplifier modules.

Kyocera Corporation (Kyoto, Japan)
+81-(0)75-604-3416
http://global.kyocera.com

Specialty cordierite ceramics

IPS Ceramics USA will launch two new cordierite ceramic product lines at Ceramics Expo 2018, May 1–3, 2018, in Cleveland, Ohio. Cordierite ceramics have exceptional resistance to thermal shock and are often used for components that are subject to rapid thermal cycling. IPS will offer porous cordierite (C520), which is best for thermal shock resistance and use at higher temperatures, and non-porous cordierite (C410), which is stronger and impermeable. The manufacturing processes allow production of a wide variety of shapes and sizes, offering customers an attractive mix of design flexibility and high-temperature capability.

IPS Ceramics USA Ltd.
(Cornelius, N.C.)
704-897-3775
www.ipsceramics.com

Glass manufacturing industry report


Glass Manufacturing Industry Council (Columbus, Ohio)
614-818-9423
www.gmic.org/glass-manufacturing-industry-report

Glass manufacturing industry report


Glass Manufacturing Industry Council (Columbus, Ohio)
614-818-9423
www.gmic.org/glass-manufacturing-industry-report

Rotary batch mixer

A new Munson rotary batch mixer with integral lump breaker provides inline deagglomeration of compacted bulk materials before blending batches gently with total uniformity in one to three minutes. As the mixer’s horizontal drum rotates, proprietary mixing flights tumble, turn, cut, and fold the material, minimizing or eliminating degradation. Internal flights lift and direct the entire batch into the stationary discharge spout for evacuation with no residual material, eliminating waste and improving product quality while facilitating rapid, thorough cleaning.

Munson Machinery Company Inc.
(Utica, N.Y.)
800-944-6644
www.munsonmachinery.com

Safety light curtain

Ross now offers protective light curtains that provide automatic safety shutoff of tumble blenders whenever an operator crosses a defined security boundary. Tumble blenders provide gentle agitation and are ideal blenders for batches requiring dispersion of extremely small minor components and low shear intensity. Due to the nature of the rotating mix chamber, a safety railing is supplied standard on all Ross tumble blenders. The addition of optional light curtains further improves operator safety.

Charles Ross & Son Co.
(Hauppauge, N.Y.)
800-243-ROSS
www.mixers.com

Composite materials handbook

SAE International has a new book that offers technical guidance and properties on ceramic matrix composite material systems. “Composite Materials Handbook Volume 5: Ceramic Matrix Composites” is the fifth volume of the six-volume Composite Materials Handbook. This book helps standardize engineering methodologies related to testing, data reduction, and reporting of property data for current and emerging composite materials. Selected guidance includes material selection, processing, characterization, testing, data reduction, design, analysis, quality control, and more.

SAE International (Warrendale, Pa.)
http://books.sae.org/r-426
888-875-3976
Calendar of events

March 2018
21–22 54th Annual St. Louis Section/Refractory Ceramics Division Symposium on Refractories – Hilton St. Louis Airport Hotel, St. Louis, Mo.; www.bit.ly/54thRCDSymposium

April 2018
10–13 ✪ ceramic 2018 – Munich Germany; www.ceramic 2018.com
18–20 ✪ CICM 2018: IMAPS/ACerS 14th Int’l Conference and Exhibition on Ceramic Interconnect and Ceramic Microsystems Technologies, University of Aveiro, Aveiro, Portugal; www.imaps.org

May 2018
1–3 ✪ 4th Ceramics Expo – I-X Center, Cleveland, Ohio; www.ceramicsexpousa.com

June 2018
4–14 14th Int’l Ceramics Congress and the 8th Forum on New Materials – Perugia, Italy; http://2018.cimtec-congress.org
5–8 ✪ ACerS Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Columbia, S.C.; www.bit.ly/2018SCPDmeeting
11–12 ✪ 9th Advances in Cement-Based Materials – Pennsylvania State University, University Park, Pa.; www.ceramics.org
17–21 ✪ ICC7: 7th Int’l Congress on Ceramics – Hotel Recanto Cataratas, Foz do Iguaçu, Brazil; www.icc7.com.br

July 2018

August 2018

September 2018

October 2018
8–12 ✪ ic-cmp5: 5th Int’l Conference on Competitive Materials and Technology Processes – Hunguest Hotel Palota, Miskolc, Hungary; http://www.ic-cmp5.eu
14–18 ✪ MS&T18, combined with ACerS 120th Annual Meeting – Greater Columbus Convention Center, Columbus, Ohio; www.matscitech.org

November 2018
5–8 ✪ 79th Conference on Glass Problems – Greater Columbus Convention Center, Columbus, Ohio; www.glassproblemsconference.org

January 2019

Dates in RED denote new entry in this issue.
Entries in BLUE denote ACerS events.
IMO denotes meetings that ACerS cosponsors, endorses, or otherwise cooperates in organizing.
✯ denotes Corporate partner
SOMETHING ABOUT THE DOCUMENT

The document contains various advertisements and listings for different services and products, such as high-temperature vacuum furnaces, aftermarket services, and laboratory testing services.

1. **Thermal Analysis Materials Testing**
   - Diatometry
   - Filing Facilities
   - Custom Testing
   - Glass Testing
   - DTA/TGA
   - Grinding
   - Refractories Testing
   - Clay testing

2. **Spectrochemical Laboratories**
   - Complete Elemental Analysis
   - ISO 17025 Accredited
   - Ceramics & Glass - Refractories & Slag
   - Metals & Alloys
   - XRF - ICP - GFAA - CL & C-S
   - OES, SEM, TGA
   - spectrochemicalme.com | 724-334-4140

3. **GELLER MICROANALYTICAL LABORATORY, INC.**
   - Analytical Services & NIST Traceable Magnification Standards
   - SEM/X-ray, Electron Microprobe, Surface Analysis (Auger), Metallography, Particle Size Counting, and Optical Microscopy
   - for Ceramics and Composite Materials
   - Specializing in quantitative analysis of boron, carbon, nitrogen, oxygen, etc. in micrometer sized areas.
   - Elemental mapping, diffusion studies, failure analysis, reverse engineering, and phase area determinations.
   - ISO 9001 & 17025 Certified
   - Put our years of experience to work on your specimens!
   - 426 Boston St. Topsfield, MA 01983
   - Tel: 978-887-7000  Fax: 978-887-6671
   - www.gellercmos.com  Email: sales@gellermicrom.com

4. **SEM • COM COMPANY, INC.**
   - Glass & Glass Ceramic Manufacturing
   - ISO 9001:2008 CERTIFIED
   - Melting to 1675°C: grams to tons
   - Flake, frit, rolled marble & powder forms
   - Redrawn & updrawn tubing or rod
   - Cast plates, billets & boules
   - Glass formula & properties development
   - Solid Si dopant source wafers in assoc. with Techramics, Ltd.
   - 1040 N. Westwood Ave.
   - Toledo, OH 43607
   - Ph: 419-537-8813
   - Fax: 419-537-7054
   - e-mail: sem-com@sem-com.com
   - web site: www.sem-com.com

5. **SOMETHING ABOUT THE DOCUMENT**

- **BUYING & SELLING**
  - Compactors & Presses
  - Isostatic Presses
  - Piston Extruders
  - Mixers & Blenders
  - Jar Mills
  - Pebble Mills
  - Lab Equipment

- **Aftermarket Services**
  - Spare Parts and Field Service Installation
  - Vacuum Leak Testing and Repair
  - Preventative Maintenance
  - Used and Rebuilt Furnaces
  - 55 Northeastern Blvd. Nashua, NH 03062
  - Ph: 603-595-7231  Fax: 614-794-5834
  - sales@centorr.com
  - www.centorr.com
  - Alan Fostier - afostier@centorr.com
  - Dan Demers - ddemers@centorr.com

- **Custom High-Temperature Vacuum Furnaces**

- **Used Ceramic Machinery**
   - Sell and buy used ceramic machinery and process lines.
   - Contact: Mona Thiel
   - 614-794-5834
   - mthiel@ceramics.org

- **ADVERTISE YOUR SERVICES HERE**

- **SOMETHING ABOUT THE DOCUMENT**

- **Dilatometry**
  - Thermal Gradients
  - Firing Facilities
  - Glass Testing
  - DTA/TGA
  - ASTM Testing
  - Refractories Creep
  - Clay testing

- **SOMETHING ABOUT THE DOCUMENT**
Call for Book Authors and Editors

CerS-Wiley seeks new authors or volume editors for textbooks, handbooks, or reference books on ceramics and glass related topics. Examples topics include, and are not limited to: oxides, non-oxides, composites, environmental and energy issues; fuel cells; ceramic armor; nanotechnology; glass and optical materials; electronic/functional ceramic technology and applications; advanced ceramic materials; bioceramics; ceramic engineering, manufacturing, processing, and usage; ceramic design and properties; and health and safety.

Authors and editors of new, original books receive royalties on worldwide sales of their books, while editors of proceedings volumes receive complimentary copies of their books. In addition, all authors and editors are entitled to a discount on Wiley books.

To learn more or to share an idea, please contact:

Michael Leventhal
Sponsoring Editor
John Wiley and Sons, Inc.
111 River Street
Hoboken, NJ 07030-5774
Tel: 201-748-6980
Fax: 201-748-8888
E-mail: mleventhal@wiley.com

Greg Geiger
Technical Content Manager
The American Ceramic Society
600 N. Cleveland Ave., Suite 210
Westerville, Ohio 43082
Tel: 614-794-5858
Fax: 614-794-5882
E-mail: ggeiger@ceramics.org
Glassy hillforts: Geoscience or materials science? Past or future?

A hillfort is a type of prehistoric fortification consisting of one or more lines of earthwork (fort) on a raised area of land (hill), which was used to defend settlements in Bronze and Iron Age Europe. The defensive earthwork structure contains ramparts made of earth, stone, and/or wood, with an external ditch. Vitrified hillforts refer to those composed of stone ramparts bound together by a glassy material produced by heating rock, which partially melts and then vitrifies upon rapid cooling.

But how could rock be transformed into glass using prehistoric technology, when mineralogy indicates that partial melting temperatures exceed 1,100°C? Questions like these continue to mystify archaeologists and geoscientists. While some researchers think that vitrification of pre-existing hillforts occurred due to natural events (e.g., lightning) or enemy attack, others believe it was done deliberately during construction for defensive reasons.

In recent years, study of vitrified hillforts has attracted much interest amongst materials scientists, particularly within the nuclear waste management community. Waste vitrification is a reliable and proven technology to immobilize wastes. It typically involves mixing a waste component with glass-forming materials, and melting and vitrifying the mixture into a stable glass form.

The integrity of such waste glasses must endure for thousands of years to avoid significant environmental and human health impacts. Therefore, it is problematic to justify such containment based solely on short-term laboratory experiments. Because hillfort glasses have been exposed to natural events and weathering for thousands of years, however, they are particularly important analogues for nuclear waste glasses due to their composition, shallow burial, and known age.

Beginning in 2016, materials scientists from Pacific Northwest National Laboratory (Richland, Wash.) and Washington State University (Pullman, Wash.), supported by the U.S. Department of Energy’s Office of River Protection, began looking into Broborg hillfort glasses located near Uppsala, Sweden, as analogues for aged nuclear glass. For a few decades, archaeologists and geologists have been studying the Broborg site, which is thought to have been built around 500 CE via constructive and intentional vitrification.

I was fortunate to be involved in this collaborative research at WSU. By using oxide precursors to replicate the same compositions as Broborg glasses, we found that these glasses require extremely high melting temperatures (>1,400°C) in ambient conditions—which would have been unachievable in antiquity. Instead, the melting temperature could have been lowered by controlling water content and/or providing a reducing atmosphere to control oxidation state of the melt. All evidence shows that ancient people were brilliant materials scientists!

Analyses also reveal extremely complex microstructures and chemistries of the vitrified rocks in different spots, such as evidence of fast cooling in the microstructures (i.e., dendritic growth of crystals). We found excess phosphorous and calcium-rich phases within the microstructure, suggesting the probability of using bone—whether from enemies or animals—to reduce melting temperatures.

Moreover, our results show that the presence of magnetic iron-bearing oxides within vitrified hillfort glasses makes them suitable for paleomagnetic measurements. Paleomagnetism includes measuring the remanent magnetization from the earth’s magnetic field recorded by vitrified rocks at the time of solidification. This will enable us to date the site within an accuracy of 50 years, which is significant for study of long-term degradation behavior of these natural glasses.

The ultimate goal of this ongoing research is to provide insight into long-term mechanisms of glass corrosion to ensure the durability of vitrified nuclear wastes and their environmental safety for future generations. Through this interdisciplinary work, I have the opportunity to collaborate with geoscientists to protect the planet from radioactive wastes—vitrified hillforts are a lesson learned from the past to improve the future.

Mostafa Ahmadzadeh is a Ph.D. candidate focusing on glass science in the Materials Science and Engineering program at Washington State University. With bachelor’s and master’s degrees in the same field, his past studies have involved varying types of research, from mechanical behaviors of metals to electrical and magnetic properties of ceramics. Ahmadzadeh is enthusiastic to learn the endless new aspects of materials science.
To read success stories from a range of industries or to register for a free pass today visit www.ceramicsexpousa.com

Advanced ceramics are solving material challenges right now across a myriad of applications

Why choose ceramics for your application?

- **Automotive**
  - Strong and lightweight
- **Energy**
  - Safe and reliable
- **Electronic/Electrical**
  - Good electrical properties
- **Medical**
  - Wear and corrosion resistant
- **Aerospace/Defense**
  - Withstands high temperatures

“It’s been a fantastic experience, I’ve learnt a lot and looking to go home and implement some things I’ve seen.”

Julien Mourou, Innovation, General Motors

May 1 – 3, 2018  Cleveland, OH, USA
A manufacturing and engineering event for advanced ceramic materials and technologies
Now Invent.™

Experience the Next Generation of Material Science Catalogs

As one of the world's first and largest manufacturers and distributors of nanoparticles & nanotubes, American Elements' re-launch of its 20 year old Catalog is worth noting. In it you will find essentially every nanoscale metal & chemical that nature and current technology allow. In fact quite a few materials have no known application and have yet to be fully explored.

But that's the whole idea!

*American Elements opens up a world of possibilities so you can Now Invent!*