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How ceramics and glass contribute to the $4.17T residential building market
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Right at home: How ceramics and glass contribute to the $4.17T residential building market

Ceramic and glass materials are integral to the construction of residential buildings—and to homes of the future.

by April Gocha and Lisa McDonald
Varistors: Armor for your circuits

As armor protects the wearer from weapons, varistors protect electrical circuits from high voltage and high currents. Learn about some of the current research being conducted to improve varistor production and performance, published in two ACerS journals.

Also see our ACerS journals...

Life cycle assessment of functional materials and devices: Opportunities, challenges, and current and future trends
By L. Smith, T. Ibn-Mohammed, L. Koh, and I. M. Reaney
Journal of the American Ceramic Society

New waste-based clinkers for the preparation of low-energy cements. A step forward toward circular economy
By S. Martinez Martínez, L. Pérez Villarejo, D. Elche Quesada, et al.
International Journal of Applied Ceramic Technology

Machine learning can predict setting behavior and strength evolution of hydrating cement systems
By T. Oey, S. Jones, J. W. Bullard, and G. Sant
Journal of the American Ceramic Society

Study of a quantitative method to evaluate the wear resistance of glazed tiles
International Journal of Applied Ceramic Technology
October 1 marked the official start of the United States fiscal year 2020 (FY20). Congress did not complete action on appropriations before the end of FY19 on September 30, so Congress passed a continuing resolution to fund the government through November 21; it was signed by President Trump on September 27.

One roadblock complicating appropriations was discretionary spending. In 2018, Congress and Trump enacted legislation to raise caps on discretionary programs by $80 billion (2018) and $85 billion (2019) for defense, and $63 billion (2018) and $68 billion (2019) for nondefense. For 2020, both defense and nondefense budgets caps would decrease by almost 10% from FY19 levels.

In August, Trump signed a two-year budget agreement that suspends the debt ceiling through July 2021 and increases defense and nondefense spending by $320 billion above the budget caps that would have taken effect. With this new agreement, appropriations advanced quickly.

In the past few weeks, both the House and Senate finished releasing their proposals for FY20 (Table 1). In a trend consistent with recent fiscal years, Congress largely ignored suggested cuts to federal science programs requested by the White House. Instead, steady or increased funding was proposed in most cases.

A few highlights from the proposals:

**Department of Defense**

The Department of Defense’s Research, Development, Test, and Evaluation (RDT&E) budget is set to continue rising above its already record-high level. The White House requested to increase the budget from $96 billion to $104 billion. In contrast, the House proposed a 5% increase to $101 billion, while the Senate Appropriations Committee proposed a 9% increase to $105 billion.

Within RDT&E, the three early-stage “Science and Technology” accounts—Basic Research, Applied Research, and Advanced Technology Development—are generally in line for cuts, though the Senate is proposing an increase for Basic Research, which currently stands at $2.5 billion.

In their bills, the House and Senate propose to channel resources to various high-priority technology areas, such as hypersonic missiles, 5G telecommunications, directed energy weapons, and space capabilities. Senate appropriators emphasized these areas when advancing their legislation.

**National Science Foundation**

House and Senate appropriators rejected the White House’s request to shave 12% from the agency’s current budget of $8.1 billion. Instead, the Senate Appropriations Committee proposed a 3% overall increase to $8.3 billion while the House proposed a 7% increase to $8.6 billion.

Most of the additional resources would go toward research and education accounts, and fully funding major construction projects. Additionally, both the House and Senate reiterate language from last year’s legislation that NSF should use the “10 Big Ideas” as a “focusing tool” in allocating its budget. Descriptions for the Big Ideas can be seen at https://www.nsf.gov/news/special_reports/big_ideas.

**Department of Energy**

The White House requested to decrease DOE’s budget from $44.6 billion to $31.7 billion. Both the House and Senate rejected the request, proposing to increase the total budget to $46.4 billion and $48.9 billion, respectively.

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**Table 1. FY20 budget proposals ($ in millions)**

<table>
<thead>
<tr>
<th></th>
<th>DOD S&amp;T total</th>
<th>NSF</th>
<th>DOE Office of Science</th>
<th>NIST</th>
<th>NASA</th>
<th>NIH</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY19 appropriation</td>
<td>15,960</td>
<td>8,075</td>
<td>6,585</td>
<td>986</td>
<td>6,906</td>
<td>39,084</td>
</tr>
<tr>
<td>White House</td>
<td>14,059 (-12%)</td>
<td>7,066</td>
<td>5,546 (-16%)</td>
<td>687</td>
<td>6,394 (-7%)</td>
<td>34,368 (-12%)</td>
</tr>
<tr>
<td>House</td>
<td>14,843 (7%)</td>
<td>8,636</td>
<td>6,870 (1%)</td>
<td>1,040 (6%)</td>
<td>7,161 (1%)</td>
<td>41,100 (5%)</td>
</tr>
<tr>
<td>Senate</td>
<td>15,699 (2%)</td>
<td>8,317</td>
<td>7,215 (10%)</td>
<td>1,038 (5%)</td>
<td>6,906 (0%)</td>
<td>42,084 (8%)</td>
</tr>
</tbody>
</table>

American Ceramic Society Bulletin, Vol. 98, No. 9 | www.ceramics.org
Office of Science: The Senate proposed raising the DOE Office of Science budget 10% to $7.22 billion, an increase that exceeds the House’s proposal of 4%. The Office of Science is currently boosting efforts in five areas identified as priorities by the Trump administration: quantum information science, artificial intelligence, exascale computing, microelectronics, and biosecurity.

Applied energy R&D: The House proposed steady spending on nuclear and fossil energy R&D while significantly increasing funding for other programs. In contrast, Senate appropriators proposed even larger increases covering all of DOE’s applied R&D programs. Both the House and Senate proposed increasing ARPA-E’s budget 17% to $428 million.

National Nuclear Security Administration: As with the DOE Office of Science, the Senate’s proposed 11% increase to $16.9 billion far exceeds the House’s proposed 4% increase to $15.9 billion. The increases are largely directed toward efforts to modernize the U.S. nuclear weapons stockpile and associated infrastructure, continuing a multiyear budget surge.

National Institute of Standards and Technology: House and Senate appropriators rejected the White House’s request to cut the agency’s current budget of $986 million by 30%. Instead, the Senate Appropriations Committee proposed an increase of $53 million to the budget while the House proposed an increase of $55 million.

The proposed increases include increases to the Scientific and Technical Research and Services (STRS) account, which funds NIST’s laboratory programs and extramural research activities. Much of the additional resources are directed toward quantum information science and artificial intelligence research.

National Aeronautics and Space Administration: Despite the White House request to decrease NASA’s science budget by 7%, most parts of the agency’s science portfolio are not in line for major changes based on House and Senate proposals. The House proposed raising the budget of NASA’s Science Mission Directorate by 4% to $7.16 billion while Senate appropriators proposed keeping the science budget level.

The biggest outstanding questions concern the Astrophysics Division. The Senate’s spending proposal for the flagship Wide Field Infrared Survey Telescope (WFIRST) would offer less than what NASA says the mission needs to keep on schedule. Additionally, the Senate’s proposal would leave many of the division’s smaller-budget programs potentially in line for cuts.

National Institutes of Health: The Senate Appropriations Committee and the House proposed to increase the NIH budget by $3 billion and $2 billion, respectively, from its current budget of $39 billion, in direct opposition to the White House’s request to cut the budget by almost $5 billion.

The House and Senate bills would distribute their proposed funding increases relatively evenly across NIH institutes and centers. The House report expresses a concern that Congress has focused too heavily on targeted funding for specific initiatives, thus reducing funding for foundational research. Similarly, the Senate report stresses that “many revolutionary discoveries often come from unexpected, untargeted research” and so their proposal targets clinical and translational research that moves basic discoveries from “bench-to-bedside.”

For more information on the federal budget, visit the American Institute of Physics FYI “Budget Tracker” at https://www.aip.org/fyi/federal-science-budget-tracker.

Corporate partner news

Nobel Laureate joins XJet to lead Scientific Advisory Board

XJet Ltd. (Rehovot, Israel), the additive manufacturing company, announces the appointment of professor Daniel Shechtman to lead its Scientific Advisory Board. Winner of the 2011 Nobel Prize in Chemistry for the discovery of quasicrystals, Shechtman’s role will be to help steer XJet’s material and application development roadmap.
PLANTS, CENTERS, AND FACILITIES

Siemens to invest 500 million euros in Colombia energy infrastructure
Germany-based technology company Siemens will invest 500 million euros in energy technology and transmission and transportation infrastructure in Colombia. Currently, what projects the company would invest in and the time frame for the investments are unknown.

O-I plots European MAGMA glass technology expansion
Owens-Illinois plans to expand its European MAGMA glass manufacturing process. The company announced in September it will install the technology at its Holzminden, Germany, plant following a successful installation in its Streator, Illinois, plant. But now O-I reports it is planning the implementation of a further three additional lines in Europe.

AFRL set to open new Center of Excellence with Carnegie Mellon University
The Air Force Research Laboratory and Carnegie Mellon University partnered to set up a center of excellence that will focus on addressing materials design challenges through machine learning and data science approaches.

ACQUISITIONS AND COLLABORATIONS

Laurier joins the Novatech Group
The Novatech Group, manufacturer of steel entry doors, doorglass, patio doors, and insulated glass, and Laurier, manufacturer of glass products, announced that Laurier has joined Novatech. Laurier will now be known as Laurier Architectural.

Argonne and University of Illinois to form hydrogen fuel cell coalition
On October 8, in recognition of National Hydrogen and Fuel Cell Day, Argonne National Laboratory and the University of Illinois Urbana-Champaign’s Grainger College of Engineering announced their intent to form the Midwest Hydrogen and Fuel Cell Coalition.

Rivian demonstrates battery second-life capabilities in Honnold Foundation partnership
Electric vehicle manufacturer Rivian (Plymouth, Mich.) announced a project to use its second-life batteries as energy storage units in a microgrid initiative in Adjuntas, Puerto Rico, which was severely impacted by Hurricane Maria in 2017. Rivian will use 135kWh of battery packs from its development vehicles to support the project (expected to launch in 2020).

MARKET TRENDS

Emhart: Demand booming for glass contains
Bucher Emhart Glass, the Swiss supplier of forming and inspection machinery for the glass manufacturing industry, says demand for glass containers has outstripped capacity, leading container glassmakers to invest, expand, and modernize their capacities.

Glass container recycling rates hits 76% in the EU
Industry data published by the European Container Glass Federation showed the EU28 average collection for recycling rate for glass packaging grew to the record rate of 76% in 2017. Most of the 30 billion collected containers go back into the batch of one of the 160 plants in Europe.
Portable battery-powered products: Global markets

By Robert Eckard

Battery-powered products and the batteries that power them grew spectacularly in the early 2000s. Now, after a nearly decade-long hiatus, battery market development is back and running strong.

Global markets for batteries used in portable battery-powered products reached $53.0 billion in 2018 and will advance from $56.5 billion in 2019 to $94.8 billion through 2024, for a compound annual growth rate (CAGR) of 10.9% during that period. Secondary (rechargeable) batteries account for most of the market share and will continue to capture market share through 2024, growing at a CAGR of 13.8% from 2019 through 2024. Overall growth for primary (single-use) batteries will be negligible through 2024; however, this summary level trend overlooks internal transitions within primary battery markets, as new technologies and changing cost structures drive a shift in consumer purchases.

There are three commonly available commercial rechargeable or secondary battery systems routinely used in portable products: nickel-cadmium batteries, nickel-metal hydride batteries, and lithium-ion and lithium-polymer. In addition, several specialty secondary batteries have established portable product applications in limited or niche markets, including sealed lead-acid, nickel-zinc, silver-zinc, and silver-cadmium batteries. Most portable products that employ primary batteries use one of three systems: zinc-carbon, alkaline, or primary lithium. Specially primary zinc-air, silver oxide and magnesium cells are used to a much lesser extent or in niche applications, while mercury batteries are no longer widely used because of environmental consequences.

Among battery-powered products, cell phone and (overwhelmingly) smartphone applications have the largest market share at 37% of the total battery market for battery-powered products, as of 2018. This segment is expected to show moderate to strong growth, at an approximately 7.1% CAGR from 2019 through 2024, based mostly on continuing increases in battery costs, rather than increased unit sales. Portable computer products and tablets comprise the second largest application category, accounting for 24% of the total market, and will show a 6.9% CAGR from 2019 through 2024, similar to that of cell phones, and largely (but not entirely) based on increased battery unit cost overall. Trendy smartwatches will drive the portable navigation, cameras, and timepieces application segment to be the fastest growing of the applications for batteries used in portable products, increasing in market value at a very strong CAGR of 29.7% from 2019 through 2024.

The portable battery product industry encompasses multiple market-specific driving forces that shape the various battery/portable product market segments. Examples of markets and driving forces include:

- **Cell phones and smartphones:** Transition to 5G, ongoing decline in basic cell phones, development of multiple pricing points, and lengthening replacement cycles.
- **Portable audio equipment:** Dominance of Bluetooth, streaming services, and affordable systems.
- **Battery-powered lighting:** LED technology and lighting beyond flashlights (e.g., accent lighting, holiday lights).
- **Portable medical and scientific equipment:** Continued dependence

On primary batteries and transition of some devices from primary to secondary rechargeable batteries (e.g., pacemakers, drug delivery pumps).

- **Personal transportation:** Proliferation of electric scooters and growing number of bicycles with electric drive.

Asia leads the global market for batteries used for battery-powered products, with a total regional market value of $21.3 billion in 2018. This amount is expected to increase to $23.1 billion in 2019 and will continue to increase rapidly through 2024, to $42.8 billion during the same year. This anticipated growth is equivalent to a strong CAGR for the period of 2019 to 2024 of 13.1%. The North American market is the second largest after Asia. Although select segments are growing faster than others, the region’s market is growing at a moderate to high pace overall.

**Table 1. Global market for batteries used for portable battery-powered products, by battery technology, through 2024 ($ millions)**

<table>
<thead>
<tr>
<th>Battery technology</th>
<th>2018</th>
<th>2019</th>
<th>2024</th>
<th>CAGR% 2019–2024</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium-ion (rechargeable)</td>
<td>33,881</td>
<td>36,477</td>
<td>56,744</td>
<td>9.2</td>
</tr>
<tr>
<td>Lithium-polymer (rechargeable)</td>
<td>2,566</td>
<td>3,088</td>
<td>19,477</td>
<td>44.5</td>
</tr>
<tr>
<td>Alkaline and zinc-carbon (primary)</td>
<td>14,024</td>
<td>14,346</td>
<td>14,608</td>
<td>0.4</td>
</tr>
<tr>
<td>Nickel-metal hydride (rechargeable)</td>
<td>2,048</td>
<td>2,132</td>
<td>2,562</td>
<td>3.7</td>
</tr>
<tr>
<td>Specialty rechargeable batteries</td>
<td>63</td>
<td>68</td>
<td>870</td>
<td>66.5</td>
</tr>
<tr>
<td>Lithium (primary)</td>
<td>254</td>
<td>262</td>
<td>310</td>
<td>3.4</td>
</tr>
<tr>
<td>Nickel-cadmium (rechargeable)</td>
<td>23</td>
<td>23</td>
<td>16</td>
<td>-7.0</td>
</tr>
<tr>
<td>Other primary batteries</td>
<td>138</td>
<td>146</td>
<td>171</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2,462</td>
<td>2,621</td>
<td>11,208</td>
<td>30.0</td>
</tr>
</tbody>
</table>

About the author

Robert Eckard is a research analyst for BCC Research. Contact Eckard at analysts@bccresearch.com.

Resource

The American Ceramic Society rolls out a new magazine this month designed to serve ceramic and glass manufacturers and businesses—Ceramic & Glass Manufacturing.

“This new magazine rounds out ACerS publishing portfolio,” says Eileen De Guire, ACerS director of technical content and communications. “We really didn’t have a publication dedicated to the urgent information needs of manufacturers and businesses. Now we do,” she says.

ACerS already publishes four peer-review journals that serve researchers and the far-horizon applications of their work. The ACerS Bulletin covers topics with near term applications.

Initially, C&G will publish within the pages of the Bulletin (see p. 37). However, it will have its own website (www.ceramics.org/ceramicandglassmanufacturing) and electronic distribution. De Guire says a companion e-Newsletter is planned for early 2020.
GOMD nomination deadlines

The Glass & Optical Materials Division seeks nominations for the following awards. Nominations for all five awards must be received by January 21. For more information, visit ceramics.org/awards or contact Erica Zimmerman at ezimmerman@ceramics.org.

The Norbert J. Kreidl Award for Young Scholars recognizes research excellence in glass science, is open to all degree-seeking graduate students (M.S. or Ph.D.) or those who have graduated within a 12 month period of this meeting.

The George W. Morey Award recognizes new and original work in the field of glass science and technology. The criteria for winning the award is excellence in publication of work, either experimental or theoretical, done by an individual.

The Stookey Lecture of Discovery Award recognizes an individual's lifetime of innovative exploratory work or noteworthy contributions of outstanding research on new materials, phenomena, or processes involving glass, that have commercial significance or the potential for commercial impact.

The L. David Pye Lifetime Achievement Award recognizes lifetime dedication, vision, and accomplishments in advancing the field of glass science and engineering.

The Varshneya-Mauro-Jain Guru-Chela Travel Fund provides a travel grant up to $1,000 to a current teacher/student pair engaged in glass science (or related) research at a higher education or research institution. The travel grant will support attendance at GOMD’s Annual Meeting, and both teacher (guru) and student (chela) are expected to give technical presentations on their work.

Society award nominations due January 15

ACerS is fully committed to running a thriving awards program that recognizes the contributions of deserving individuals and companies within the ceramics and glass community.

We urge you to submit nominations for awards including Distinguished Life Member, Morgan Medal and Global Distinguished Doctoral Dissertation, Kingery, Jeppson, Coble, Corporate Achievement, Spriggs, Du-Co Ceramics Young Professional, Medal for Leadership, Purdy, Schwartzwalder-Pace, Friedberg, and Fulrath. Note that nominees not selected this year, for most awards, will be reconsidered in future years.

For more information, visit ceramics.org/awards or contact Erica Zimmerman at ezimmerman@ceramics.org.

ACerS Morgan Medal Global Distinguished Doctoral Dissertation Award

The purpose of this award is to recognize a distinguished doctoral dissertation in the ceramics and glass discipline. The awardee must have been a member of the Global Graduate Researcher Network and have completed a doctoral dissertation as well as all other graduation requirements set by their institution for a doctoral degree within 12 months prior to the application deadline. The nomination deadline is January 15, 2020. Visit www.ceramics.org/doctoraldissertationaward.

In memoriam

James Sullivan
Edmond Hyatt

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

Volunteer Spotlight

This month ACerS shines it Volunteer Spotlight on Christopher Kassner in recognition of his outstanding volunteer service to The American Ceramic Society.

Kassner is currently a Ph.D. candidate in materials science and engineering at the University of Virginia. He specializes in high-temperature processing and has developed novel routes for making submicron porous SiOC foams. Kassner also conducts research on vapor phase deposition of refractory systems.

Kassner participates in ACerS President’s Council of Student Advisors, serving on the outreach committee (2017–present). In the 2018–2019 term, he was the outreach chair. He made contributions to developing media to educate K–12 students on ceramic engineering as well as implementing new strategies to distribute the media to teachers and students. Additionally, Kassner volunteered for the Mini-Materials Demo Camp, Schott Glass Competition, as well as other student-led events. He also served on the planning committee for the ACerS Annual Winter Workshop held in Daytona Beach during ICACC18.

We extend our deep appreciation to Kassner for his service to our Society!
Congratulations to the winners of the 2019 Ceramographic Exhibit and Contest

Sponsored by the Basic Science Division, the annual competition at ACerS Annual Meeting promotes microscopy and micro-analysis tools for investigating ceramic materials. The winning entries will be featured on the back covers of the *Journal of the American Ceramic Society* in 2020.

Awardees by Category

**Roland B. Snow Award for Best in Show**

*Purdue’s ZnO Loops* by Xin Li Phuah and Haiyan Wang, Purdue University

**Scanning/Transmission Electron Microscopy**

**First place**

*Stars and Stripes* by Joshua Smeltzer, Christopher J. Marvel, and Martin P. Harmer, Lehigh University; Anit Giri, B. Chad Hornbuckle, and Kristopher Darling, U.S. Army Research Laboratory–Aberdeen Proving Ground

**Second place**

*Artistic artifact* by Yolande Berta, Yong Ding, Salil Joshi, Ning Xia, and Rosario Gerhardt, Georgia Institute of Technology

**Third place**

*Porous nanoscale Y-Ti oxide resembling lotus receptacle* by Mallikarjun Karadge and Shenyan Huang, GE Research

**Optical/Confocal Microscopy**

**First place**

*Basket weave* by Chris McLasky, Shenyan Huang, Scott Weaver, Cole Crawford, and Evan Dolley, GE Research

**Second place**

*Deformation and cracking in a ceramic powder compact during de waxing* by Mayu Kato, Junichi Tatami, Motoyuki Iijima, and Takuma Takahashi, Yokohama National University, Japan

**Second place**

*Intermediate reduction of cobalt oxide* by Madison Gianelle, Animesh Kundu, and Helen Chan, Lehigh University

**Optical/Confocal Microscopy**

**First place**

*Basket weave* by Chris McLasky, Shenyan Huang, Scott Weaver, Cole Crawford, and Evan Dolley, GE Research

**Second place**

*Deformation and cracking in a ceramic powder compact during de waxing* by Mayu Kato, Junichi Tatami, Motoyuki Iijima, and Takuma Takahashi, Yokohama National University, Japan

**Second place**

*Microstructure of electrochromic NiO film* by Kristen Wong and Khalid Rafique, University of California, Irvine
ACerS Nuclear and Environmental Technology Division (NETD)

Four $500 travel stipends help students fund their attendance to ACerS Annual Meeting at MS&T19 in Portland, Ore.

Congratulations to this year’s NETD travel stipend winners:
- Levi Gardner, University of Utah
- Adam Bratten, Missouri University of Science and Technology
- Jenniffer Bustillos, Cornell University
- Hong Zhong, Washington State University

Congratulations to the 2019 GEMS award finalists
ACerS Basic Science Division recently announced the winners of its 2019 Graduate Excellence in Materials Science (GEMS) awards.

Diamond Ranking
- Xin Li Phuah, Purdue University; Beecher Watson, The Pennsylvania State University; Talia Barth, University of Michigan

Sapphire Ranking
- Mingyang Zhao, Clemson University; Archana Loganathan, Florida International University; Jacob Cordell, Colorado School of Mines; Kimiko Nakajima, University of California, Davis; Shenglong Mu, Clemson University; Yi Yuan, Simon Fraser University; Jun Gao, Clemson University

Graduate students whose abstracts are accepted for a talk at MS&T20 in Pittsburgh, Pa., should consider applying for the 2020 GEMS Awards. For more information, visit www.ceramics.org/gems.

Material Advantage and PCSA competitions at MS&T

Both the Material Advantage Student Program and the ACerS President’s Council of Student Advisors sponsored various contests for undergraduate and graduate students during MS&T19 in Portland, Ore. Thank you to all who helped judge and organize the contests this year, and congratulations to all winners.

Graduate Student Poster Competition

First place
Achieving the upper bound of piezoelectric response in tunable, wearable 3D printed nanocomposites by Desheng Yao, Virginia Polytechnic Institute and State University

Second place
Spatial distribution of spherical Al$_3$Ti particles in Al-Al$_3$Ti composite by equal-channel angular pressing and multi-directional forging by Sarath Babu Duraisamy, Nagoya Institute of Technology, Japan

Third place
Homogenization on manganese microsegregation in continuous cast microalloyed steel slabs by Rishav Raj, University of Alberta, Canada
STUDENTS AND OUTREACH

Undergraduate Student Poster Competition

First place
Thermodynamic properties of strontium-lead alloys determined by electromotive force measurements by Yuran Kong, The Pennsylvania State University

Second place
Testing conflicting theories of ionic conductivity using molecular dynamics by Rebecca Welch, Coe College

Third place
Validating the compression-tension asymmetry in Mg using microscale testing by Skye Supakul, University of Nevada

Undergraduate Student Speaking Contest

First place
Phase filed modeling of corrosion by Victoria Reichelderfer, University of Connecticut

Second place
Recycling of post-consumer glass cullet: An opportunity for cost savings and sustainability by Bailey Ricketts, Missouri University of Science and Technology

Third place
Bio-inspired routes to damage tolerant materials: the unique microstructure of enamel in the grinding dentition of a hadrosaurid dinosaur by Shane Johnson, University of Nevada, Reno

Fourth place
Plastic fluctuations in a Cu-Al intermetallic by Jose Mancias, University of Illinois at Urbana-Champaign

Ceramic mug drop contest (organized by Keramos)

Winner
Alissa Reynolds, Missouri University of Science and Technology

Most aesthetic mug
Jingjing Cui, Wuhan University of Technology, China

Ceramic disc golf (organized by Keramos)

Winner
Harrison Jones, Virginia Polytechnic Institute and State University

Most aesthetic disc
Harrison Jones, Virginia Polytechnic Institute and State University

ACerS PCSA 2019 Humanitarian Pitch Contest award winners

First place
PSU Piezos, Elizabeth McIntyre, Isabella Urbina, Haley Myer, and Arshiya Bhadu, The Pennsylvania State University

Second place
Concrete Communities Construction Co., Rachel Cook, Austin J. Martin, Cambria Ryckman, and Nicholas Timme, Missouri University of Science and Technology

Third place
Aqua Nurture, Claralys Hernandez-Santiago, Amir Gomez-Perez, and Willam Crespo, University of Puerto Rico – Mayagüez

Undergraduate student speaking contest finalists. From left: Victoria Reichelderfer, Bailey Ricketts, Jose Mancias, and Shane Johnson.
CGIF will welcome students from around the world to Winter Workshop

Winter Workshop 2020, sponsored by the Ceramic and Glass Industry Foundation and ACerS, will take place Jan. 24–28, 2020, at the Hilton Daytona Beach Oceanfront Resort in Daytona Beach, Fla.

Winter Workshop provides a combination of technical and professional development sessions, outstanding networking opportunities, and includes a tour of the Kennedy Space Center. The annual event is designed for ceramic and glass students and young professionals from around the world. As in years past, the European Ceramic Society will provide 15 travel grants for students in Europe. Because of the popularity of the event, the number of attendees is limited to 50.

The Friday evening and Saturday morning sessions will feature several prominent experts:

• William Fahrenholtz of Missouri University of Science and Technology, on Ultra-high temperature ceramics for extreme environments,
• Jared Weaver of GE Global Research, on Current CMC/EBC development at GE,
• Giorgia Franchin of the University of Padua in Italy, on Additive manufacturing of ceramics: strategies, technologies, and applications,
• Geoff Brennecka of Colorado School of Mines, on Fund Yourself! Strategies for proposal writing for graduate fellowships and beyond,
• Romain Gaume of the College of Optics and Photonics, University of Central Florida, on A tutorial on lasers and scintillators.

The afternoon session will feature speakers and activities on professional development.

The Ceramics Career Panel will lead interactive discussions on career paths taken by successful members of the ceramics field, who will then be available to answer attendees’ questions on a variety of topics.

The Basic Science Division of ACerS is offering partial support to attend Winter Workshop. For more information, go to https://bit.ly/2WrTDZ5.

Winter Workshop registration allows participants to attend all events of the 44th International Conference and Exposition on Advanced Ceramics and Composites (ICACC). For more information, go to: https://ceramics.org/winter-workshop-2020.
Researchers from the University of California, San Diego, and the University of California, Riverside, discovered how to weld ceramics at room temperature using ultrafast pulsed lasers.

Currently, ceramics are joined used high-temperature diffusion bonding using the principle of solid-state diffusion. However, diffusion bonding can be used only in limited situations. “Diffusion bonding requires long-term exposure of entire assemblies to high temperature and often requires precise modeling of shrinkage dynamics to achieve tight tolerances,” the researchers explain in a recent paper.

They go on to say that lasers, a key to certain additive manufacturing techniques, could be instrumental in welding ceramics. Unfortunately, attempts to weld ceramics using powerful continuous-wave (CW) lasers without high-temperature preheating have been unsuccessful because of macroscopic cracking attributed to thermal shock.

But CW is not the only way to operate lasers. “Successful demonstrations of joining glasses were accomplished with ultrafast pulsed (UF) lasers,” the researchers write in the paper.

Unlike CW lasers, which strike a material continuously with a laser beam, UF lasers strike the material in short pulses. This technique allows the laser to be focused into the material, stimulating nonlinear and multiphoton absorption processes that lead to localized absorption and melting” in the case of glass, the researchers explain.

In their study, the researchers hypothesized that tuning optical transparency (absorption plus scattering) would allow them to focus laser light into ceramics—placing energy where it can cause localized melting at the interfaces, thus effectively welding ceramic components.

To highlight the versatility of a UF laser welding approach, the researchers demonstrated the technique on both transparent ceramics (with varying absorption properties) and conventionally sintered ceramics (with limited light transparency). They used these ceramics to present two different concepts:

1. Transparent ceramics for hermetic (airtight) encapsulation, and
2. Diffuse ceramics for joining simple geometries.

In the paper, the researchers highlight several key parameters necessary to a successful ceramic weld, including

- **Dynamic rotation of the ceramics through the beam focus**, to ensure not only melting at a point but also continuous melting along the joint interface, and
- **Low number of pulses and pulse lengths in the picosecond regime**, to induce good energy coupling at a 1-MHz repetition rate.

“The sweet spot of ultrafast pulses was two picoseconds at the high repetition rate of one megahertz, along with a moderate total number of pulses. This maximized the melt diameter, minimized material ablation, and timed cooling just right for the best weld possible,” Guillermo Aguilar, professor and chair of mechanical engineering at UC Riverside, says in an UC San Diego press release. The UF laser welding technique would allow creation of such assemblies.

Additionally, “The visible-RF light access allowed by ceramic packaging is important for developing optoelectronic devices, facilitating optical communication as well as wireless electronic charging,” the researchers write in the conclusion.

The paper, published in Science, is “Ultrafast laser welding of ceramics” (DOI: 10.1126/science.aaw6699).
ceramics in the environment

Reduce (and reuse) carbon emissions from cement production

Researchers from the Massachusetts Institute of Technology experimented with using electrolysis to create cement and found that in addition to reducing carbon emissions, byproducts from the process can be reused.

Concrete is second only to water as the most-consumed resource on the planet, and it boasts a significant carbon footprint because of cement, the binding ingredient in concrete. The production of more than four billion tonnes of cement each year account for about 8% of the world’s carbon dioxide (CO₂) emissions, according to a report by think tank Chatham House.

To tackle cement’s emission problem, many research groups investigate replacing cement with alternative supplementary cementitious materials or develop devices that capture the emitted CO₂. However, another way to tackle carbon emissions from cement production is to replace the emission-heavy steps of the manufacturing process with alternative techniques.

Ordinary Portland cement is made by grinding calcium carbonate (CaCO₃, generally limestone) and then cooking it with sand and clay at high heat, produced by burning coal. The cooking process decarbonizes CaCO₃ and produces calcium oxide (CaO) and CO₂. The CaO is then reacted with silica (SiO₂) to produce alite, the major mineral phase in Portland cement.

Two parts of the process are responsible for CO₂ production: burning coal and heating CaCO₃.

One way to reduce emissions is to heat CaCO₃ using renewable sources, and such a process is what the MIT researchers investigated.

“Our reactor takes advantage of the inherent pH gradients in an electrolysis cell to carry out CaCO₃ decarbonation and Ca(OH)₂ precipitation and collection,” the researchers write in the paper.

Electrolysis could offer a way to produce emissions-free cement.

FROM BRICKS TO NANOS

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The researchers, led by ACerS Fellow and Kyocera Professor of Materials Science and Engineering Yet-Ming Chiang and postdoc Leah Ellis, dissolved pulverized \( \text{CaCO}_3 \) in the acid at one electrode and calcium hydroxide \( [\text{Ca(OH)}_2] \) precipitated out as a solid at the other one. Though \( \text{Ca(OH)}_2 \) is slightly different from \( \text{CaO} \), the material produced in a conventional cement manufacturing process, \( \text{Ca(OH)}_2 \) “readily reacts with silica to form alite while giving off only water,” Chiang explains in an email.

In addition to \( \text{Ca(OH)}_2 \), dissolving \( \text{CaCO}_3 \) in acid produced a stream of \( \text{O}_2/\text{CO}_2 \) gas at that electrode, while a concentrated hydrogen gas stream was released from the other one.

In the paper, the researchers explain how these gas streams could be harnessed for other applications. “Since here the \( \text{CO}_2 \) is delivered in a highly concentrated form mixed only with \( \text{O}_2 \) (and some \( \text{H}_2\text{O} \) vapor), direct capture using the same simple compression processes now used for purified and concentrated \( \text{CO}_2 \), could be used,” they explain. That means the \( \text{CO}_2 \) could be economically captured and reused in various applications, including synthetic liquid fuel, enhanced oil recovery, and even carbonated beverages.

Additionally, the hydrogen could also be captured and reused to support the cement process. “It could be directly combusted to provide heat or electric power back to the cement operation, or the \( \text{H}_2 \) and \( \text{O}_2/\text{CO}_2 \) gas streams could supply a fuel cell that generates on-site electricity to power the electrochemical reactor or other plant operations such as grinding, mixing, and handling,” the researchers write.

Ultimately, “These results suggest a pathway to cost-competitive emissionless cement manufacturing wherein all energy is supplied by renewable electricity,” they conclude.

Chiang says they are currently designing and testing a scalable version of the electrochemical reactor and studying the reaction product under various operating conditions. More broadly, they are analyzing the scalability of producing cement electrochemically.

The paper, published in *Proceedings of the National Academy of Sciences of the United States of America*, is “Toward electrochemical synthesis of cement—An electrolyzer-based process for decarbonating \( \text{CaCO}_3 \) while producing useful gas streams” (DOI: 10.1073/pnas.1821673116).
Right at Home—
How ceramics and glass contribute to the $4.17T residential building market

by April Gocha and Lisa McDonald

A cross the globe, 230 billion m² in new construction is expected to be built over the next 40 years. For scale, that unprecedented rate is the equivalent of building Paris every week for the next four decades.¹

In part, this is because of growing global population—approaching eight billion people—each of whom needs a place to live. Urban areas are growing at a rate of 200,000 people per day,² causing many cities to feel the pressure under struggling infrastructures, skyrocketing housing prices, and rising homelessness.
So it is no surprise that residential housing represents a sizeable portion of the globe’s total future construction. The global market for residential building construction, including new builds, renovation, and remodeling, was worth nearly $4.17 trillion in 2017 and is predicted to reach nearly $6.80 trillion by 2022, growing at a healthy compound annual growth rate (CAGR) of 10.3%. The Asia Pacific region, driven by growth in China, constitutes 58.1% of that market, followed by North America (19.4%) and western Europe (11.5%).

Construction has a significant impact on global economies as well. The residential building construction market comprised an estimated 5.8% of global gross domestic product (GDP) in 2019 and is expected to reach 6.9% by 2022. Also considering both residential investment and consumption spent on housing services, which includes things like rent and utilities, housing contributes an average 15–18% GDP.

“At the national level, the impact is broad-based, as jobs are generated in the industries that produce lumber, concrete, lighting fixtures, heating equipment, and other products that go into a home or remodeling project,” according to the National Association of Home Builders report. “Other jobs are generated in the process of transporting, storing, and selling these projects. Still others are generated for professionals such as architects, engineers, real estate agents, lawyers, and accountants who provide services to home builders, home buyers, and remodelers.”

In total, construction of each new single-family home in the U.S. contributes an estimated 2.97 jobs to the economy and $280,433 in combined wages and profits. In other words, the construction industry is large, it is significant, and its impact extends wide.

Energy efficiency

In addition to having a significant impact on global economies and markets, buildings and construction together account for about a third of global energy use and energy-related CO₂ emissions—making construction a prime target for efforts to reduce energy consumption.

“If there’s a defining theme for the building sector in 2019, it’s energy codes,” according to a New Buildings Institute article. “Actions to update the rules that cities and states set to determine how effectively new residential and commercial buildings use energy are progressing on several fronts across the U.S.”

Regulations and initiatives nudge toward increased energy efficiency across the globe, nudging companies and industries to act to reduce their use of energy, water, and resources as well as their total negative impact on the environment.

In the U.S., a national model for energy use standards called the International Energy Conservation Code (IECC) forms a precedent for more local adoption of energy-use standards by U.S. states and cities. Updated every three years, IECC codes target building envelopes as well as mechanical, lighting, and power systems for opportunities to increase energy efficiency.

In Europe, the European Energy Performance in Buildings Directive mandates that all new buildings achieve nearly zero-energy status by 2020—meaning that the buildings must use low amounts of energy sourced mostly from renewables.

Materials offer solutions

Considering that the construction industry uses over 400 million tons of material every year, materials provide vast potential to improve building energy efficiency.

For instance, producing an annual estimated 76 million tons of finished concrete for U.S. construction generates 9.8 million tons of CO₂. However, efforts to reduce concrete use can only go so far, so changes to reduce the negative environmental impact of producing and using concrete become important for future sustainability.

Advancements in the materials themselves as well as improvements to their production, use, and disposal are all important considerations to reduce overall energy use and mitigate negative environmental impacts.

Advanced materials offer broad advantages, such as increased recyclability, reduced construction time, and higher quality, versatility, and durability and are already changing residential construction, according to a BCC market report.

“Fluor, a U.S.-based construction company, is using 50%-faster-curing concrete in its construction projects. Other advanced construction materials in the market include super-lightweight ceramic sidings, organically coated steel, self-healing concrete, rain-absorbing roof-mats, and micro-encapsulated phase-change material.”

In other words, materials offer solutions.

These solutions represent substantial industries for diverse building products, which, due to the size and scope of the construction industry, significantly influence supply chains, R&D, and manufacturing of the even more diverse materials they incorporate.

“The European Commission estimates that 70% of product innovation across all industries is derived from new or improved materials,” according to a World Economic Forum report on the future of construction. “With approximately one-third of construction cost attributed to building materials, the scope for applying advanced building materials is considerable.”

Enabled by ceramics and glass

In the U.S., the median size of a new single-family home sold in 2018 was 2,435 ft² (median price: $281,200). However, that size varies significantly across the developed world, with an average for all homes closer to 1,200 ft². The variation gets even wider if you consider all the dwellings called home across the entire globe.

Each of those dwellings contain a host of materials, which themselves vary widely based on the region, climate, availability, preference, and local practice.

What most people call home, however, includes ceramic and glass materials on the interior and exterior surfaces, within walls and spaces, and affixed throughout—top and bottom, inside and out. Ceramic and glass materials are integral to both building homes and making homes functional buildings to inhabit.

This article provides a snapshot into use of ceramics and glass in and around a home and the markets they drive. While the full extent of these applications is beyond the scope of this article, Figure 1 shows some examples of specific applications.
Right at home—How ceramics and glass contribute to the $4.17T residential building market

and places where ceramic and glass materials can be found in residential homes.

Further, the materials and the products they enable represent significant industries that contribute to the global economy. Table 1 provides a sampling of companies that manufacture ceramic and glass materials or products tied to the construction industry and a glimpse of the commerce involved.

**MATERIALS MAKE THE HOME**

*Raise the roof*

Globally, roofing sales are expected to hit $120 billion by 2022, with bituminous products, the category that includes asphalt shingles, the most popular choice for roofing in 2017 with 34% of global sales. Concrete and clay tiles accounted for 30% of the market in terms of area of roofing, although they account for the largest fraction of sales due to the products’ higher price. The rest of the roofing market divides between metal (11%), fiber cement (6%), rubber (4%), and plastic materials (5%) (“other” materials account for the remaining 10%). Demand for all types of roofing globally is expected to rise 2.4% annually through 2022.11

It is no surprise that the roofing market itself is heavily influenced by weather. Weather-related reroofing alone accounts for about a third of U.S. demand for residential roofing per year.12

“With storms becoming more powerful and more frequent, roofing must boast increased durability and impact resistance,” says Lucas J. Hamilton, manager of applied building science for Saint-Gobain Corp. (Malvern, Pa.).

Storm-resistant roofing is predicted to account for a growing portion of the market, especially as insurers require installation of these products as a term of coverage and building codes increasingly demand them. These include wind-resistant, impact-resistant, and UV-resistant products, as well as those that withstand extreme temperatures or prolonged moisture.12

Modern laminated asphalt shingles have been engineered to withstand wind gusts of up to 140 mph, have impact resistance to intense hail and windborne debris, or better reflect solar radiation to improve homes’ energy efficiency. These properties are significant developments from the first iterations of asphalt shingles, which were often composed of organic matter such as cotton rags, paper, and wood pulp, coated with asphalt, and topped with crushed slate, oyster shells, or other rock-like materials.

“In the 1970s, there was a big transformation in the industry to use fiberglass mat to serve as the backbone or the structure of shingles,” says Carmen LaTorre, senior R&D leader for shingle innovation at Owens Corning. Fiberglass mats themselves not only provide modern asphalt shingles with much more

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*Figure 1. Ceramic and glass materials contribute function and beauty in every room and system in a home.*
durability, but they have also allowed shingles to get thinner and lighter, allowing multilayer designs that further improve strength and durability.

The other major improvement in modern shingles, LaTorre says, is that modern asphalt shingles are topped with engineered ceramic-coated granules instead of crushed rocks. The ceramic coatings can contain different additives, ingredients, and pigments to achieve various performance functions or desired colors. Granules can even receive multiple coatings, each applied as a slurry and kiln-fired onto the granules, to achieve a desired combination of performance or processing benefits. For example, by mixing together granules with different pigments and shades of pigments, manufacturers can fabricate shingles with rich dimensional effects that mimic other types of roofs but have the enhanced performance of asphalt shingles (Figure 2).

Pigmented ceramic-coated granules are not just for looks, however—they also can be designed with specific functional features, such as better light reflectivity. Roofs that better reflect the sun’s radiation, commonly called “cool roofs,” help buildings reduce energy use by preventing radiation from being absorbed into buildings as heat. Whereas standard asphalt roofs reflect less than 20% of sunlight, cool roofs reflect an average 67% of direct sunlight.13

In the U.S., regulations in California have been particularly influential in driving demand for roofing materials with enhanced reflectivity to increase the energy efficiency of buildings and reduce urban heat island effects. The state’s CalGreen standards—the first statewide set of mandatory green building codes in the U.S.—specify that buildings must adhere to various practices spanning planning and design, energy efficiency, water conservation, material conservation and resource efficiency, and environmental quality.

For roofing materials in particular, CalGreen codes include standards for solar reflectance index, which measures a material’s ability to reflect solar heat.

“Roofing is being influenced by energy efficiency requirements, and the industry must meet these requirements by being nimble and efficient despite the ongoing labor shortage,” Hamilton says.

While California’s regulations drive development of cool roofs, industry is watching this market segment and technology closely. “The industry is monitoring this and coming up with higher reflective coatings or granules” LaTorre says. “Even today, discussion continues around what those standards are and whether they will be even more stringent in the future.”

If codes do become more stringent, roofing materials will undoubtedly evolve alongside. But designing and testing new roofing materials is a difficult task, partly because the existing materials today already have such high performance.

“For any new material, you must have a really rigorous protocol to show...
Right at home—How ceramics and glass contribute to the $4.17T residential building market

that it can withstand the cold, the hot, the cycling temperatures," LaTorre says. “So that’s one of the biggest challenges to product developers—you’ve got a great track record with existing materials, so how do you make sure that you evaluate that the next generation of materials can have that same durability?”

Better with brick

For thousands of years, human civilizations have inhabited brick structures—many of which, impressively, still stand today.

While the clay-based materials in brick changed relatively little across thousands of years, the manufacturing processes shifted dramatically.

“On the operations side, there’s been a lot of innovations to try to make product as efficiently and cost effectively as possible,” says Stephen Sears, chief operating officer and vice president of marketing for the Brick Industry Association (Reston, Va.).

In addition to automation, modern brickmaking plants also adopted extensive innovations in the kilns and dryers—including variable speed drives to electronically control fan speed and pulsed firing technology to improve firing efficiency—that significantly improved the industry’s energy efficiency. "These methods have really enhanced the industry’s fuel efficiency per unit of production," according to Garth Taylor, an expert with more than 50 years of experience in the brick industry and retired technical director for Acme Brick (Fort Worth, Texas).

The U.S. clay brick and product manufacturing industry—which includes clay brick, ceramic tiles, and refractory products—is estimated to reach $7 billion in total revenue in 2019, representing an annual 2.3% growth from 2014–2019.14

Despite this incremental growth, the brick industry is still recovering from the 2008–2009 Great Recession. “Our total manufacturing net sales, what’s called value product shipments, was about $1.2 billion total in 2018. We were up to $2.2 billion at some point in the 2000s but we got hit really hard in 2011,” Sears adds.

And although he says the brick industry recovered from that trough, it is still not yet back up to pre-recession levels.

Part of that is due to the reduced number of new homes starts since the Great Recession hit its hardest. While numbers have been steadily increasing year over year, the number of new single-family homes built in the U.S. in 2018 was nearly 50% of that in 2005 (Figure 3). That change of pace was felt across the construction industry.

In 2018, 21% of new single-family homes had exteriors clad in brick, a percentage that remained relatively stable in the U.S. over the past several decades.15

Today, homeowners and builders have more choices than ever for exterior cladding, and that is one of the biggest current challenges for brick. “We are under incredible competition," Sears says. “And there are some really strong competitors.”

Perhaps the strongest competition comes from fiber cement siding, a durable composite siding product composed of cement reinforced with cellulose fibers, often wood pulp. Fiber cement represents the fastest growing exterior material category, expected to increase 3.6% annually through 2022.16 While fiber cement clad the exterior of just 9% of new single-family homes in the U.S. in 2005, that share jumped to 20% in 2018—just behind brick’s 21%.15

While other cladding materials offer lower cost than brick, none comes close to its strength and durability.

“Brick is by far the most durable and requires the least amount of maintenance,” says John Hewitt, assistant plant manager of Interstate Brick (West Jordan, Utah). After considering the cost of maintenance and replacement, which can become significant with other materials, he says, brick comes out on top.

Research at the National Brick Research Center (NBRC; Anderson, S.C.) measures and quantifies brick properties, which demonstrate that brick as a cladding material is unsurpassed in terms of thermal performance and impact resistance.

“The way energy codes work right now, is all based on R-value,” says John Sanders, director of NBRC and research associate professor of materials science and engineering at Clemson University. “It’s an artificial sort of temperature measurement that doesn’t simulate the real world. And it completely neglects materials like brick that have a significant amount of thermal mass.”

The R-value reflects the ability of a material or system to resist heat transfer through conduction. A higher R-value indicates greater insulating ability because the material or system prevents more heat transfer.

To more accurately test and demonstrate the real-world performance of brick walls, NBRC specially built hot boxes to quantify the thermal performance of entire 6-foot by 8-foot wall panels. “When we subject brick wall panels to real-world temperature cycles, what we find is that energy use is up to 50% less that what R-value would tell you,” Sanders explains.

Based on these results, Sanders says brick likely performs even better than its

Figure 2. Ceramic-coated granules can be manufactured in an array of colors and functionalities to provide dimensional effects and performance to asphalt shingles.
R-value indicates. However, current codes do not reflect these new data because the codes are based on the assumption that convection is the major contributor to heat flow for brick walls. “What we’ve been able to prove is that it’s actually radiation in that air space that is the dominant means of air flow, and convection is a very minor contributor,” he adds.

Using these kinds of data, NBRC is researching how to further improve the performance of brick wall systems, such as incorporating radiant barriers in the wall and optimizing the size and coring of brick.

A recent innovation in the brick industry is thin brick. Thin brick, just 0.5–1.5-inch thick instead of the typical 3-5/8-inch thickness of standard brick, offers versatility. In addition to both interior and exterior applications, it can go places where a full brick is space or weight prohibitive. Installation is faster and easier, and thin brick can be added in renovations and installed on accent walls and backsplashes, for example.

Demand for thin brick is high, and companies are certainly investing in them. Whereas many companies simply manufacture standard brick and saw the faces off to fabricate thin bricks, Interstate Brick recently invested in a separate extrusion line specifically designed to fabricate thin brick, Hewitt says. “In general, the industry is currently faced with the challenge of how to make enough of these without additional manufacturing steps, particularly saw cutting full-sized brick down into thin-brick slices.”

**Insulation keeps us comfortable**

Each year, cities around the globe continue to set new records for hottest and coldest days on record. These temperature extremes and increasing

<table>
<thead>
<tr>
<th>Table 1. Select companies that manufacture ceramic and glass building products</th>
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<tbody>
<tr>
<td><strong>Company (location)</strong></td>
</tr>
<tr>
<td>Saint-Gobain (Courbevoie, France)</td>
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<tr>
<td>“CertainTeed, subsidiary of Saint-Gobain (Malvern, Pa.)”</td>
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<tr>
<td>LIXIL Group Corp. (Tokyo, Japan)</td>
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<tr>
<td>Mohawk Industries Inc. (Calhoun, Ga.)</td>
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<tr>
<td>&quot;Del-Tile, subsidiary of Mohawk (Dallas, Texas)&quot;</td>
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<tr>
<td>Kohler Co. (Kohler, Wisc.)</td>
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<tr>
<td>Owens Corning (Toledo, Ohio)</td>
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<td>Boral (Sydney, Australia)</td>
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<td>Toto (Kitakyushu, Japan)</td>
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<td>Carlisle (Scottsdale, Ariz.)</td>
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<td>Johns Manville (Denver, Colo.)</td>
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<td>GAF Materials ( Parsippany, N.J.)</td>
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<td>“Schott North America Inc. (Elmsford, N.Y.)”</td>
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<td>Roca (Barcelona, Spain)</td>
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<td>Ferro Corp. (Mayfield Heights, Ohio)</td>
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<td>IKO Industries (Calgary, Alberta, Canada)</td>
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<td>Acme Brick Co. (Fort Worth, Texas)</td>
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<td>Knauf Insulation (Abu Dhabi, United Arab Emirates)</td>
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<tr>
<td>SCG Ceramics (Bangkok, Thailand)</td>
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<td>Mansfield Plumbing LLC (Perrysville, Ohio)</td>
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*Conversions per Google as of October 19, 2019. All financial data obtained from company reports unless otherwise noted.
†Data obtained from NAICS codes.
‡Private company or data not available; revenue estimated from owler.com or hoovers.com.
Urbanization are expected to drive growth in sales of new and upgraded heating and air conditioning systems, especially in Europe. The number of European households that buy and install a new air conditioning system is expected to increase by an average of 4.3% per year through 2040.  

Ceramic components can be found in both forced-air furnaces, the most common system in the U.S. (58% of heating systems in newly completed single-family houses in 2018), and heat pumps (40% of heating systems), which act as both furnace and air conditioner. For instance, modern gas furnaces commonly contain a silicon carbide or silicon nitride hot surface ignitor. The U.S. Department of Energy estimates that about half of a home’s energy use is spent heating and cooling spaces, while 18% is spent heating water, indicating these systems and proper insulation of these systems have a significant role to play in residential energy savings.

In fact, modeling studies show that electricity consumption could have been reduced by 37 terawatt-hours per year in the U.S. just by increasing insulation to 2012 IECC levels in all existing single-family homes in 2013, representing a total 3.4% reduction in annual electricity consumption.

Demand for insulation of all types is predicted to rise in the U.S. through 2021, influenced by increasing demand for energy efficiency and by states increasingly adopting IECC mandates.

Although there are various types of insulation materials, fibrous mineral insulation, which includes fiberglass and mineral wool, represents the largest portion of the U.S. insulation industry. This is a significant industry—insulation manufacturing is a $13.9 billion industry in the U.S. and generates more than 500,000 total jobs, including manufacture, distribution, and installation of insulation.

In residential homes, insulation is most common in the exterior walls and the attic or roof area, where most heat escapes. Home Innovation’s 2019 Annual Builder Practices Survey of home builders indicates that fiberglass insulation (batt and blown) comprises 71% of insulation in new single-family homes built in 2018 (including floors, walls, and roofs). Fiberglass insulation consists of loosely bonded thin glass fibers separated by pockets of air.

“The focus of manufacturing for insulation materials continues to be driven by efforts to lower environmental impacts and decrease embodied energy,” says Saint-Gobain’s Lucas Hamilton.

One way for insulation manufacturers to lower their environmental impact is by using recycled content. Most fiberglass manufacturers in the U.S. spin glass fibers from 40%–60% recycled glass content, which both diverts a material waste stream from landfills and offers additional energy savings during insulation manufacturing.

Including recycled glass in the melt reduces the energy requirements to manufacture fiberglass. “From a manufacturing standpoint, it’s easier to melt already formed glass than it is to melt raw materials going into the glass,” says Matthew Gawryla, insulation R&D leader at Owens Corning.

Recycling diverts a considerable amount of materials away from landfills. A 2018 survey from the North American Insulation Manufacturers Association indicates that U.S. manufacturers recycled 2.2 billion pounds of glass into insulation.

Mineral wool, which consists of ceramic instead of glass fibers, contains recycled slag from steel mills. Mineral wool has a higher density than fiberglass, which translates to higher R-values and greater insulating performance. Plus, it has the added benefit of acoustic insulation as well as higher temperature resistance than fiberglass.

Figure 3. U.S. Census Bureau data showing total new single-family houses (dotted line) and houses by primary type of exterior wall material completed in the U.S., 1973–2018.
More expensive than fiberglass insulation, mineral wool is used primarily in commercial building applications. However, mineral wool does seem to be gaining some popularity in the insulation market in general.24

“Owens Corning has invested significantly in the mineral wool area of the market because it’s a growing segment, especially as used in exterior continuous insulation,” Gawryla says. “There is a desire in the market for high-temperature, noncombustible materials, a lot in commercial buildings but also somewhat in residential buildings.”

Another trend in the insulation industry is a move toward mixed materials. “The combined thermal, moisture, and air resistance properties of the insulation are so varied that we tend to mix and match different materials on a job based on climate, building usage, and where in the envelope the material is being deployed,” Hamilton says. “What you’re beginning to see is a lot of mixing and matching various insulation products in order to control moisture.”

**Windows: Portals to the outdoors**

While the ultimate goal of a home is to separate inside space and outside environment, windows provide a portal between these two worlds—they allow light into homes and provide a view to the outdoors.

“Most of the innovation has been to the value add of the base glass. The formulation of the glass we see in everyday windows hasn’t really changed—it’s the same types of raw components and same system for getting to that glass, which is the float process,” according to Julia Schimmelpenninching, industry technical manager of architectural customer applications and service lab manager at Eastman Chemical Co. (Kingsport, Tenn.). “What has happened is the innovation of what we’re doing to that glass, adding color or putting coatings or specific surfaces on the glass.”

Those coatings allow the glass to achieve functions such as improved protection and resistance to breakage, for example, or aesthetic appeal. But perhaps the most important function of glass coatings has been to improve energy efficiency.

Modern windows have dramatically boosted their efficiency with low-emissivity (low-e) coatings. These thin silver or tin oxide coatings, applied during the float process or sputtered onto the glass, offer additional energy efficiency savings by blocking long-wavelength heat radiation yet allowing short-wavelength light to pass through.

**Functional pottery in the home**

From ceramicists setting personal sales records at auction houses to *Vogue* declaring “pottery is the new yoga,” ceramic art and pottery is having its moment in both traditional and contemporary venues.

Decorative figurines, bowls, and cups make up a large proportion of the ceramic art and pottery showcased in popular media. However, there are many other functional ways ceramic art and pottery can be integrated into a home, including muffin pans, citrus juicers, and watering cans.

There are three main types of pottery: earthenware, stoneware, and porcelain.

**Earthenware**, the oldest type of pottery, is a lightweight, low-fired porous clay body made from common clay components that cover the planet. Its color is a natural robust red to buff colors, and earthenware containers will absorb their contents unless a glaze is applied.

**Stoneware** is a nonporous composition of higher-temperature fire and ball clays, and is more durable and substantial than earthenware. It features a subtler color palette, and it does not absorb its contents.

**Porcelain** is a nonporous, nonstick material typically made from kaolin, quartz, andfeldspathic rock that has been fired at very high temperatures to vitrification. It is strong and tough when thick and translucent when thin, and it does not absorb its contents.

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*(a) Originally published in the Vol. 19, Iss. 1 Jan/Feb 2016 issue of *Pottery Making Illustrated*, page 44. (b) Originally published in the Vol. 19, Iss. 6 Nov/Dec 2016 issue of *Pottery Making Illustrated*, page 42. (c) Originally published in the Vol. 19, Iss. 3 May/June 2016 issue of *Pottery Making Illustrated*, page 29.*
Most modern windows in residential homes also are double glazed, meaning they contain two panes of glass separated by a small air space, which improves the window’s insulation ability. Window R-values are usually further boosted by filling the space with a lower conductivity gas such as argon.

“The U.S. window market today represents a remarkable transformation to products that use about 50% of the energy that was typical of early 1980s products, but windows still account for about 4 Q [quadrillion BTU] of energy use at an annual cost of $40B,” according to an article from Lawrence Berkeley National Laboratory. 25

While the technology exists to significantly improve the energy efficiency of windows even further—and even take a dynamic leap forward (see sidebar, Rooms with a view)—the challenge is making these products at volume and competitive cost.

One such technology is triple glazing, in which windows contain an additional layer of glass (or, alternatively, a membrane) to further improve insulation by providing two air spaces compared to one with double glazing (Figure 4). Triple glazing is not new, but previous iterations of these windows were bulky, heavy, and expensive.

However, a few key recent events in other markets have now converged to allow manufacturers to further refine tripling glazing technology, making these systems more compact and efficient. First, the rise of smartphones and flatscreen TVs expanded the production sizes and reduced the cost of fabricating large, thin panels of glass. Second, replacement of halogen lamps with LEDs dramatically reduced the demand and thus price of krypton gas, which is used to fill the air space in triple glazed units. 26

Now, thin triple glazing units can be manufactured at more competitive prices with a 1-mm thin pane of glass in between a standard double-glazed unit, with krypton gas filling the now-divided air space (Figure 5).

U.S. window manufacturers Alpen and Andersen are working with Berkeley Lab to develop these window technologies, and it seems these technologies may be coming to the market soon, although they are still more expensive than standard double glazing.

“We have spent some significant time investigating more automated lines capable of making thin-glass units,” Brad Begin, Alpen CEO, says in a Building Green article from early 2019. 26 “I am actively working through a capital plan and in further discussions with potential capital sources to fund the plan.”

Another option to reduce thermal conduction and convection in windows is to nearly eliminate these parameters—by eliminating all air between the glass.

This idea is the concept behind vacuum glazing, a technology that, similar to triple glazing, has been around for decades. “But how we produce it, the sizes we produce it in, and the efficiency in production of materials are all changing,” Schimmelpenningh says.

With vacuum glazed units, however, the seal remains a challenge. “Because the vacuum between the glazing tends to pull the panes of glass together, tiny glass or ceramic spacers are also needed in a grid pattern to hold the glass apart—a technical and aesthetic complication,” according to a Building Green article. 27

The spacing, materials, and design of these spacers are significant considerations beyond aesthetics, as these parameters impact the performance of the resulting window unit as well. However, if technological barriers can be removed, vacuum insulated glazing...
offers the ability to produce windows that are thin and low weight with much higher energy performance.

“New vacuum insulated glass from Guardian Glass (made in the U.S.) and VIG Technologies (made in China) are poised to make serious inroads into the high-performance glazing market in the US. They are not cheap, but if their long-term thermal performance can be verified, they may very well be worth the cost,” according to a recent Building Green article.28

Surfaces: Covered with choices

Floors, ceilings, walls—a house is filled with surfaces waiting to be covered. Many materials fulfill this purpose, from carpets, cement, tile, and wood on the floor to paint, paper, tile, and wood paneling on the walls.

In the late 1980s, U.S. Census Bureau data showed ceramic tile consumption at just over 1 billion ft² per year.29 Thirty years later, consumption reached 3.11 billion ft² in the U.S. in 2018.30 That growth reflects just a 1.5% increase over 2017 numbers, as figures for ceramic tile consumption over the past decade clearly demonstrate that the industry is still recovering from the recession.

In the future, demand for decorative tile is expected to increase 2.4% annually through 2023, with the fastest growth for porcelain tile due to its durability, performance, and aesthetics.31 Part of that slower growth can be attributed to a transformation in the resilient flooring market lately due to rising popularity of multilayer flooring, which includes new hybrid materials such as wood-plastic composite and solid polymer core (SPC) flooring.32 These alternative materials offer durability, comfort, low cost, and ease of installation.

“[SPC is] a very stable product—it’s warm to the touch and it’s much cheaper to install than ceramic tile, so it’s definitely cannibalizing ceramic tile sales,” says Paul Raiche, president and CEO of Ceratec, a ceramic tile manufacturing company (Quebec City, Canada).

Ceramic tile has to innovate because it’s moving around in the value chain right now.”

Part of that innovation is enabled by advancements in the equipment used to manufacture ceramic tiles, which has allowed tile sizes to get much bigger, Raiche says. Technological advancements in production lines allowed manufacturing of larger thin porcelain tiles, along with changes to improve the durability and reduce the weight of these larger formats.

As a testament of the growing popularity of larger format tiles, Italian porcelain tile company Iris Ceramica opened the first large-format thin porcelain tile panel production line in the U.S. in 2018 with its plant in Crossville, Tenn.

“This $70 million investment enhanced the production capacity of the company’s sole U.S. tile manufacturing plant by 20%, adding manufacturing capabilities for 120”×60” panels, as well as large-format panels with 6-mm thicknesses,” according to a Freedonia article.33

The ceramic tile market still has a firm grip on walls, Raiche says. “What is not necessarily changing is feature wall products and backsplashes. What goes on the wall has become more important, as small shapes, geometric shapes, and very decorative materials coming out of ceramic tile factories are being used for walls.”

Innovation in thin glazes to create new finishes and textures allowed tile manufacturers to create looks such as wood grains at the kiln, offering the ability to produce tiles in more shapes, sizes, textures, patterns, and finishes than ever before.

Essential sanitaryware

In the U.S., demand for all plumbing fixtures (which includes bathtubs,
showers, sinks, toilets, hot tubs, spas, bidets, and drinking fountains) is expected to grow at a 5.0% CAGR through 2021 to reach an estimated market size of $7.6 billion.\textsuperscript{34}

While these fixtures are now available in a variety of materials, ceramics still dominate many of the markets. For certain ceramic materials, sanitaryware accounts for a significant proportion of their end-use applications—for example, sanitaryware consumes 15% of ball clay\textsuperscript{35}.

Sanitaryware includes vitreous china (which leads the market), traditional fireclay, and fine fireclay.

“The fine fireclay is more popular in Europe because it gives you the opportunity to have really large formats, big dimensions,” says Felipe Mejia, ceramic engineer manager at Mansfield Plumbing Products. “The fine fireclay offers lower shrinkage rate and more dimensional stability, but it’s also harder to make or to produce [compared to traditional porcelain or washbasins],” which drives up the cost.

While various ceramics are used in washbasins (Figure 6), porcelain continues to be the preferred option for toilets. “It is a relatively cheap material, reliable, it lasts for many years, it doesn’t break easy unless you let something drop on top of it,” Mejia says.

The manufacturing process for toilets has remained relatively unchanged over the years. Innovations instead have focused on toilet functionalities, such as water consumption. “There is a trend always to go toward a lower consumption of water every time you flush,” Mejia says. “Old toilets can use two, three, four times more water than the current toilets that we have on the market. So you can save the environment but at the same time you can save some money if you remodel and switch to the newest versions of the toilet.”

Other innovations in toilet technology include coatings that make the bowl easier to clean and more stain resistant. For example, Lixil (Tokyo, Japan) engineered a super-hydrophilic ceramic surface, called AquaCeramic, that uses water to lift oils and substances off the surface (Figure 7).

According to a Lixil article,\textsuperscript{36} “The more problematic issue of hard water stains, which are caused by silica in the rinse water chemically combining with hydroxyl groups on the surface of the ceramic, has also been solved. AquaCeramic reinvents toilet materials by using a structure that does not expose hydroxyl groups, meaning that hard water stains are unable to build up and the ceramic surface remains flat and smooth.”

Although the company is not willing to share additional details about the AquaCeramic formulation or process, a Lixil press release indicates the company also developed a new glazing technique for the finish that “integrates a special substance to resist waste and hard-water stains at the molecular level,” which it says makes the finish last for 100 years.\textsuperscript{37} Watch a video of AquaCeramic in action at youtu.be/D9MSrnfGQM.

Now we are cooking

Not many materials can claim they provide a sanitary, corrosion-resistant, easy-to-clean, extremely durable, heat-resistant, color-stable, and environmentally friendly finish—yet porcelain enamel can. Perhaps that is why it once coated entire homes (see Figure 8).

Porcelain enamel is primarily limited in modern kitchen appliances to the oven and stove, where it can be found on the top surfaces of burner cooktops, inside the oven cavity and door, and under the cooktop. Porcelain enamel covers cookware too, with an inert, antimicrobial, and long-lasting finish. Porcelain enamel’s durable finish also can still be found on the tops and spinner baskets of some laundry appliances as well as hot water tank liners.

Plastic has replaced porcelain enamel in many appliances because it is quicker, easier, and cheaper to manufacture. “You can injection mold an entire dishwasher cavity, which takes minutes, and it’s done. You don’t have to coat it, and you don’t need any particular labor input to fabricate it—it’s just a cheaper way to go,” says Cullen Hackler, executive vice president of the Porcelain Enamel Institute (Norcross, Ga.).

Color is an important consideration in the porcelain enamel industry. Higher-end appliance models often use porcelain enamel finishes to provide color on the exterior of units, although more affordable units today are likely painted or plastic instead. “One of the biggest drivers in the market is demand for new and different colors to make a product stand out,” says Charles Baldwin, R&D manager of porcelain enamels at Ferro Corp. (Cleveland, Ohio).

Because of those reasons, applications for porcelain enamel in modern homes are growing and can be increasingly
Porcelain enamel can be found as finishes on grills, woodburning stoves, and outdoor fireplaces. Porcelain enamel can be found in the bathroom as well, as a finish for plumbingware such as sinks, bathtubs, and shower trays. Plumbingware actually comprises the largest market for porcelain enamel today, followed by storage water heaters, and then major appliances, Hackler says. That order is reversed from 20 years ago.

In addition to competition from other materials, a significant current challenge for the porcelain enamel industry, perhaps surprisingly, is batteries.

Surging demand for lithium-ion batteries to power the modern world created significant supply and demand imbalances for raw materials lithium and cobalt—materials also important in porcelain enamel manufacturing—resulting in inflated market prices.

“Lithium in porcelain enamel is the most effective glass modifier flux for lowering the melting point of enamel while maintaining a dense glass structure that provides high corrosion resistance and high electrical resistivity for electrostatic application,” Baldwin says.

But replacing these raw materials in porcelain enamel is not a matter of simply swapping a new material in, Baldwin explains. “Other changes need to be made to glass formers and glass modifiers to obtain enamel with similar properties.”

The porcelain enamel industry continues to innovate with new formulations, however. Baldwin says one of the trends Ferro sees is the emergence of alternatives to selfcleaning pyrolytic ovens, once a great selling feature for these appliances. Eliminating the high heat and fumes associated with these cycles is both an energy and health consideration, so more appliances are turning to steam and water cleaning cycles instead.

Ferro’s hydrophilic AquaRealEase enamel product provides new functionality for such appliances. “In a low-temperature oven lined with AquaRealEase, tough soils like baked-on strawberry pie spills wipe clean with a damp cloth after soaking or exposure to steam from water heated at just 190°F for one hour,” according to a Ferro press release.

When it comes to cleaning cooktops, however, nothing beats a smooth or flat cooktop. Often referred to as glass cooktops, that material is actually a glass-ceramic.

“One of the very interesting things about glass-ceramic that makes it a unique material compared to glass or other materials is its near-zero coefficient of thermal expansion,” Karen Elder, product manager of glass-ceramics at Schott North America (Louisville, Ky.), explains. That means it does not react to rapid changes in temperature or large temperature differentials without shattering, warping, or deforming, making it ideal for applications such as cooktops and fireplaces.

One big innovation in glass-ceramic cooktops is induction cooktops, Elder says, which are currently much more popular in Europe than in the U.S. Induction cooktops do not use radiant heating elements to generate thermal energy but rather use an electromagnetic field to induce currents, which heat pots made of metals such as stainless steel and cast iron. Induction cooking generates far less waste heat than radiant heating elements, making it a much more energy efficient process.

However, the lack of traditional heating elements comes with a caveat—because there is no open flame or red-hot heating element, it can be difficult to visually determine if the induction cooktop burner is on.

One solution is to incorporate lights into induction cooktops. “We’re moving into new formulations that allow different colors of light to come through the cooktop, which opens up design opportunities for our customers to integrate things like white light,” Elder says.

Schott’s glass-ceramic provides better light transmission through the material so that lights can be integrated underneath the cooktop—when the lights are off, the cooktop appears uniformly monochromatic; when on, the lights provide a visual cue that a burner is active (Figure 9).

Plus, the lack of heating elements in induction cooktops also opens up new abilities to integrate additional electronics, such as liquid-crystal displays, into cooktops to further bring technology into the kitchen.

Other uses for glass-ceramic include innovations such as grills and toasters equipped with clear glass-ceramic windows. “We are always tweaking [the glass-ceramic] recipe and seeing what we can do to enhance it,” Elder says.

What will the homes of tomorrow look like?

FUTURE HOME

“If you look at current trends, I think you’re going to see smaller homes where you have multifunctional materials, and therefore you don’t need big spaces,” says Eastman Chemical’s Julia Schimmelpenningh. “But those materials are going to have to do more, they’re going to continue to evolve to be multifunctional.”

One of the ways that materials are doing more is through integration of
Right at home—How ceramics and glass contribute to the $4.17T residential building market

Figure 9. Schott’s glass-ceramic cooktop can incorporate lights underneath the cooktop, opening up interesting new possibilities for technology in the kitchen.

Technology. Technology allow us to connect with our homes through the Internet of Things (IoT) and smart technologies in unprecedented ways, allowing integration and crosstalk across diverse platforms.

“The kitchen is one of the places where there’s so much activity happening in the house, and it’s definitely where there’s a gap—there can be more efficient ways to use that time in the kitchen,” says Schott’s Karen Elder.

Innovations in materials such as transparent glass-ceramic options for cooktops are enabling these advances by integrating displays into cooking surfaces, for example, and providing connected multimedia experiences such as the ability to interact with a recipe while actively cooking. These advancements further blur the lines of technology within the home by integrating them ever more seamlessly.

In addition to connecting us to our homes, technology brings improved energy efficiency in buildings. By incorporating sensors, actuators, and microchips to automate processes such as heating and cooling, ventilation, lighting, and security, smart homes offer additional opportunities for houses to improve energy efficiency. “With companies such as Hitachi, IBM, Cisco investing in this technology, the demand for the smart buildings is expected to rise and generate a global revenue of $8.5 billion by 2020,” according to the BCC report.

Future homes will continue adapting to the changing environment as well, especially as severe weather patterns continue to challenge a warming world. “Materials will continue to evolve to be increasingly impact resistant to endure stronger and more frequent storms,” says Saint-Gobain’s Lucas Hamilton.

For example, laminated glazing dramatically increased the safety of building glass especially in hurricane-prone areas, allowing the material to more effectively protect against wind-borne debris.

In many cases, ceramic and glass materials already offer superior solutions over alternative building materials. For example, brick is one of the strongest exterior cladding materials available for homes.

NBRC’s tests with walls built from various exterior cladding materials show that, when faced with a 9lb wooden 2x4 “missile” traveling at about 50 mph, brick is the only material that can withstand the abuse.

“When we hit a typical particle board wall, it goes through the wall. When we hit vinyl siding, it goes through the wall. When we hit EFIS [exterior insulation finishing system, a stucco-like finish], it goes through the wall,” says Sanders, director of NBRC. “When we hit brick, we tend to destroy the missile.” A video of NBRC’s test is available at youtu.be/fDk0QKEc02Q.

Brick also boasts excellent thermal performance as well, which is an important consideration in some parts of the U.S. in light of growing frequency of devastating wildfires. “Having that ceramic material on the outside of your house could buy you extra time,” Sanders adds.

Entire homes constructed out of concrete offer a still more extreme solution to protect inhabitants from severe environmental conditions, including fire and debris.

Ultimately, these diverse evolutions in the construction industry and more broadly in the world may point to serious changes ahead for many building products—but they also represent significant opportunities.

“As the complexity of these systems increases, so does the methodology, the science, the innovation—all that is able to come into these systems more and more,” Schimmelpenningh says. “So the opportunities for innovation increase with the complexity.”

That is good news for the materials that make these building products, as innovation is something the materials do exceedingly well. As preferences continue to demand products that do more, materials will rise to the challenge—pushing for higher performance, becoming more multifunctional, and improving in many other ways.

Ceramic and glass materials have been and will continue to be a significant part of this equation because they provide a unique combination of durability, reliability, performance, and beauty to the structures we inhabit.

“The combination of safety, lifespan, and thermal performance, when you look at the whole, makes ceramic materials really a no brainer,” says Sanders. “They are so far superior to everything else.”

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“The combination of safety, lifespan, and thermal performance, when you look at the whole, makes ceramic materials really a no brainer”
– John Sanders (NBRC)
EMA 2020 is designed for researchers, engineers, technologists, and students interested in basic science, engineering, and applications of electroceramic materials. Speakers include an international mix of university, industrial, and federal laboratory participants exchanging information and ideas on the latest developments in theory, experimental investigation, and applications of electroceramic materials.

Students are highly encouraged to participate in the meeting. Prizes will be awarded for the best oral and poster student presentation.

Please join us in Orlando, Florida, to participate in this unique experience!

SCHEDULE OF EVENTS

TUESDAY, JANUARY 21, 2020
Conference registration 5 – 6:30 p.m.

WEDNESDAY, JANUARY 22, 2020
Conference registration 7:30 a.m. – 6 p.m.
Plenary session 1 8:30 – 9:30 a.m.
Concurrent technical sessions 10 a.m. – 5:30 p.m.
Poster session set up 12:30 – 5 p.m.
Lunch on own 12:30 – 2 p.m.
Coffee break 3:30 – 4 p.m.
Poster session & reception 5:30 – 7:30 p.m.
Basic Science Division tutorial 7:40 – 8:45 p.m.

THURSDAY, JANUARY 23, 2020
Conference registration 7:30 a.m. – 6 p.m.
Plenary session 2 8:30 – 9:30 a.m.
Concurrent technical sessions 10 a.m. – 5:30 p.m.
Lunch on own 12:30 – 2 p.m.
Coffee break 3:30 – 4 p.m.
Student & young professionals reception 5:30 – 6:30 p.m.
Conference dinner 7 – 9 p.m.

FRIDAY, JANUARY 24, 2020
Conference registration 7:30 a.m. – 4 p.m.
Concurrent technical sessions 8:30 a.m. – 5 p.m.
Lunch on own 12:30 – 2 p.m.
Failure: The greatest teacher 3:30 – 5 p.m.

PLENARY SPEAKERS

WEDNESDAY, JANUARY 22
8:30 AM | ROOM: ORANGE A

A.J.H.M. (Guus) Rijnders
Rijnders, MESA+ Institute for Nanotechnology, University of Twente, Netherlands
Title: Novel functionalities in atomically controlled oxide heterostructures by pulsed laser deposition

THURSDAY, JANUARY 23
8:30 AM | ROOM: ORANGE A

Elizabeth Dickey
Associate head of Department of Materials Science and Engineering, North Carolina State University, USA
Title: Defect disorder and dynamics in functional oxides

HOTEL INFORMATION
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Rate:
Group rate from $156+ tax is based on availability. Cut off is on or before December 31, 2019.
Group Name: The American Ceramic Society
Group Code: ACS
TECHNICAL PROGRAM

S1 Characterization of Structure-Property Relationships in Functional Ceramics

S2 Advanced Electronic Materials: Processing Structures, Properties, and Applications

S3 Frontiers in Ferroic Oxides: Synthesis, Structure, Properties, and Applications

S4 Complex Oxide Thin Film Materials Discovery: From Synthesis to Strain/Interface Engineered Emergent Properties

S5 Mesoscale Phenomena in Ferroic Nanostructures: Beyond the Thin-Film Paradigm

S6 Complex Oxide and Chalcogenide Semiconductors: Research and Applications

S7 Superconducting and Magnetic Materials: From Basic Science to Applications

S8 Structure-property Relationships in Relaxor Ceramics

S9 Ion-Conduting Ceramics

S10 Point Defects and Transport in Ceramics

S11 New Directions in Sintering and Microstructure Control for Electronic Applications

S12 Electronic Materials Applications in 5G Telecommunications

S13 Thermal Transport in Functional Materials and Devices

S14 Agile Design of Electronic Materials: Aligned Computational and Experimental Approaches and Materials Informatics

S15 Functional Materials for Biological Applications

S16 Molecular, Inorganic, and Hybrid Ferroelectrics for Optoelectronic and Electronic Applications

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OFFICIAL NEWS SOURCES
Organized by ACerS Engineering Ceramics Division, the 44th International Conference and Exposition on Advanced Ceramics and Composites (ICACC) will be held January 26–31, 2020, in Daytona Beach, Fla. As one of the largest international meetings on emerging ceramic materials and technologies, ICACC20 promises a strong technical program that includes 18 symposia, five focused sessions, and three special symposia covering a variety of topics. ICACC has a strong history in attracting thought leaders and renowned experts on the latest research and developments on advanced structural and functional ceramics.

The technical program will include areas of research, development, engineering, and applications of advanced structural ceramics, composites, and other emerging materials and technologies. The technical program includes topics such as mechanical behavior and performance of ceramics and composites; advanced ceramic coatings for structural, environmental, and functional applications; developments in armor ceramics; bioceramics and biocomposites; advanced materials for rechargeable energy storage; applications and developments of porous ceramics; machine learning; geopolymers and sustainable materials; and much more. Peruse the complete technical program on the next page to see the wide range of symposia topics.

ICACC20 is also a lucrative opportunity for exhibitors looking to connect with decision makers. If you have not already secured your booth space, check out the details on the next page on how to put your company in front of this audience.

We look forward to seeing you in Daytona Beach, Fla., in January 2020!

Valerie Wiesner
Program chair, ICACC 2020
NASA Glenn Research Center
E-mail: valerie.l.wiesner@nasa.gov
Follow @icaccchair on Twitter for updates
TENTATIVE SCHEDULE OF EVENTS

Sunday, January 26, 2020
Conference registration 2 – 7 p.m.
Welcome reception at Hilton 5:30 – 7 p.m.

Monday, January 27, 2020
Conference registration 7 a.m. – 6 p.m.
Opening awards ceremony and plenary session 8:30 a.m. – Noon
Companion coffee 9 – 10:30 a.m.
Lunch on own Noon – 1:20 p.m.
Concurrent technical sessions 1:30 – 5:30 p.m.
Young Professional Network, GGRN, student mixer 7:30 – 9 p.m.

Tuesday, January 28, 2020
Conference registration 7:30 a.m. – 6 p.m.
Concurrent technical sessions 8:30 a.m. – Noon
Lunch on own Noon – 1:20 p.m.
Concurrent technical sessions 1:30 – 6 p.m.
Exhibits and poster session A, including reception 5 – 8 p.m.

Wednesday, January 29, 2020
Conference registration 7:30 a.m. – 5:30 p.m.
Concurrent technical sessions 8:30 a.m. – Noon
Lunch on own Noon – 1:20 p.m.
Concurrent technical sessions 1:30 – 5 p.m.
Exhibits and poster session B, including reception 5 – 7:30 p.m.

Thursday, January 30, 2020
Conference registration 7:30 a.m. – 5:30 p.m.
Concurrent technical sessions 8:30 a.m. – Noon
Lunch on own Noon – 1:20 p.m.
Concurrent technical sessions 1:30 – 5 p.m.
Last night reception 5:30 – 6:30 p.m.

Friday – January 31, 2020
Conference registration 8 a.m. – Noon
Concurrent technical sessions 8:30 a.m. – Noon

REGISTER TODAY!
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EXHIBITION INFORMATION

Reserve your booth today for the premier international advanced ceramics and composites expo. Connect with decision makers and influencers in government labs, industry, and research and development fields. ICACC20 is your destination to collaborate with business partners, cultivate prospects, and explore new business opportunities.

Exhibit hours
Tuesday, Jan. 28, 2020, 5–8 p.m.
Wednesday, Jan. 29, 2020, 5–7:30 p.m.

Exposition location
Ocean Center Arena, 101 North Atlantic Avenue, Daytona Beach, FL

Exhibit space is filling up fast. To reserve your booth, visit www.ceramics.org/icacc2020 or contact Mona Thiel at mthiel@ceramics.org or 614-794-5834.

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Anton Paar 301
AVS, Inc. 307
Centorr Vacuum Industries 200
Ceramics Expo 311
CM Furnaces 214
Eurofins EAG 317
FCT Systeme GmbH 319
Fritsch Milling & Sizing, Inc. 219
Gasbarre 203
Haiku Tech 208
Harper International 313
Honeywell FMT 109
Lithoz America LLC 103
Netzsch Instruments 300
Nordson SONOSCAN 302
Oxy-Gon Industries, Inc. 215
Praxair Surface Technologies 217
Reserved 210
Springer Nature 107
Tethon 3D 111
Tev Tech 206
Thermcraft, Inc. 303
ZEISS Microscopy 201
ZIRCAR Ceramics, Inc. 202
The Pan American Ceramics Congress is to bring together a wide variety of experts from academia, industries, research institutes, and laboratories to discuss current state-of-the-art and various technical challenges in research, development, engineering, manufacturing, and application of ceramic and glass materials. The Congress will provide a collegial forum for information exchange on current status and emerging trends in various technologies in the American continent (South and Central America, Canada, and the United States).

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

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

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About the Pan American Ceramics Congress
During the last 50 years, wide-ranging and groundbreaking research, technology development, and commercialization in the field of ceramics and glass has taken place in the Americas. These seminal contributions to design and engineering of ceramics and glasses for multifunctional properties led to their wide scale applications in energy, aerospace, healthcare, communication, infrastructure, transportation, environmental, and other industries. These technologies and systems led to significant improvements in living standards and quality of life for people from all over the world.

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

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About the Ferroelectrics Meeting of Americas
Ferroelectrics, as well as related phenomena and novel electronic materials development, which introduced new cross-coupled effects like multiferroics and bioferroics to the scientific community, are beginning to integrate with emerging science of the new era around the world. It is especially important to accelerate such communications to the scientific community in the developing countries of the Americas. We brought together representatives from several Central and South American countries working in areas of ferroelectrics and related materials research that includes representatives from each country of the Americas as the members of the FMAs board to conduct a series of meetings, “Ferroelectrics Meeting of Americas–FMAs.”

The FMAs will provide a platform to bring together researchers from academia, industry, and government laboratories to share their knowledge in the field and to present the development of novel applications of ferroelectricity in various interdisciplinary and cross-coupled research areas. FMAs-2 will be held jointly with the Pan American Ceramics Congress.

The conference program may also include some special topical areas for interested participants. The peer-reviewed and accepted papers presented at the meeting will be published in the special volume of International Journal of Ferroelectrics.

PACC TECHNICAL PROGRAM

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

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

January 2020

March 2020
25–26 56th Annual St. Louis Section/Refractory Ceramics Division Symposium on Refractories—Hilton St. Louis Airport Hotel St. Louis, Mo.; https://ceramics.org/event/56th-annual-st-louis-section

April 2020

May 2020
5–6 6th Ceramics Expo – I-X Center, Cleveland, Ohio.; https://ceramics.org/event/6th-ceramics-expo
6–7 Ceramic Manufacturing Solutions Conference – I-X Center, Cleveland, Ohio; https://ceramics.org/event/ceramic-manufacturing-solutions-conference

June 2020

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

August 2020


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

Dates in RED denote new entry in this issue.
Entries in BLUE denote ACerS events.
➤ denotes meetings that ACerS cosponsors, endorses, or otherwise cooperates in organizing.
* denotes Corporate partner

Statement of Ownership
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Toward a structural interpretation of fragility for glass-forming phosphate liquids

The viscosity of glass-forming liquids spans over nearly 15 orders of magnitude between the melting temperature and the glass transition temperature \( T_g \). The rate of how rapidly the viscosity drops with increasing temperature above \( T_g \) is often expressed in terms of “fragility” as:

\[
m = \frac{d \log \eta}{dT} T \to T_g
\]

Scientists have frequently used fragility to classify different glass-forming materials ever since Angell first introduced this important concept in 1988.\(^1\) Strong liquids with small \( m \) are typically network-forming oxides (such as SiO\(_2\)), and the viscosity of these liquids displays an Arrhenius behavior over a large temperature range. In contrast, fragile liquids with large \( m \) are typically molecular or characterized by chains and sparsely connected networks, and their viscosity response is strongly non-Arrhenius. Finding an atomistic explanation to connect the seemingly universal variation of a liquid’s fragility to its structural connectivity is an active area of research in glass physics.

Phosphate liquids, characterized by their wide composition range for glass formation and consequently by a wide range of structural connectivity, serve as excellent model systems for this purpose. Unlike other oxide glasses, the fundamental structures of phosphate glasses are quite unique due to the existence of the P=O double bond on the PO\(_4\) tetrahedra that does not take part in the P-O-P network formation.

The structural connectivity between PO\(_4\) tetrahedra can be lowered by the progressive addition of modifier cations (Figure 1). Moreover, at similar levels of inter-tetrahedral connectivity, the strength of crosslinking between the network elements can be tailored by varying the modifier cation. Stronger crosslinking can be obtained with modifier cations characterized by high coordination number and field strength.

Extensive structural studies have been carried out to understand the structural connectivity and fragility behavior in binary alkali and alkaline-earth phosphate glasses. However, the consistency between the structural results—especially the coordination environment of modifier cations—obtained via different methods (e.g., spectroscopy and diffraction) need to be established. On the other hand, to date only a handful of structural results on binary transition metal phosphate glasses have been reported.

My current research focuses on establishing a mechanistic connection between structural connectivity and fragility of binary transition metal phosphate liquids, particularly tin, zinc, and silver phosphates, using a combination of rheological measurements and NMR spectroscopy.\(^2,3\) In a recent study, I investigated the viscosity and the shear relaxation behavior of supercooled silver- and tin-metaphosphate liquids using rheometric measurements. The fragility index \( m \) of these liquids is shown to be a sensitive function of the strength and extent of crosslinking between the phosphate chains provided by the modifier-oxygen coordination polyhedra.

The silver-metaphosphate liquid displayed a high fragility (\( m = 90 \)), which is a manifestation of the weak inter-chain coupling in this liquid, resulting from the low Ag-O coordination number and the weak field strength of silver ions. The silver-metaphosphate liquid displays a rheological behavior similar to that of a chain polymer, a finding that is in sharp contrast with the network-like behavior of the metaphosphate liquids with lower \( m \). We are now exploring the atomistic details of the chain polymer-like dynamics of silver-metaphosphate liquid using dynamical \(^{31}\)P NMR spectroscopy.

I feel excited to be involved in this research project and sincerely hope my work will shed some light on the fundamental relationship between structural connectivity and fragility in glass-forming liquids. By understanding the network structure better, the manufacturing and processing of glass, which is closely related to the glass transition temperature and fragility behavior of the melts, may be simplified.

References


Yiqing Xia is a Ph.D. candidate in materials science and engineering at the University of California, Davis. In his spare time, he loves to cook and enjoys exploring new recipes and trying out new cuisines. He also enjoys science fiction novels and movies.
In an August blog post, Statistica (statistica.com), the online aggregator of statistics on just about anything, reported that 7,218 magazines were published in the United States—42 more than were published in 2017.

Does the world need a new magazine?

Yes, if the content is relevant, timely, and trusted!

Manufacturers certainly care about near-term and long-term horizons, but they worry about today, tomorrow, next week, and next month. Their concerns are urgent.

_Ceramic & Glass Manufacturing_—ACerS’ NEW B2B magazine—delivers news and information for ceramic and glass manufacturers and businesses. Published quarterly starting December 2019, _C&GM_ provides useful, relevant, and timely articles from experts in the industry.

If you are a manufacturer, plant engineer, plant manager, production leader, operator, supply chain vendor, purchasing manager, sales team member, product developer, or otherwise connected with making and selling ceramic or glass components—this magazine is for you.

In every issue, you will find information you can use to build your business:

- Feature articles focused on practical solutions
- People news
- Business news
- Trade show news and reports

Working with advisors who are themselves ceramic industry manufacturers, we developed themes on topics that relate to your business’s bottom line, your business relationships, and your business efficiency. We look forward to bringing you great content on themes that impact manufacturers.

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ACerS has more than a century of history as the most trusted source of information for the ceramic and glass industry. The Society publishes four peer-review journals and the _ACerS Bulletin_. Late-breaking news and information is published three times weekly in _Ceramic Tech Today_. Discover these resources at www.ceramics.org/publications-resources.

I’d also like to introduce you to David Holthaus, content editor, for _C&GM_. Holthaus, an experienced business journalist, brings many years of insight that will benefit readers.

This is our industry. Ceramics and glass are our business, too. Ensure you get every issue! Sign up today for your free copy at www.ceramics.org/ceramicandglassmanufacturing.

We welcome your feedback and suggestions!

Happy reading,

Eileen De Guire  
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David Holthaus  
Content editor, _C&GM_  
dholthaus@ceramics.org
APPLE INVESTS IN GLASS RESEARCH AT CORNING

Tech giant Apple awarded Corning, a supplier of its precision glass, $250 million from its Advanced Manufacturing Fund.

The award builds on the $200 million the company received from Apple’s Advanced Manufacturing Fund in May 2017. The investments support Corning’s research and development into state-of-the-art glass processes, equipment, and materials for next-generation consumer devices, Apple said.

Glass for every generation of Apple’s iPhone, the Apple Watch, and many generations of iPad, have all been made in Corning Inc.’s Harrodsburg, Ky. facility.

JOINT VENTURE ANTICIPATES DEMAND FOR 5G NETWORK TECHNOLOGY

Rising demand for ceramic filters used in 5G communications networks is behind a joint venture between Kyocera Corp. and Ube Industries, Ltd. The two companies signed an agreement to manufacture filters for 5G base stations.

Kyocera will acquire 51 percent of the shares of Ube Electronics, Ltd., a wholly-owned subsidiary of Ube Industries. Kyocera and Ube Industries will then establish a joint venture named Kyocera-Ube RF TEC Corporation.

5G mobile network technology enables high-capacity, low-latency communications for more connected devices in smart homes, driverless cars, health care, and other applications.

SAINT-GOBAIN TRIMS ITS GLOBAL BUSINESS PORTFOLIO

Saint-Gobain completed several transactions in its ongoing plan to streamline its global portfolio.

The company, based outside of Paris, completed the sale of its Optimera construction materials distribution business in Denmark to Davidsens Tommerhandel. The business posted annual sales of 120 million euros in 2018.

The company completed the sale of its K par K business to two of its managers. The business specializes in the door-to-door sale of customized woodwork and windows in the French market.

K par K generated sales of around 130 million euros in 2018 and employs nearly 1,000 people.

Saint-Gobain also reached an agreement to sell its construction glass unit in South Korea, called Hankuk Glass Industries, to Glenwood Private Equity.

STRATEGIC PORTFOLIO REVIEW UNDERWAY AT O-I

As part of its goal of reducing debt, Owens-Illinois is conducting a strategic review of its business portfolio.

The company is considering a sale of its Asia-Pacific glass container manufacturing business, which consist of four glass manufacturing plants in Australia, two in China, and one each in Indonesia and New Zealand. The company hired investment banking firm Goldman Sachs to negotiate the potential sale.

The company has also announced that it’s planning to install a new furnace at its plant in Holzminden, Germany.

Glass packaging for food and beverages is O-I’s leading product.
AGROMAT PLANS GLASS FACTORY IN UKRAINE

The first float glass factory in Ukraine will be built in that country’s Kiev region by Agromat. Currently, the country’s economy is dependent on products that are imported from Europe and Russia.

The plant’s capacity is expected to be 300 tons a day. The main products will be glass for architectural applications, solar panels, and for household appliances, electronics, and automotive uses.

The facility is expected to employ about 300 and represent a total investment of 300 million euros.

RESEARCH PARTNERSHIP FOCUSES ON LIGHTWEIGHT MATERIALS FOR AUTO SECTOR

Oak Ridge National Laboratory and the University of Toledo reached an agreement to collaborate on research into the advanced design and manufacturing of high-strength, intelligent, lightweight materials for the automotive sector.

The partnership brings together the National Laboratory’s expertise in manufacturing, carbon fiber and composites, machining, energy storage, and metrology with the university’s capabilities in manufacturing system modeling, metals engineering, and assembly systems. The institutions also expect to work with the automotive industry in Ohio and Michigan.

$5 MILLION GRANT EXPANDS RARE EARTH PROJECT AT WEST VIRGINIA UNIVERSITY

West Virginia University was awarded $5 million by the U.S. Department of Energy to scale up its Rare Earth Recovery Project, which will include building a facility at a new acid mine drainage treatment plant.

The university will partner with the West Virginia Department of Environmental Protection to design and build the plant. Rockwell Automation will provide sensor and control technology, and TenCate Corp. will engineer materials for rare earth element extraction from acid mine drainage sludge.

GLOBAL RESEARCH NETWORK LAUNCHED FOR CEMENT AND CONCRETE

The Global Cement and Concrete Association (GCCA) formed a new network to bring together the cement and concrete industry with scientific institutions to expand global research. It’s called Innovandi – the Global Cement and Concrete Research Network.

Network partners plan to research process technology, carbon dioxide reduction, sustainability, and the use of alternative fuels, among other areas.

Twenty-four companies, including cement and concrete manufacturers, admixture specialists, and equipment suppliers, have committed to the initiative.
FIRST CERAMITEC CONFERENCE FEATURED SPEAKERS FROM ACADEMIA AND INDUSTRY

A new ceramitec conference event premiered in September in Munich with more than 200 in attendance from 21 countries.

Speakers from academia and industry focused on new industrial opportunities for ceramics and additive manufacturing processes in the automotive, aerospace, electronics, manufacturing, and health sectors. They included representatives from NASA, Germany’s aerospace research center DLR, the Fraunhofer Institutes and universities, as well as experts from companies including Eirich, Netzsch, and Xjet.

“We wanted to give ceramic an additional forum alongside our trade fairs,” said Gerhard Gerritzen, board member of Messe München, organizer of the conference and the ceramitec trade fair.

The agenda was divided into two tracks. “Shape the Future” looked at the use of additive manufacturing processes in high-performance ceramics. The second track, “Industrial Applications,” examined new uses for high-performance ceramics in industry.

The conference was accompanied by an exhibition that included 3DCERAM, Bayern Innovativ, Ceramic Applications, CFI, Linseis, Lithoz, Nanoe, Netzsch, PresTEC, Schenck Process, Springer Nature, and Steinbach AG.

The next ceramitec trade fair is scheduled for May 17–20, 2021, in Munich.

https://www.ceramitec.com/conference INFORMATION/index.html

CERAMICS EXPO 2020 WILL FEATURE A NEW THEME—CLEAN, ELECTRIFIED, AND EFFICIENT MOBILITY

Ceramics Expo returns to Cleveland, Ohio on May 5–6, 2020. This free-to-attend conference is North America’s leading industry event, bringing the latest news on the application and manufacturing processes of technical ceramic and glass materials. The conference is specially designed for engineers and decision makers from OEMs and tier suppliers in the aerospace, automotive, electronics, energy, medical, and industrial applications.

Brand new for 2020: The conference will adopt the innovative theme of clean, electrified, and efficient mobility. Speakers will share the latest news and information on technologies such as CMCs, catalysts and filtration, technical and industrial coatings, metallization of ceramics, and ceramic coatings on metal alloys, among many other key topics.

MORE THAN 60,000 EXPECTED AT 2020 WORLD OF CONCRETE

Registration opened for World of Concrete, to be held at the Las Vegas Convention Center Feb. 4–7, 2020. More than 60,000 industry professionals are expected at the commercial construction industry’s largest international event for concrete and masonry professionals.

The program features more than 170 seminars covering new technology, technical applications, and strategies for more efficient operations and increased profitability.

Attendees can also visit 1,500 exhibiting companies at the 700,000 square feet of indoor and outdoor exhibit space at the Las Vegas Convention Center.


REGISTRATION OPEN FOR MINERALS RECYCLING FORUM 2020

Mineral Recycling Forum 2020 will be held March 10–11, 2020, in Aachen, Germany, at the Pullman Hotel Aachen Quellenhof. The forum will bring together panelists to discuss trends and developments in secondary raw materials sourcing, supply, processing, quality control, logistics, and their market applications. It will interest those active in the sourcing, processing, distribution, and use of secondary raw materials, especially established industrial mineral suppliers and buyers. Register at imformed.com, and early bird rates are available until Jan. 27, 2020.

www.imformed.com

INDUSTRIAL MINERALS SUPPLY CHAIN FOCUS OF RENDEZVOUS 2020

Imformed Rendezvous 2020 will be held April 6–8, 2020, at the Grand Hotel Huis ter Duin (Noordwijk) in Amsterdam. The forum launched in April 2019 as a conference for a high-caliber overview and outlook across the industrial minerals business. The industrial minerals supply chain from mine to market will be examined. Registration is available at imformed.com.

www.imformed.com
HOW TO DO BUSINESS IN THE CHANGING ECONOMY OF CHINA

By David Holthaus

With the world’s second-largest economy, and one that is still growing, China is an attractive market for any manufacturer looking to expand and do business in one of the most populous countries in the world.

And while the country holds great promise for a business seeking to grow internationally, it should be approached with eyes wide open and an awareness of the potential obstacles. That’s the advice of Michael Silver, who shared his thoughts on doing business in China in an interview with Ceramics & Glass Manufacturing.

Silver knows of what he speaks. He and his company, American Elements, have been operating in China since the early ’90s.

American Elements is one of the world’s largest manufacturers and distributors of advanced materials for industry and research, and its products include rare earths, alloys, and nanoparticles.

Silver is the company’s founder and CEO and an international expert in the field of rare earths, particularly in the political and economic issues surrounding the global supply chain for these elements, which are found in the Earth’s crust and are critical for the production of things we use every day, including computers, cell phones, and fluorescent lighting.

American Elements operates plants, a warehouse, and a sales office in China.
“You can do business in China,” Silver says. “The Chinese are extremely honest people to do business with and the government can be trusted in most respects,” he says.

But changing economic conditions there could present issues. “It’s now a very difficult place to do business for a host of reasons,” he says.

Silver says China is already experiencing a recession that the government has not officially acknowledged. The ongoing trade war, as well as vestiges of China’s planned economy, have contributed to the slowdown, he says.

“There’s a lot bad debt on the banks’ books that they’re not willing to admit to,” he says.

Although China started implementing market reforms in the late ’70s, its conversion from a centrally planned economy is still not complete and that is apparent in a real estate market that has expanded too quickly, he says.

China’s import and exports have been slowing for months amid the protracted trade dispute with the United States that has resulted in the overall China economy growing at a slower pace. For years, the country’s economy grew at an accelerated rate, with its gross domestic product growth averaging nearly 10 percent a year—the fastest sustained expansion by a major economy in history, according to the World Bank.

But in the third quarter of this year, the country’s gross domestic product grew by only 6 percent. That’s strong growth by the standards of the developed world, but for China, it was the weakest economic growth in 27 years.

Over the past eight years, China has contributed nearly a third of the world’s economic growth, the World Bank says. Its current five-year economic plan, from 2016 to 2020, set an annual growth target of 6.5 percent, still fast, but reflecting the rebalancing of its economy, says the global financial institution.

At the start of 2019, the Chinese government announced a stimulus package equivalent to more than $200 billion in U.S. dollars to shore up its economy.

Along with a trade war and a slowing economy, rising labor costs can present another obstacle to growth in China, Silver says.

China’s workforce has been shrinking for nearly 10 years, according to government statistics. That has heated up competition for available

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Michael Silver suggests Vietnam as a good country in which to enter the Southeast Asian market, partly due to its low labor costs, its good ports, and the trustworthiness of its government.

There are other reasons, too. The Vietnam economy is growing at a quick pace. Vietnam’s shift from a centrally planned to a market economy has transformed the country from one of the poorest in the world to a lower-middle income country, according to the World Bank.

The international organization calls Vietnam "one of the most dynamic emerging countries in the East Asia region."

In the medium-term, Vietnam’s economic outlook is positive, the World Bank says. Real gross domestic product growth peaked at 7.1 percent in 2018. The government forecasts that its gross domestic product will grow by 6.8 percent in 2020, due to weaker external demand and continued tightening of credit and fiscal policies. Inflation will be kept to 4 percent, it forecasts.

The country is in the process of privatizing state-owned enterprises and is investing in its infrastructure.

Through the first three quarters of 2019, the country recorded a trade surplus of $6.8 billion, with three main categories of export goods recording a turnover of more than $1 billion, including telephones and components, computers, and electronics and components.

Between 2002 and 2018, more than 45 million Vietnamese people were lifted out of poverty, as poverty rates declined sharply from more than 70 percent to below 6 percent, the World Bank says.
American Elements’ facility in Baotou, China.

Every year, the American Ceramic Society profiles the ceramic and glass industry in a particular country in the October/November issue of the *ACerS Bulletin*.

A profile of China, “China—Tradition and transformation,” was just published this year, and Southeast Asia—Singapore, Malaysia, Thailand, and Indonesia—was profiled in 2017 in an article titled “Markets of magnitude.”

Learn about economic drivers and how those play out in the ceramic and glass industry. Each profile includes a directory to the country’s national labs, universities, and other institutions.

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labor and driven up wages for manufacturers. The cost of labor has more than doubled since American Elements began doing business there in 1993, Silver says.

Manufacturers interested in exploring business opportunities in Southeast Asia could look to two other options—Vietnam and Indonesia—over China, Silver says. Both have business ties to the U.S., low production and labor costs, and good logistics.

Vietnam, in particular, is attractive, he says.

“For those who are labor or cost sensitive, I’d choose Vietnam. They have great ports. The government is honest. The labor pool is interested in working, and the costs are much lower than in China.”

Despite a slowing of its economic momentum, China is critical to the future of refractories and ceramic manufacturers.

Ceramic and glass makers are among the world’s top users of rare earths, and China produced 70 percent of those essential minerals in 2018, the U.S. Geological Survey reports. From 2014 to 2017, China was the source of 80 percent of the imports of rare-earth elements into the U.S., the agency says.

The country possesses more than a third of the world’s rare-earth reserves, with Brazil and Vietnam being distant second and third.

“The most valuable, the rarest, the most expensive rare earths are 100 percent in China,” Silver says.

Other critical elements, while not technically rare earths, are also controlled by China. Hafnium, for example, which is used in filaments and electrodes, as well as semiconductors.

China created what Silver called a “sovereign monopoly” with its rare-earth riches. The government employed export duties and a quota system to drive up prices of the materials outside of China. That put pressure on downstream producers to move their operations, jobs, and technologies to China.

In 2010, the country reduced its exports by 40 percent, sending rare earths prices in the U.S. and other markets outside China soaring. That led to the U.S., Japan, and the European Union bringing a case before the World Trade Organization, which they won. After an appeal, China dropped its export restrictions in 2015.

More recently, with trade tensions between China and the U.S. heating up, China has suggested that it might restrict exports of rare earths to the U.S.

Silver says it would be in the economic interests of China, the U.S., and the rest of the global manufacturing industry if rare earths are included as part of any trade deal between the two countries.

Despite these potential hurdles, China can be a promising place to set up shop, especially if manufacturers already have established supply chain relationships in the country, Silver says.

And, speaking from more than two decades of experience there, the people are good to work with.

“You can make a deal in China and people will honor it,” he says.
THE 2020 CMSC PROGRAM WILL TAKE A DEEP DIVE ON THREE IMPORTANT AREAS:

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

www.Ceramics.org/CeramicMfgCon
India has always been one of the world’s great sources and markets for industrial minerals, but now looks set to significantly raise its profile.

Already the world’s fifth largest manufacturer, India remains on track to be the world’s fastest growing economy with the International Monetary Fund estimating gross domestic product growth of 7.3 percent for fiscal 2019 and 7.4 percent for fiscal 2020.

Meanwhile, the fiscal average in GDP growth in the last five years has topped 7.5 percent, defining a new normal for the Indian economy.

This economic boom has naturally driven strong growth in primary mineral consuming market sectors such as construction, steel, foundry, cement, glass, ceramics, paper, paint, and plastics. This growth has been reflected in recent activity by overseas manufacturers keen to establish subsidiaries and participate in joint ventures in India, for example, RHI Magnesita, Imerys, Vesuvius, Omya, and Almatis.

At the start of 2019, India overtook Japan as the world’s second largest steel producer, and by the end of the year is expected to become the world’s second largest steel consumer.

However, despite having an abundance of mineral resources, some of which still enjoy strong export markets, there are certain domestic markets which have been caught out by their over-reliance on Chinese mineral imports—now interrupted, and in some cases declining in availability, while fluctuating in price—which has forced an urgent reassessment of domestic and import options.

This has given rise to a new wave of mineral resource and product development in India (and other Asian countries) as the challenge grows for consumers keen to secure new and alternative sources of industrial mineral supply as their markets expand.

The mining and minerals sector in India is expected to witness a major upward transition in the next few years, boosted by a new National Mining Policy unveiled in February 2019 (to mixed reviews), and driven by nationwide reforms such as “Make in India” initiative (making India a global manufacturing hub), “Smart Cities Mission” (urban renewal and retrofitting), “Saubhagya scheme” (rural electrification), and a focus on building renewable energy projects under the National Electricity Policy.

Rising demand from infrastructure and transportation sector schemes such as housing for all by 2022, “Bharatmala Pariyojana scheme” (84,000 kilometers of new highways by 2022), expansion of the railway network, and development of “Industrial Corridors” (e.g., Amritsar-Delhi-Kolkata, Bengaluru-Mumbai, Visakhapatnam-Chennai) will also help boost and facilitate mineral demand.

**INDIA’S MINERALS: DOMINATED BY NONMETALLICS**

During 2017–18, India’s mining and quarrying industry accounted for about 2.3 percent of the gross value added (GVA) at current prices, and, according to the latest data from the Indian Bureau of Mines (IBM), mineral production in India increased by 2.3 percent (as per index of mineral production base year 2011–12) compared to the previous year.

This increase was mainly owed to a rise in production of raw coal, lignite, and natural gas among fuel minerals; copper concentrates, gold, iron ore, lead concentrates, zinc concentrates, manganese ore, and tin concentrates, among metallic minerals; and phosphate, diamond, fluor spar, garnet, kyanite, sillimanite, and limestone among nonmetallic minerals.
The value of metallic minerals produced in 2017–18 was INR500 billion (US $7 billion), an increase of about 27 percent over the previous year. Nonmetallic minerals’ value was INR82 billion (US $1 billion), representing a decrease of 2 percent.

However, it should be noted that these figures do not account for “atomic minerals” (uranium, thorium, niobium, tantalum, beryllium, lithium, zirconium, titanium, rare earths), and, crucially, “minor minerals” (all other industrial minerals) as classified by the IBM.

INVESTMENT: CLIMATE RIPE ALTHOUGH NEW MINING POLICY QUESTIONED

With barely 20 percent of reserves mined, India presents a major opportunity for investors. The Geological Survey of India has earmarked 100 blocks for auctioning regional exploration.

One hundred percent FDI is allowed in the steel and mining sectors under the automatic route, and some US $13.83 billion of FDI has been channeled into the metallurgical and mining sectors since 2000.

On 28 February 2019, the Union Government approved the National Mineral Policy 2019, the key focus of which is on transparency, better regulations and enforcement, balanced growth, and sustainability. The National Mineral Policy 2019 replaces the National Mineral Policy 2008.

Key features include:

- Encouraging the private sector to take up exploration
- Encouragement of merger and acquisition of mining entities
- Creation of dedicated “mineral corridors” to boost private sector mining areas
- Proposals to grant status of industry to mining activity to boost financing of mining for private sector and for acquisitions of mineral assets in other countries by private sector
- Long term import-export policy for minerals will help private sector in better planning and stability

Of high concern is a perceived lack a focus on the future of India’s minerals security. Owing to little or no major exploration and discoveries of certain domestic minerals, there has not been any significant change to their inventory base for decades. Moreover, there has been little development in required mineral processing technology. Opportunity knocks for new mineral investors and developers?

REFRACTORIES: DRIVEN BY STEEL GROWTH

India is now the second largest crude steel producer in the world, generating an output of 106.5 million tonnes in 2018, a growth of 3.7 percent year-on-year. Indian steel demand is set to grow by 7.1 percent in 2019 while globally, steel demand has been projected to grow by 1.3 percent. India is certainly one of the few bright spots for world steel growth.

As well as expanding, the Indian steel industry is producing higher grade steels which is demanding higher quality refractories and consequently higher quality refractory minerals. A major challenge is that much of India’s refractory raw material requirements are imported.

Refractories production in India for fiscal 2018–19 was 1.2 million tonnes, representing a significant recovery and growth of 9 percent over the previous year, driven mostly by steel, but also by the country’s growing cement and glass sectors.

Leading international refractory groups are present in India, for example Krosaki Harima, RHI Magnesita, and Vesuvius, and activity is increasing.

May 2019 saw Dalmia Seven, the Katni, Madhya Pradesh-based monolithics joint venture between Dalmia-OCL, India’s fastest growing refractory company, and Seven Refractories of Slovenia come on stream.

CERAMICS & FILLERS: CONSTRUCTION BOOM LOOMS

Driven by the growing construction sector and a rise in exports, the Indian ceramic industry, which has the potential to be the largest producer in the world, is looking to double its turnover by 2021.

The industry produces around 2.5 percent of the total global output, in which Gujarat accounts for 70 percent of the total output.

With many new infrastructure projects in the pipeline, the construction sector is growing at an approximate rate of 7–8 percent per annum. The demand for industrial ceramic products such as ceramic tiles, sanitaryware, and pipes required in construction applications are therefore expected to follow suit.

PROCESSING: ESSENTIAL SUPPORT TO MINERAL DEVELOPMENT

Core to the successful development and expansion of India’s mineral sector is the investment in and utilization of modern processing technology.

Without the appropriate crushing and grinding equipment, calcination technologies, and beneficiation methods, India’s minerals will be unable to meet the growing and increasingly sophisticated requirements of the expanding minerals consuming markets.

FUTURE DEVELOPMENTS: ELECTRIFICATION & BATTERY MARKETS

As well as meeting the demand of India’s growing existing markets, mineral developers are also looking to the future mineral consuming markets in the region, in particular, the new generation energy markets using lithium-ion batteries and solar power.

The lithium-ion battery market is expected to grow exponentially in the next five years in India, driven by initiatives such as the National Electric Mobility Mission Plan 2020, with a projection of having 6–7 million electric vehicles on Indian roads by 2020, and installation of 175 GW of renewable energy by 2022.

ABOUT THE AUTHOR

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ACerS Annual Meeting at MS&T—New awards, new officers, future meetings

The ACerS President’s Council of Student Advisors (PCSA) also held their annual meeting on Saturday, September 28. At their annual meeting, new PCSA officers for 2019–2020 were initiated.

AWARD LECTURES

Several important ACerS award lectures took place during the Annual Meeting, including the Edward Orton Jr. Memorial Lecture given by Minoru Tomozawa (Rensselaer Polytechnic Institute); the Arthur L. Friedberg Ceramic Engineering Tutorial and Lecture given by Kathleen Richardson (University of Central Florida); the Rustom Roy Lecture given by Jennifer Lewis (Harvard University); the Distinguished and Young Scholar Alfred R. Cooper Award Lectures given, respectively, by Richardson and Wataru Takeda (Coe College); and the Robert B. Sosman Lecture given by Yury Gogotsi (Drexel University).

New this year was the Navrotsky Award for Experimental Thermodynamics of Solids, named in honor of ACerS Fellow Alexandra Navrotsky (Arizona State University). The award is given biennially to an author who made the most innovative contribution to experimental thermodynamics of solids technical literature during the two calendar years prior to selection. The first winner of the Navrotsky Award was Alexander Beaulé, a junior scientist at the Austrian Institute of Technology.

A

CerS 121st Annual Meeting at MS&T19 took place Sept. 29–Oct. 3, 2019, in Portland, Ore. Over 2,900 people, including 788 students, from 47 countries attended the event.

“This year’s ACerS Annual Meeting at MS&T was very successful, and demonstrates the huge commitment put in by everyone involved to make this event happen,” Mark Mecklenborg, ACerS Executive Director, says.

Various meetings, award lectures, and student competitions took place during the Annual Meeting, a few of which are highlighted below.

MEETINGS

On Monday, September 30, the 121st ACerS Annual Meeting took place at the Oregon Convention Center in Portland. ACerS president Sylvia Johnson (2018–2019) summarized the Society’s 2018–2019 accomplishments, specifically making note of the steps taken to increase diversity and inclusion in the Society within the past year. After retiring officers and directors on the ACerS Board of Directors and Executive Committee were recognized and new officers and directors sworn in, ACerS president Tatsuki Ohji (2019–2020) talked about his goals for the Society next year.

The day before the Annual Meeting, on Sunday, the ACerS Board of Directors and ACerS Division, Section, and International Chapter leaders met to report on the current state of their respective groups and discuss ideas for making each group more active.

Newly sworn-in ACerS president Tatsuki Ohji (2019–2020) addresses everyone at the ACerS 121st Annual Meeting.
At the ACerS Annual Banquet on Monday, September 30, ACerS president Sylvia Johnson (2018–2019) presented the 2019 ACerS Fellows and Distinguished Life Members with plaques. Twenty members were elevated to Fellow Status this year, and three members were awarded the distinction of Distinguished Life Member: Winnie Wong-Ng, Minoru Tomozawa, and Dawn Bonnell.

STUDENT COMPETITIONS

On Sunday, September 29, students competed in the Material Advantage Undergraduate Student Speaking Contest, a contest meant “to encourage undergraduate students to present technical papers and to improve their presentation skills.” Four students competed in the finals, and Victoria Reichelderfer (University of Connecticut) was announced the winner for her presentation “Phase field modeling of corrosion.”

The annual ceramic mug drop and disc throw contests sponsored by Keramos, the national professional ceramic engineering fraternity, took place Tuesday, October 1. Thirty-two mugs were entered in the mug drop competition this year. Undergraduate and graduate student poster contests also took place that day.

New this year was Humanitarian Pitch Competition, a competition for students to pitch ideas to a panel of judges about how to address a challenge that a community is experiencing. Three student teams competed in this new event, which took place Sunday, September 29.

ACerS 122nd Annual Meeting at MS&T20 will take place Oct. 4–8, 2020, in Pittsburgh, Pa. ACerS and its MS&T partners—TMS and AIST—arranged 10 additional symposia for next year, which increases the number of technical sessions at MS&T20 to almost 100.

Abstracts for MS&T20 can be submitted any time before March 15, 2020.

Career Opportunities

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| Electricity Conducting Powders | Electrode | Electrochemical Analysis Instruments | Electrolytes |
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- Hexion Inc OH

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- Polymer Innovations Inc CA
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- Shamrock Technologies Inc NJ
- Tetron 3D NE
- Trinity Ceramic Supply Inc TX
- Vanderbilt Minerals LLC CT
- Wesbond Corp DE
- Zschimmer & Schwarz GA

**Colorants**
- American Chemet Corp IL
- Artimin Industries CO
- Cancarb Limited Canada See ad page 117
- Ceramic Color & Chemical Mfg Co PA See ad page 75
- Fusion Ceramics Inc OH
- Hunter Chemical LLC PA
- Imerys Refractory Minerals GA
- Laguna Clay Co CA
- Mason Color Works Inc OH
- RISE Research Institutes of Sweden RISE Glass Sweden
- Sauereisen Inc PA
- Wistra GmbH Germany

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**Glaze Hardeners**
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Hunter Chemical LLC PA
Innovam - Advanced Materials SA Portugal
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Vanderbilt Minerals LLC CT
Zschimmer & Schwarz GA

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Zschimmer & Schwarz GA

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Zschimmer & Schwarz GA

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Empower Materials Inc DE
Nyacol Nano Technologies Inc MA
Polymer Innovations Inc CA
Starfire Systems Inc NY

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Zschimmer & Schwarz GA
ZYP Coatings Inc TN

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Polymer Innovations Inc CA

Viscosity Stabilizers
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Norcross Viscosity Controls MI
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Advanced Ceramic Technology CA
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Altena NA LLC OH
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Aremco Products Inc NY
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Carfase France
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Israel Ceramic & Silicate Inst Israel
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Zibo Guangtong Chemical Co Ltd China
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Dowa High Temp Furnaces India
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CeramTec-ETEC Germany
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Blasch Precision Ceramics Inc NY

Ceramco Inc NH
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- CerarNova Corp MA
- Ceraminov France
- Ceristle France
- CerPoTech AS Norway
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CerPoTech AS Norway
FELDCO Int’l CA
H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany

Terbium Oxide
Alfa Aesar Johnson Matthey MA
C&L Development Corp CA
CerPoTech AS Norway
Leico Industries Inc NJ
Nanocerox UT

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Arlimin Industries CO
CerPoTech AS Norway
FELDCO Int’l CA
Goodfellow Corp PA
Trinity Ceramic Supply Inc TX

Titanium & Compounds
APF Recycling Inc OH
Atlantic Equipment Engineers NJ
C&L Development Corp CA
FELDCO Int’l CA
Goodfellow Corp PA
H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
Leico Industries Inc NJ
Nanocerox UT
TAM Ceramics NY

Titanium Carbide
Atlantic Equipment Engineers NJ
Beijing Cerametek Materials Co Ltd China
FELDCO Int’l CA
H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
Reade Advanced Materials RI

Titanium Diboride
Dunhuang Zhengyong Abrasive Co Ltd China
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H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
Momentive Performance Materials Inc NY
New Tech Ceramics Inc IA
Pred Materials International Inc NY
Surmet Corp MA

Titanium Dioxide
BassTech Int’l NJ
Beijing Cerametek Materials Co Ltd China
FELDCO Int’l CA
Fusion Ceramics Inc OH
Nanocerox UT
ngimat LLC KY
Pred Materials International Inc NY

Titanium Nitride
Atlantic Equipment Engineers NJ
FELDCO Int’l CA
H.C. Starck North American Trading LLC MA
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Pred Materials International Inc NY

Tungsten Carbide
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Atlantic Equipment Engineers NJ
C&L Development Corp CA
Centerline Technologies MA
Custom Processing Services PA
FELDCO Int’l CA
H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
MSE Supplies AZ
PicoParts Ltd Israel
Pred Materials International Inc NY

Tungsten Oxide
CerPoTech AS Norway
FELDCO Int’l CA
H.C. Starck North American Trading LLC MA

Uranium & Compounds
Wistra GmbH Germany

Vanadium & Compounds
Atlantic Equipment Engineers NJ
CerPoTech AS Norway
FELDCO Int’l CA

Yttria
APF Recycling Inc OH
Associated Ceramics & Technology Inc PA
Bullen OH
CoorsTek CO
ESL ElectroScience PA
H.C. Starck North American Trading LLC MA

See ad page 67
See ad page 77
Zirconia, High-Purity
APF Recycling Inc OH
Applied Ceramics Inc CA
CoraTek CO
Innovano - Advanced Materials SA Portugal
Nanocerox UT
Nanoface
Sauereisen Inc PA
Zibo Guangtong Chemical Co Ltd China

Zirconia, Refractory-Grade
McDaniel Advanced Ceramic Technologies LLC PA
Nanoface
Washington Mills Electro Minerals Co NY
Zircoa Inc OH

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CerPoTech AS Norway
FELDCO Int’l CA
Goodfellow Corp PA
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H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
Innovano - Advanced Materials SA Portugal
Ludger MEL Technologies NJ
Monofrax LLC NY
Saint-Gobain Ceramics & Plastics MA
Zibo Guangtong Chemical Co Ltd China

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H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany

Zirconium Carbonate
C&L Development Corp CA
Zibo Guangtong Chemical Co Ltd China

Zirconium Diboride
H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany

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Fluid Energy Processing & Equipment Co PA
Hindaco Industries Limited India
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Prince Minerals Inc TX

Bentonite
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Reade Advanced Materials RI
Trinity Ceramic Supply Inc TX
Vanderbilt Minerals LLC CT

Borax
Rio Tinto Minerals Australia

Chromite
Prince Minerals Inc TX

Clays, Ball
Fusion Ceramics Inc OH
Imerys GA
Old Hickory Clay Co KY
Sheffield Pottery MA

Clays, China
Fusion Ceramics Inc OH
Imerys GA
Old Hickory Clay Co KY
Sheffield Pottery MA
Sibelco Benelux Belgium
Vanderbilt Minerals LLC CT

Clays, Enamel
Old Hickory Clay Co KY
RISE Research Institutes of Sweden RISE Glass Sweden
Sibelco Benelux Belgium
Vanderbilt Minerals LLC CT

Clays, Engobe
Imerys GA
Old Hickory Clay Co KY
Sheffield Pottery MA
Sibelco Benelux Belgium
Vanderbilt Minerals LLC CT

Clays, Fire or Refractory
Alley Refractories Co MO
Christy Minerals LLC MO
Endecott Clay Products Company NE
Furnace Products & Services Inc PA
Imerys Refractory Minerals GA
Maryland Refractories Co OH
Old Hickory Clay Co KY
Peter Pugger Mfg Inc CA
Riverside Refractories Inc AL
Sheffield Pottery MA
Sibelco Benelux Belgium

Clays, Glaze
Imerys GA
Old Hickory Clay Co KY
Peter Pugger Mfg Inc CA
Sheffield Pottery MA
Sibelco Benelux Belgium

Clays, Stoneware
Christy Minerals LLC MO
Old Hickory Clay Co KY
Peter Pugger Mfg Inc CA
Sheffield Pottery MA
Sibelco Benelux Belgium
Vanderbilt Minerals LLC CT

Cordierite
Maryland Ceramic & Steatite Co Inc MD
Mason Color Works Inc OH
Reade Advanced Materials RI
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Diatomaceous Earth
Reade Advanced Materials RI

Dolomite
Fusion Ceramics Inc OH
Sibelco Benelux Belgium
Trinity Ceramic Supply Inc TX

 Feldspar
Avolon Advanced Materials Inc Canada
Fusion Ceramics Inc OH
Imerys GA
Prince Minerals Inc TX
Sheffield Pottery MA
Sibelco Benelux Belgium
Trinity Ceramic Supply Inc TX

Flint
Christy Minerals LLC MO
Fusion Ceramics Inc OH
Sheffield Pottery MA

Forsterite
Du-Co Ceramics Company PA
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD See ad page 75

Kaolin
Arkema Inc PA
Bosai Minerals Group Co Ltd China
Christy Minerals LLC MO
Fusion Ceramics Inc OH
Imerys GA
Imerys Refractory Minerals GA
M&M Clays Inc GA
Old Hickory Clay Co KY
RE Carroll Inc PA
Reade Advanced Materials RI
Sheffield Pottery MA
Trinity Ceramic Supply Inc TX
U.S. Silica Co MD
Vanderbilt Minerals LLC CT

Kyanite
Kyanite Mining Corp VA

Lime & Limestone
Prince Minerals Inc TX
RE Carroll Inc PA

Lithium Minerals
Avion Advanced Materials Inc. Canada
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Fluid Energy Processing & Equipment Co PA
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Mica
Imerys GA

Montmorillonite
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Mullite
Christy Minerals LLC MO
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Momentive Performance Materials Inc NY
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Rutile
Fusion Ceramics Inc OH
Prince Minerals Inc TX

Sapphire
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Centerline Technologies MA See ad page 86
Goodfellow Corp PA
MSE Supplies AZ

Silica
APF Recycling Inc OH
Centerline Technologies MA See ad page 86
CONSTRUCTION CERAMICS

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Imerys Refractory Minerals GA
Maryland Refractories Co OH
Prince Minerals Inc TX
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Trinity Ceramic Supply Inc TX
U.S. Silica Co MD

Soda Ash

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NE Carroll Inc PA

Spinels

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Fluid Energy Processing & Equipment Co PA
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Washington Mills Electro Minerals Co NY

Spodumene

Avalon Advanced Materials Inc. Canada
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Prince Minerals Inc TX
Trinity Ceramic Supply Inc TX

Steatite

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Talc

Custom Processing Services PA
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Vanderbilt Minerals LLC CT

Wollastonite

Bosai Minerals Group Co Ltd China
Fusion Ceramics Inc OH
Reade Advanced Materials RI
Trinity Ceramic Supply Inc TX

Zircon

APF Recycling Inc OH
Fusion Ceramics Inc OH
Lithoz GmbH NY
Prince Minerals Inc TX
Reade Advanced Materials RI
TAM Ceramics NY

Brick

Belden Brick Co OH
Belden Brick Industry Aesn VA
Cancarb Limited Canada  See ad page 117
Endicott Clay Products Company NE  See ad page 56
Niokem Inc NC
Zibo Guangtong Chemical Co Ltd China

Brick & Paving

Belden Brick Co OH
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Pipe Ceramic-Lined

CerCo LLC OH

Sanitaryware

Roca Sanitario SA Spain
Zibo Guangtong Chemical Co Ltd China

Tile, Floor & Pavers

Endicott Clay Products Company NE  See ad page 56
Foundation Floors FL
Heartland Wood Flooring FL
Somany Ceramics Ltd India

Tile, Wall

Comtrust Architectural Mesh Co Ltd China

Endicott Clay Products Company NE  See ad page 56
Peter Pugger Mfg Inc CA
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Advanced Materials Associates CO
Bharat Heavy Electricals Ltd India
Cerakote Ceramic Coatings OR
CoorsTek CO
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New Tech Ceramics Inc IA
Technology Assessment and Transfer Inc (TA&T) MD
Teeter Marketing Services LLC FL
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD  See ad page 75
Viridis3D LLC MA

Analytical Services

Activation Laboratories Ltd Canada
Alfred University NY
AVEKA MN

Bamas Machine Specialties Inc MA  See ad page 85
Cancarb Limited Canada  See ad page 117
CelSian Glass & Solar BV The Netherlands  See ad page 83
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CoorsTek CO
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Geller Microanalytical Laboratory Inc MA
GrainBound LLC PA  See ad page 111
H&M Analytical Services Inc NJ
Hindalco Industries Limited India
Hitech Materials Pty Ltd New South Wales
Israel Ceramic & Silicate Inst Israel
JTF Microscopy Services Inc NY
Micrometrics Instrument Corp GA
Micron Inc DE
NSL Analytical Services Inc OH
OPF Enterprises TX
Particle Technology Labs IL
Quantachrome Instruments FL
Refractory Consulting Services OH
RISE Research Institutes of Sweden RISE Glass Sweden
SEMTech Solutions Inc MA

Spectrochemical Laboratories XXXX PA
TA Instruments DE

Brick & Structural Clay Processing

Ceramic India
Lucideon UK
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OPF Enterprises TX
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Zircon Inc OH

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Certherm France
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Litigation
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Lucideon UK
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Ceramic Tech North America Corp SC
Cerimorph France
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Lucideon UK
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O’Keefe Ceramics Inc CO
OPF Enterprises TX
P-Ker Engineering NY
Refrac Systems AZ
SEMETCOR
Semiconductor Energy Laboratory Co Ltd Japan
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Wistra GmbH Germany

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NSL Analytical Services Inc OH
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Particle Technology Labs IL
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Refractory Consulting Services OH
Semiconductor Energy Laboratory Co Ltd Japan
See ad page 111

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Patents
Modern Times Legal MA
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Spontaneous Materials CO
Teeter Marketing Services LLC FL

Professional Engineer
NSL Analytical Services Inc OH
Spontaneous Materials CO
Texers Technical Ceramics Inc Canada
Verity Technical Consultants LLC OH

Quality Management/ISO 9000
Lucideon UK

Refractories
CelSian Glass & Solar BV The Netherlands See ad page 83
Ceramitec Germany
Dunhua Zhengxing Abrasive Co Ltd China
Edward Orton Jr Ceramic Foundation OH
Fluid Energy Processing & Equipment Co PA
Fosbel Inc OH
Hitech Materials Pty Ltd New South Wales
Industrial Ceramic Products Inc OH
Ipsen Ceramics IL
JTF Microscopy Services Inc NY
Laguna Clay Co CA
Lucideon UK
Maryland Refractories Co OH
Missouri Refractories Co (MORCO) MO
NSL Analytical Services Inc OH
Refractory Consulting Services OH
Silicon Carbide Products Inc NY
Teeter Marketing Services LLC FL
Texers Technical Ceramics Inc Canada
Viridis3D LLC MA
Wistra GmbH Germany

Research
Advanced Materials Associates CO
Alfred University NY
ARBURG GmbH + Co KG Germany
AVEKA MN
CelSian Glass & Solar BV The Netherlands See ad page 83
Ceralink Inc NY
Cerilase France
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GrainBound LLC PA See ad page 111
Inst for Applied Materials-Ceramics in Mechanical Engineering Karlsruhe Inst of Technology Germany
Laitéis GmbH Luxembourg
Lithoz GmbH NY
Lucideon UK
OPF Enterprises TX
Refrac Systems AZ
RISE Research Institutes of Sweden RISE Glass Sweden
Technology Assessment and Transfer Inc (TA&T) MD
Viridis3D LLC MA
Wistra GmbH Germany

Semiconductors (Consultants)
Suntech Advanced Ceramics (Shenzhen) Co Ltd China
3D-Printing Market Revenues Expected To Skyrocket By 2020

The additive manufacturing industry is poised for a boom between now and 2020, according to International Data Corp. The value of the worldwide market for 3D printing is expected to jump to $35.4 billion by 2020, more than double the $15.9 billion forecast for the end of 2016, IDC data shows.

The compound annual growth rate between 2015 and 2020 is 24.1%, the IDC said.

"While 3D printers and materials will represent nearly half the total worldwide revenues throughout the forecast, software and related services will also experience significant growth," said an IDC statement.

"Revenues for computer-aided design software are forecast to triple over the five-year forecast period while the market for on-demand parts printing will nearly match this growth. The gains in both software and on-demand parts printing are being driven by the rapidly expanding use of 3D printing for design prototyping and products that require a high degree of customization in non-traditional environments."
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FCT Ingenieurkeramik GmbH Germany
FELDCO Int CA
Ferro Ceramic Grinding Inc MA
Fosbel Inc OH
Laserage Technology Corp IL
Machined Ceramics Inc KY
Maryland Ceramic & Steatite Co Inc MD
McDanel Advanced Ceramic Technologies LLC PA See page 65
Morgan Technical Ceramics CA

O’Keeffe Ceramics Inc CO See page 87
Ortech Inc CA
Precision Ceramics FL

PremaTech Advanced Ceramics XXXX MA
Progressive Technology Inc CA
Ram Products Inc OH
Refractory Machining Services PA
RocCera LLC NY
Stahil USA Inc WI
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Technical Products Inc WI
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Ferro Ceramic Grinding Inc MA
Fluid Energy Processing & Equipment Co PA
MSE Supplies AZ
Powder Processing & Technology LLC IN
Precision Ceramics FL
PremeTech Advanced Ceramics MA
Reade Advanced Materials RI
Refractory Machining Services PA
RocCera LLC NY
Stedman Machine Co IN
Union Process OH
Valley Design Corp MA
Washington Mills Electro Minerals Co NY

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Morgan Technical Ceramics CA
Peter Pugger Mfg Inc CA
Refract Systems AZ
Verity Technical Consultants LLC OH

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CerPoTech AS Norway
Electrosciences Ltd UK
Haiku Tech Europe BV The Netherlands
Haiku Tech Inc FL
Meggitt Piezo Technologies IN
Sparkler Ceramics Pvt Ltd India

Powder Synthesis
CerPoTech AS Norway

Prototypes
Accuratus Corp NJ
Advanced Ceramic Technology CA
Astro Met Advanced Ceramics Inc OH
Bullen OH

Screen Printing
Aremco Products Inc NY
Gwent Electronic Materials Ltd UK
Haiku Tech Europe BV The Netherlands
Haiku Tech Inc FL

Screening, Custom
AVEKA MN
CerPoTech AS Norway
Fluid Energy Processing & Equipment Co PA
General Spray LLC NJ
Reade Advanced Materials RI

Seals
Astro Met Advanced Ceramics Inc OH
Bharat Heavy Electricals Ltd India
CerCo LLC OH
Dunhua Zhengxing Abrasive Co Ltd China
Elan Technology GA
Ferro Ceramic Grinding Inc MA
Morgan Technical Ceramics CA
Ortech Inc CA
P-Ker Engineering NY
Precision Ceramics FL
Refrac Systems AZ
Saint-Gobain High Performance Ceramics & Refractories MA
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CeramTec North America Corp SC
CerPoTech AS Norway
Dorst America Inc PA
Elan Technology GA
General Spray LLC NJ

Superconductors
Precision Ceramics FL

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CerPoTech AS Norway
Custom Processing Services PA
Euro Support Advanced Materials The Netherlands
Fluid Energy Processing & Equipment Co PA
Fusion Ceramics Inc OH
General Spray LLC NJ
Gwent Electronic Materials Ltd UK
Peter Pugger Mfg Inc CA
Powder Processing & Technology LLC IN
Reade Advanced Materials RI
Refrac Systems AZ
TAM Ceramics NY

Toll Firing, Contract
ACCCO Inc/Burley Clay Products Co OH
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Astro Met Advanced Ceramics Inc OH
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Enamels
Ceramic Color & Chemical Mfg Co PA See ad page 75
Cerinnov France
Cerlase France
Fusion Ceramics Inc OH
RISE Research Institutes of Sweden RISE Glass Sweden

Engobes
American Art clay Co Inc IN

Frits
Ceradyne Inc a 3M Co KY
Ceramic Color & Chemical Mfg Co PA See ad page 75
Fusion Ceramics Inc OH
RISE Research Institutes of Sweden RISE Glass Sweden

Glazes
American Art clay Co Inc IN
Ceramic Color & Chemical Mfg Co PA See ad page 75
Cerlase France
Fusion Ceramics Inc OH
Laguna Clay Co CA
Mason Color Works Inc OH
RISE Research Institutes of Sweden RISE Glass Sweden
Sheffield Pottery MA

Glazing Equipment
Artimin Industries CO
Cerinnov France
Du-Co Ceramics Company PA
HED INtl Inc NJ

Inks
American Art clay Co Inc IN
Ceramic Color & Chemical Mfg Co PA See ad page 75
Fusion Ceramics Inc OH
Gwent Electronic Materials Ltd UK
Zibo Guangtong Chemical Co Ltd China

Lehrs
Nabertherm Inc DE
Recco Furnaces CA

Pigments
Artimin Industries CO
Ceramic Color & Chemical Mfg Co PA See ad page 75
Fusion Ceramics Inc OH
Mason Color Works Inc OH

Porcelain Enamels
Cerlase France
Fusion Ceramics Inc OH
RISE Research Institutes of Sweden RISE Glass Sweden

Precious Metals
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Fusion Ceramics Inc OH
Gwent Electronic Materials Ltd UK

Screen Printing Equipment
Aremco Products Inc NY
Haliku Tech Europe BV The Netherlands
Haliku Tech Inc FL

Silver Pastes Conducting
Master Bond Inc NJ

Spray Booths
American Art clay Co Inc IN
Laguna Clay Co CA

Stains
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ARBURG GmbH + Co KG Germany
AVS Inc MA
Digital Press Inc PA
Dorst America Inc PA
Gasbarre Products Inc PA
Laes GmbH Luxembourg
Materials Research Furnaces Inc NH
See ad page 79
Mohr Corp MI
See ad page 87
Ram Products Inc OH

Gasbarre Products (PTX Pentronix) PA
See ad page 105
Gasbarre Products Inc PA
Mohr Corp MI
See ad page 87
Quintus Technologies LLC OH

Presses, Dry
Advanced Machinery Inc MI
Dorst America Inc PA
Gasbarre Products Inc PA
Maryland Ceramic & Steatite Co Inc MD
Suntech Advanced Ceramics (Shenzhen) Co Ltd China

Molds, Models
Petro Mold Company PA
Ram Products Inc OH
Viridis3D LLC MA

Molds, Models
Petro Mold Company PA
Ram Products Inc OH
Viridis3D LLC MA

Plasma Etching Systems
Advanced Energy CO
Liberty Machinery Co IL

Pneumatic Systems
Cyclonaire Corp NE
Ram Products Inc OH
Young Industries Inc PA

Polishing Equipment
Allied High Tech Products Inc CA
Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
LECO Corp MI
Liberty Machinery Co IL
OptiPro Systems LLC NY
Sigmadiamant Spain
Stahli USA Inc WI

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**Tools, Modeling**
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Virdis3D LLC MA

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Liberty Machinery Co IL
OptiPro Systems LLC NY

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Cerinnov France
Dorst America Inc PA
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
LECO Corp MI
Liberty Machinery Co IL
Ram Products Inc OH
Virdis3D LLC MA

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Liberty Machinery Co IL
Rockwell Automation Inc WI

**Wheels, Cutoff & Grinding**
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Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
LECO Corp MI
Liberty Machinery Co IL

**Wheels, Diamond**
Aremco Products Inc NY
Diacut Inc CO
Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
LECO Corp MI
Sigmadiamant Spain
Stahli USA Inc WI

**Presses, Other**
ARBURG GmbH + Co KG Germany
Isomat Ltd UK

**Presses, Pressure Casting**
Cerlase France
Dorst America Inc PA
Peter Pugger Mfg Inc CA
Ram Products Inc OH

**Presses, Refractory Shapes**
Laeis GmbH Luxemburg

**Presses, Rotary**
Advanced Machinery Inc MI
Materials Research Furnaces Inc NH See ad page 79

**Presses, Tile (Ceramic)**
Laeis GmbH Luxembourg
Peter Pugger Mfg Inc CA

**Pug Mills**
Advanced Machinery Inc MI
Basic Machinery Co Inc NC
Dorst America Inc PA
Mohr Corp MI See ad page 87
Peter Pugger Mfg Inc CA
Sheffield Pottery MA
Young Industries Inc PA

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Teeter Marketing Services LLC FL

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Laeis GmbH Luxemburg

**Setting Equipment**
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**Slab Rollers**
North Star Equipment Inc WA

**Spray Booths**
Treibacher Industrie AG Austria

**Presses, Pressure Casting**
Cerlase France
Dorst America Inc PA
Peter Pugger Mfg Inc CA
Ram Products Inc OH

**Presses, Rotary**
Advanced Machinery Inc MI
Materials Research Furnaces Inc NH See ad page 79

**Presses, Tile (Ceramic)**
Laeis GmbH Luxembourg
Peter Pugger Mfg Inc CA

**Pug Mills**
Advanced Machinery Inc MI
Basic Machinery Co Inc NC
Dorst America Inc PA
Mohr Corp MI See ad page 87
Peter Pugger Mfg Inc CA
Sheffield Pottery MA
Young Industries Inc PA

**PVD Equipment**
Liberty Machinery Co IL
Teeter Marketing Services LLC FL

**Roofing Tile Machinery**
Laeis GmbH Luxembourg

**Setting Equipment**
Basic Machinery Co Inc NC

**Slab Rollers**
North Star Equipment Inc WA

**Spray Booths**
Treibacher Industrie AG Austria

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American Isostatic Presses OH
Cerinnov France
Cerlase France
Detroit Process Machinery MI
Dorst America Inc PA

**Sputtering Equipment**
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Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
Liberty Machinery Co IL
Teeter Marketing Services LLC FL

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Engis Corp IL
Greenlee Diamond Tool Co IL
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Liberty Machinery Co IL
Ram Products Inc OH
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Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
LECO Corp MI
Liberty Machinery Co IL

**Wheels, Diamond**
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Diacut Inc CO
Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
LECO Corp MI
Sigmadiamant Spain
Stahli USA Inc WI

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Saint-Gobain Recherche France
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Elan Technology GA See ad page 77
Garg Process Glass India Pvt Ltd India
RISE Research Institutes of Sweden RISE Glass Sweden
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RISE Research Institutes of Sweden RISE Glass Sweden
Saint-Gobain Recherche France
Saxon Glass Technologies Inc NY
Schott North America Inc NY
Vesuvius SC

**Container Glass**
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Cerinnov France
Owens-Illinois Inc OH
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Saint-Gobain Recherche France
Vesuvius SC

**Fibers Continuous**
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Fibers Optical
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Flat & Safety Glass
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Saint-Gobain Recherche France
Vesuvius SC

Fused Silica Glass
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Arkema Inc PA
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Ferro Ceramic Grinding Inc MA
Imerys Refractory Minerals GA
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Valley Design Corp MA

Glass-Ceramics
Accuratus Corp NJ
Advanced Ceramic Technology CA
Arkema Inc PA
Bullen OH
Cerlase France
Elan Technology GA See ad page 77
Petro Mold Company PA
PremTech Advanced Ceramics MA
Schott North America Inc NY
Specialty Glass Inc FL
StudioLX - Home Decor IL
TevTech LLC MA See ad page 99
Texers Technical Ceramics Inc Canada
Valley Design Corp MA
Xiamen Innovacera Advanced Materials Co Ltd China

Glass/Specialty

Specialty Glass Inc FL

Glass-to-Metal Seals
Elan Technology GA See ad page 77
ESL ElectroScience PA
RISE Research Institutes of Sweden RISE Glass Sweden
Schott North America Inc NY
Specialty Glass Inc FL

Laboratory & Technical Glass
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Garg Process Glass India Pvt Ltd India
LECO Corp MI
RISE Research Institutes of Sweden RISE Glass Sweden
Saxon Glass Technologies Inc NY
Schott North America Inc NY
Specialty Glass Inc FL
TevTech LLC MA See ad page 99

Laminated Glass
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RISE Research Institutes of Sweden RISE Glass Sweden
Vesuvius SC

Laser Glasses
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Israel Ceramic & Silicate Inst Israel
RISE Research Institutes of Sweden RISE Glass Sweden

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Lighting
Oxram Sylvania Inc MA

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NEVZ-Ceramics Close JSC Russia
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TevTech LLC MA See ad page 99
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Optical Substrates
Bullen OH
FELDCO Int'l CA
Schott North America Inc NY
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Saxon Glass Technologies Inc NY
Schott North America Inc NY
Vesuvius SC

Technical Glass
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Elan Technology GA See ad page 77
RISE Research Institutes of Sweden RISE Glass Sweden
Saxon Glass Technologies Inc NY
Schott North America Inc NY

Tubing & Rod
AdValue Technology LLC AZ See ad page 69
Garg Process Glass India Pvt Ltd India
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HunterLab VA

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Micromeritics Instrument Corp GA
Particle Technology Labs IL
Quan achrome Instruments FL
RocCera LLC NY

Detectors
Control Instruments Corp NJ
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA

Dimension Measurement Instruments
CSC Force Measurement Inc MA

Dryers
Applied Test Systems Inc PA
Ceramic Services Inc PA
Cober Muegge LLC CT
Detroit Process Machinery MI
Eirich Machines Inc IL
Giacom AB Sweden
Littleford Day Inc MI
Reco Furnaces CA
Wysomst Co NJ

Fiberoptic Illuminators
Carl Zeiss Microlmaging Inc NY See ad page 109
Mo-Si Corp MD See ad page 107
RISE Research Institutes of Sweden RISE Glass Sweden
Taber Industries NY

Glossimeters
Horiba Instruments Inc CA

Hardness Measurement Instruments
Allied High Tech Products Inc CA
Buehler Ltd IL
Carl Zeiss Microlmaging Inc NY See ad page 109
LECQ Corp MI
Nanoscience Instruments AZ
Penn Tool Co NJ See ad page 111
Taber Industries NY

Hot Plates
RocCera LLC NY
Zhengzhou Mission Ceramic Products Co Ltd China

Lab Crucibles
AdValue Technology LLC AZ See ad page 69
Ceranco Inc NH See ad page 89
CoorsTek CO
McDaniel Advanced Ceramic Technologies LLC PA See ad page 65
Robocasting Enterprises LLC NM
Xianm Innovacera Advanced Materials Co Ltd China
Zhengzhou Mission Ceramic Products Co Ltd China

Lab Furnace Tubes
AdValue Technology LLC AZ See ad page 69
Cortenite Gero UK
McDaniel Advanced Ceramic Technologies LLC PA See ad page 65
Nabertherm Inc DE
Xianm Innovacera Advanced Materials Co Ltd China
Zhengzhou Mission Ceramic Products Co Ltd China

Lab Furnaces
Advanced Machinery Inc MI
American Isostatic Presses OH
Applied Test Systems Inc PA
AVIS Inc MA
Carbolite Gero UK

Ceramic Services Inc PA
CM Furnaces Inc NJ
CSC Force Measurement Inc MA
Deltech Inc CO
Detroit Process Machinery MI
L&L Special Furnace Co Inc PA See ad page 101
Lucifer Furnaces Inc PA
Materials Research Furnaces Inc NH See ad page 79
Nabertherm Inc DE
Oxy-Gon Industries Inc NH See ad page 94
Paragon Industries LP TX
RD Webb Company Inc MA

TevTech LLC MA See ad page 99
The Furnace Source LLC CT
Thermcraft Inc NC See ad page 95
Trent Inc PA
Verder Scientific Inc PA
Zhengzhou Mission Ceramic Products Co Ltd China
ZIRCAR Ceramics Inc NY
Zircar Zirconia Inc NY

Light Sources
Allied High Tech Products Inc CA
Carl Zeiss Microlmaging Inc NY See ad page 109
Spectronics Corp NY

Mechanical Property Measurement Instruments
Applied Test Systems Inc PA
Buehler Ltd IL
BuzzMac Intl LLC ME
CSC Force Measurement Inc MA
Nanoscience Instruments AZ
Penn Tool Co NJ See ad page 111
TA Instruments DE
Taber Industries NY

Microscopes Hot Stages
Carl Zeiss Microlmaging Inc NY See ad page 109
Dalmia Inst of Scientific & Industrial Research India
TA Instruments DE

Microscopes, Interference
Buehler Ltd IL
Carl Zeiss Microlmaging Inc NY See ad page 109

Microscopes, Other
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Buehler Ltd IL
JTF Microscopy Services Inc NY
Microscopes, Reflected Light
Allied High Tech Products Inc CA
Buehler Ltd IL
Carl Zeiss Microlmaging Inc NY  See ad page 109
LECO Corp MI

Microscopes, Scanning Electron
Buehler Ltd IL
Carl Zeiss Microlmaging Inc NY  See ad page 109
LECO Corp MI

Microscopes, Transmission Electron
Nanoscience Instruments AZ
SEMTech Solutions Inc MA

Mills, Laboratory
Advanced Ceramics Manufacturing AZ
Custom Processing Services PA
Detroit Process Machinery MI
Fluid Energy Processing & Equipment Co PA
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc. NC
MSE Supplies AZ
Stedman Machine Co IN
Union Process OH

Mixers, Laboratory
Custom Processing Services PA
Detroit Process Machinery MI
Eirich Machines Inc IL
Fritsch GmbH - Milling and Sizing Germany
Lancaster Products PA
Littleford Day Inc MI
Peter Pugger Mfg Inc CA
Ram Products Inc OH
Verder Scientific Inc PA

Moisture Testing
LECO Corp MI
Micromeritics Instrument Corp GA

Optical Property Measurement Instruments
Fritsch GmbH - Milling and Sizing Germany

pH Meters
Horiba Instruments Inc CA
Mettler-Toledo Inc OH
Ocean Optics Inc FL

Porosimeters
Micromeritics Instrument Corp GA
Particle Technology Labs IL
Quantachrome Instruments FL

Powders Samplers
Fritsch Milling & Sizing Inc NC
Quantachrome Instruments FL

Recorders
CSC Force Measurement Inc MA
Datapaq Inc NH
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA

Rheometers
Particle Technology Labs IL
TA Instruments DE

Sample Preparation Equipment
Allied High Tech Products Inc CA
Buehler Ltd IL
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc. NC
Micromeritics Instrument Corp GA
Ram Products Inc OH
Verder Scientific Inc PA

Thermometers
Optocon AG Germany
Xiamen Innovacera Advanced Materials Co Ltd China

Viscosity Measurement Instruments
Carl Zeiss Microlmaging Inc NY  See ad page 109
Norrnss Cross Viscosity Controls MI
RISE Research Institutes of Sweden RISE Glass Sweden
Rockwell Automation Inc WI
TA Instruments DE

Visual Inspection Instruments
Buehler Ltd IL
Haiku Tech Inc FL
Taber Industries NY

Weighing/Scales
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- CelSiAn Glass & Solar BV The Netherlands
- See ad page 83

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**GrainBound LLC PA**
- See ad page 111

**Hindalco Industries Limited India**
- Hysitron Inc MN
- Israel Ceramic & Silicate Inst Israel
- Japan Fine Ceramics Center Japan
- Micromeritics Instrument Corp GA
- NSL Analytical Services Inc OH
- Particle Technology Labs IL
- Quantachrome Instruments FL

**Differential Thermal Analysis**
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- Evans Analytical Group LLC CA
- High Temperature Materials Lab TN
- Hindalco Industries Limited India
- Japan Fine Ceramics Center Japan
- Micromeritics Instrument Corp GA
- Netzsch Instruments NA LLC MA
- See ad page 123
- RISE Research Institutes of Sweden RISE Glass Sweden
- Setaram Instrumentation France
- TA Instruments DE
- Technology of Materials CA

**Electronic Microprobe Analysis**
- Activation Laboratories Ltd Canada
- GrainBound LLC PA
- See ad page 111

**High Temperature Materials Lab TN**
- Japan Fine Ceramics Center Japan
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- Netzsch Instruments NA LLC MA
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- Setaram Instrumentation France
- TA Instruments DE
- Technology of Materials CA

**Electron Microprobe Analysis**
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- Micromeritics Instrument Corp GA
- Netzsch Instruments NA LLC MA
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- Setaram Instrumentation France
- TA Instruments DE
- Technology of Materials CA

**Fracture Analysis**
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- CoroTek CO
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- P-Ker Engineering NY
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- Edward Orton Jr Ceramic Foundation OH
- Evans Analytical Group LLC CA
- Geller Micrometrolarytical Laboratory Inc MA
- H&M Analytical Services Inc NJ
- RISE Research Institutes of Sweden RISE Glass Sweden
- SEMTech Solutions Inc MA

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- CSC Force Measurement Inc MA
- Edward Orton Jr Ceramic Foundation OH
- High Temperature Materials Lab TN
- Hysitron Inc MN
- Japan Fine Ceramics Center Japan
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- Custom Processing Services PA
- Cyclotron Corp NE
- Geller Micrometrolarytical Laboratory Inc MA
- H&M Analytical Services Inc NJ
- Harper International NY
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- Japan Fine Ceramics Center Japan
- Micromeritics Instrument Corp GA
- Micron Inc DE
- NSL Analytical Services Inc OH
- Particle Technology Labs IL
- Particle Technology Labs IL
- Particle Technology Labs DE
- Setaram Instrumentation France
- SEMTech Solutions Inc MA
- TA Instruments DE
- Technology of Materials CA
- Washington Mills Electro Minerals Co NY

**Pore Structure Analysis**
- GrainBound LLC PA
- See ad page 111
- GrainBound Material Diagnosis
- GrainBound LLC PA
- See ad page 111
- Harper International NY
- See ad page 101

**Residual Stress Analysis**
- American Stress Technologies Inc PA
- High Temperature Materials Lab TN
- Japan Fine Ceramics Center Japan
- RISE Research Institutes of Sweden RISE Glass Sweden
- TA Instruments DE

**Scanning Electron Microscopy**
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- Alfred University NY
- AVEKA MN
- CHEMIR - A Division of Evans Analytical Group MO
- CoroTek CO
- Edward Orton Jr Ceramic Foundation OH
- Evans Analytical Group LLC CA
- GrainBound LLC PA
- See ad page 111
- H&M Analytical Services Inc NJ

**Technology of Materials CA**
- Setaram Instrumentation France
- SEMTech Solutions Inc MA
- Taber Industries NY

**Materials Analysis**
- Activation Laboratories Ltd Canada
- Alfred University NY
- CHEMIR - A Division of Evans Analytical Group MO
- CSC Force Measurement Inc MA
- Edward Orton Jr Ceramic Foundation OH
- High Temperature Materials Lab TN
- Hysitron Inc MN
- Japan Fine Ceramics Center Japan
- TA Instruments DE
- Taber Industries NY

**Nondestructive Testing**
- Alfred University NY
- BuzzMac Intl LLC ME
- CHEMIR - A Division of Evans Analytical Group MO
- CSC Force Measurement Inc MA
- Edward Orton Jr Ceramic Foundation OH
- High Temperature Materials Lab TN
- Hysitron Inc MN
- Japan Fine Ceramics Center Japan
- TA Instruments DE
- Taber Industries NY

**Pore Structure Analysis**
- GrainBound LLC PA
- See ad page 111
- GrainBound Material Diagnosis
- GrainBound LLC PA
- See ad page 111
- Harper International NY
- See ad page 101

**Residual Stress Analysis**
- American Stress Technologies Inc PA
- High Temperature Materials Lab TN
- Japan Fine Ceramics Center Japan
- RISE Research Institutes of Sweden RISE Glass Sweden
- TA Instruments DE

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- Alfred University NY
- AVEKA MN
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- CoroTek CO
- Edward Orton Jr Ceramic Foundation OH
- Evans Analytical Group LLC CA
- GrainBound LLC PA
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**Harrop Industries Inc OH**
- See ad page 91

**High Temperature Materials Lab TN**
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- Micromeritics Instrument Corp GA
- Netzsch Instruments NA LLC MA
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- Setaram Instrumentation France
- TA Instruments DE
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- SEMTech Solutions Inc MA
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Evans Analytical Group LLC CA
GrainBound LLC PA See ad page 111
High Temperature Materials Lab TN
Japan Fine Ceramics Center Japan
Micron Inc DE
NSL Analytical Services Inc OH

Tribological Studies
High Temperature Materials Lab TN
Japan Fine Ceramics Center Japan
Micron Inc DE
Tabor Industries NY

X-Ray Diffraction
Activation Laboratories Ltd Canada
Alfred University NY
American Stress Technologies Inc PA
CHEMIR - A Division of Evans Analytical Group MO
Edward Orton Jr Ceramic Foundation OH
Evans Analytical Group LLC CA
GrainBound LLC PA See ad page 111
HAM Analytical Services Inc NJ
High Temperature Materials Lab TN
Hindalco Industries Limited India
Israel Ceramic & Silicate Inst Israel
Japan Fine Ceramics Center Japan
Micron Inc DE
NSL Analytical Services Inc OH
Technology of Materials CA
Washington Mills Electro Minerals Co NY

X-Ray Fluorescence
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■ MATERIALS PREPARATION HANDLING & PACKAGING
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Lancaster Products PA
Littleford Day Inc MI

Bagging Equipment
Applicon Co IN
Cyclonaire Corp NE
Ingredient Masters Inc
Lancaster Products PA
Nor-Tec Systems Inc MN

Barcode Labels
Rockwell Automation Inc WI

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Carolina Material Technologies NC
Cyclonaire Corp NE
General Glass Equipment Co NJ

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Eirich Machines Inc IL

Ingredient Masters Inc See ad page 113
Lancaster Products PA
Mixer Systems Inc WI
Nor-Tec Systems Inc MN
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA
Young Industries Inc PA

Bins Storage
Ingredient Masters Inc
Jennie & Johanson Inc MA
Mixer Systems Inc WI
Nor-Tec Systems Inc MN
Tempo Plastic CA

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Applicon Co IN
Cyclonaire Corp NE
Detroit Process Machinery MI
Eirich Machines Inc IL
Gasbarre Products Inc PA

Glen Mills Inc NJ See ad page 115
Laguna Clay Co CA
Lancaster Products PA
Littleford Day Inc MI

Mohr Corp MI See ad page 87
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Advanced Machinery Inc MI
Applicon Co IN
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Lancaster Products PA
Mohr Corp MI See ad page 87

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Crushers, Hammermill
AVEKA MN

Glen Mills Inc NJ See ad page 115
Mixer Systems Inc WI
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Crushers, Impact
Applicon Co IN

Glen Mills Inc NJ See ad page 115
Stedman Machine Co IN

Williams Patent Crusher & Pulverizer Co Inc M0
Wyssmont Co NJ

Conveyors
Basic Machinery Co Inc NC
Carolina Material Technologies NC
General Glass Equipment Co NJ
Netzsch Premier Technologies LLC PA
Nor-Tec Systems Inc MN
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA
Velcro GmbH Germany
Young Industries Inc PA

Conveyors, Belt
Applicon Co IN
Carolina Material Technologies NC
Ingredient Masters Inc
Mixer Systems Inc WI

Conveyors, Pneumatic
Applicon Co IN
Carolina Material Technologies NC
Cyclonaire Corp NE
Ingredient Masters Inc
Nor-Tec Systems Inc MN
Velcro GmbH Germany

Conveyors, Screw
Applicon Co IN
Carolina Material Technologies NC
Cyclonaire Corp NE
Ingredient Masters Inc
Mixer Systems Inc WI

Conveyors, Vibrating
Applicon Co IN
Carolina Material Technologies NC
Cleveland Vibrator Co OH

Crushers
Advanced Machinery Inc MI
AVEKA MN
Basic Machinery Co Inc NC
Detroit Process Machinery MI
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc. NC

Glen Mills Inc NJ See ad page 115
Lancaster Products PA
Mohr Corp MI See ad page 87
Stedman Machine Co IN
Williams Patent Crusher & Pulverizer Co Inc M0
Wyssmont Co NJ

Crushers, Hammermill
AVEKA MN

Glen Mills Inc NJ See ad page 115
Mixer Systems Inc WI
Stedman Machine Co IN

Williams Patent Crusher & Pulverizer Co Inc M0
Wyssmont Co NJ

Crushers, Impact
Applicon Co IN

Glen Mills Inc NJ See ad page 115
Stedman Machine Co IN

Williams Patent Crusher & Pulverizer Co Inc M0
Wyssmont Co NJ
Crushers, Jaw
Applicon Co IN
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc. NC
Glen Mills Inc NJ
Verder Scientific Inc PA

Crushers, Primary
Stedman Machine Co IN
Williams Patent Crusher & Pulverizer Co Inc MO

Crushers, Roll
Applicon Co IN
Lancaster Products PA
Williams Patent Crusher & Pulverizer Co Inc MO

Cullet-Handling Equipment
Applicon Co IN
General Glass Equipment Co NJ

Drum Tumblers
Glen Mills Inc NJ
See ad page 115

Dryers, Fluid Bed
Applicon Co IN
AViKA MN
Williams Patent Crusher & Pulverizer Co Inc MO

Dryers, Rotating Tray
Raymond Bartlett Snow
Wyssmont Co NJ

Dust Collectors
Cyclonaire Corp NE
Nol-Tec Systems Inc MN
RoboVent MI

Dust Control Equipment
Carolina Material Technologies NC
Mixer Systems Inc WI
RoboVent MI
Young Industries Inc PA

Edge Protectors
Tempo Plastic CA

Electric Screen Heating
Midwestern Industries Inc OH

Environmental/Waste Treatment Equipment
Carolina Material Technologies NC
Cober Muegge LLC CT
Control Instruments Corp NJ
Fritsch GmbH - Milling and Sizing Germany

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Carolina Material Technologies NC
Ingredient Masters Inc.
Jenike & Johanson Inc MA
Mixers Systems Inc WI
Reed Gunite & Shotcrete Equipment CA

Hydraulic Systems
Basic Machinery Co Inc NC
Ram Products Inc OH

Impeller Mixing
Lancaster Products PA
Mixers Systems Inc WI

Materials Handling Equipment
Basic Machinery Co Inc NC
Carolina Material Technologies NC
Cyclonaire Corp NE
Gasbarre Products Inc PA
Lancaster Products PA
Mixers Systems Inc WI
Nor-Tec Systems Inc MN
North Star Equipment Inc WA
Reed Gunite & Shotcrete Equipment CA
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA
tempo Plastic CA
Young Industries Inc PA

Mill Linings
Carlo Gavazzi OH
ER Advanced Ceramics Inc OH
Jyoti Ceramic Industries Pvt Ltd India

Mills
Custom Processing Services PA
ER Advanced Ceramics Inc OH
Euro Support Advanced Materials The Netherlands
Fritsch Milling & Sizing Inc NC

Mill, Hammer
AVEKA MN
Glen Mills Inc NJ See ad page 115
Stedman Machine Co IN
Verder Scientific Inc PA
Williams Patcong Crusher & Pulverizer Co Inc M0

Mill, Jar
Detroit Process Machinery MI
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc. NC

Mill, Jet
AVEKA MN
Fluid Energy Processing & Equipment Co PA
Netzsch Premier Technologies LLC PA

Mill, Planetary
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc. NC
Hockmeyer Equipment Corp NC
MSE Supplies AZ
Verder Scientific Inc PA

Mill, Rod
Wyssmont Co NJ

Mill, Roll
Haiku Tech Europe BV The Netherlands
Haiku Tech Inc FL
MSE Supplies AZ
Raymond Bartlett Snow
Williams Patcong Crusher & Pulverizer Co Inc M0

Mils, Vibratory
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Mining & Beneficiation Equipment
Netzsch Premier Technologies LLC PA
Reed Gunite & Shotcrete Equipment CA
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA

Mixers, Batch
Carolina Material Technologies NC
Custom Processing Services PA
Eirich Machines Inc IL

Mixers, Ball & Pebble
Advanced Machinery Inc MI
Detroit Process Machinery MI

Mixers, Centrifugal
Fritsch GmbH - Milling and Sizing Germany

Mixers, Drum
Glen Mills Inc NJ See ad page 115
Hockmeyer Equipment Corp NC

Mixers, Equipment, Refractory
Reed Gunite & Shotcrete Equipment CA
Velco GmbH Germany

Mixers, Pneumatic
Carolina Material Technologies NC
Eirich Machines Inc IL
Nor-Tec Systems Inc MN

Grinders
Buehler Ltd IL
Diamond Industrial Tools Inc IL
Fluid Energy Processing & Equipment Co PA
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Grinding Media
Carbo llc OH
CoresTek CO
Dunhua Zhengxiong Abrasive Co Ltd China
ER Advanced Ceramics Inc OH
Federal-Mogul MI
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Grinding Mills, Vibratory
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Grinding Media
Carbo llc OH
CoresTek CO
Dunhua Zhengxiong Abrasive Co Ltd China
ER Advanced Ceramics Inc OH
Federal-Mogul MI
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Glen Mills Inc NJ See ad page 115
Jyoti Ceramic Industries Pvt Ltd India
MSE Supplies AZ
Netzsch Premier Technologies LLC PA
Texers Technical Ceramics Inc Canada
Union Process OH
Verder Scientific Inc PA
Zibo Guangtong Chemical Co Ltd China
Zircos Inc OH

Gunning Equipment, Refractory
Reed Gunite & Shotcrete Equipment CA
Velco GmbH Germany

Hoppers
Basic Machinery Co Inc NC
Carolina Material Technologies NC
Ingredient Masters Inc.
Jenike & Johanson Inc MA
Mixers Systems Inc WI
Reed Gunite & Shotcrete Equipment CA

Hydraulic Systems
Basic Machinery Co Inc NC
Ram Products Inc OH

Impeller Mixing
Lancaster Products PA
Mixers Systems Inc WI

Materials Handling Equipment
Basic Machinery Co Inc NC
Carolina Material Technologies NC
Cyclonaire Corp NE
Gasbarre Products Inc PA
Lancaster Products PA
Mixers Systems Inc WI
Nor-Tec Systems Inc MN
North Star Equipment Inc WA
Reed Gunite & Shotcrete Equipment CA
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA
tempo Plastic CA
Young Industries Inc PA

Mill Linings
Carlo Gavazzi OH
ER Advanced Ceramics Inc OH
Jyoti Ceramic Industries Pvt Ltd India

Mills
Custom Processing Services PA
ER Advanced Ceramics Inc OH
Euro Support Advanced Materials The Netherlands
Fritsch Milling & Sizing Inc NC

Mill, Hammer
AVEKA MN
Glen Mills Inc NJ See ad page 115
Stedman Machine Co IN
Verder Scientific Inc PA
Williams Patcong Crusher & Pulverizer Co Inc M0

Mill, Jar
Detroit Process Machinery MI
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc. NC

Mill, Jet
AVEKA MN
Fluid Energy Processing & Equipment Co PA
Netzsch Premier Technologies LLC PA

Mill, Planetary
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc. NC
Hockmeyer Equipment Corp NC
MSE Supplies AZ
Verder Scientific Inc PA

Mill, Rod
Wyssmont Co NJ

Mill, Roll
Haiku Tech Europe BV The Netherlands
Haiku Tech Inc FL
MSE Supplies AZ
Raymond Bartlett Snow
Williams Patcong Crusher & Pulverizer Co Inc M0

Mils, Vibratory
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Mining & Beneficiation Equipment
Netzsch Premier Technologies LLC PA
Reed Gunite & Shotcrete Equipment CA
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA

Mixers, Batch
Carolina Material Technologies NC
Custom Processing Services PA
Eirich Machines Inc IL

Mixers, Ball & Pebble
Advanced Machinery Inc MI
Detroit Process Machinery MI

Mixers, Centrifugal
Fritsch GmbH - Milling and Sizing Germany

Mixers, Drum
Glen Mills Inc NJ See ad page 115
Hockmeyer Equipment Corp NC

Mixers, Equipment, Refractory
Reed Gunite & Shotcrete Equipment CA
Velco GmbH Germany

Mixers, Pneumatic
Carolina Material Technologies NC
Eirich Machines Inc IL
Nor-Tec Systems Inc MN

Grinders
Buehler Ltd IL
Diamond Industrial Tools Inc IL
Fluid Energy Processing & Equipment Co PA
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Grinding Media
Carbo llc OH
CoresTek CO
Dunhua Zhengxiong Abrasive Co Ltd China
ER Advanced Ceramics Inc OH
Federal-Mogul MI
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Grinding Mills, Vibratory
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Grinding Media
Carbo llc OH
CoresTek CO
Dunhua Zhengxiong Abrasive Co Ltd China
ER Advanced Ceramics Inc OH
Federal-Mogul MI
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Glen Mills Inc NJ See ad page 115
Jyoti Ceramic Industries Pvt Ltd India
MSE Supplies AZ
Netzsch Premier Technologies LLC PA
Texers Technical Ceramics Inc Canada
Union Process OH
Verder Scientific Inc PA
Zibo Guangtong Chemical Co Ltd China
Zircos Inc OH

Grinding Mills, Vibratory
Fritsch GmbH - Milling and Sizing Germany
Fritsch Milling & Sizing Inc NC

Gunning Equipment, Refractory
Reed Gunite & Shotcrete Equipment CA
Velco GmbH Germany
Mixers, Portable
- Jiffy Mixer Co Inc CA
- Mixer Systems Inc WI
- Peter Pugger Mfg Inc CA

Mixers, Refractory
- Applicon Co IN
- Erich Machines Inc IL
- Laesi GmbH Luxembourg
- Lancaster Products PA
- Littleford Day Inc MI
- Mixer Systems Inc WI
- Netzsch Premier Technologies LLC PA
- Peter Pugger Mfg Inc CA
- Reed Gunite & Shotcrete Equipment CA

Mixers, Vacuum
- Applicon Co IN
- Erich Machines Inc IL
- Netzsch Premier Technologies LLC PA
- Peter Pugger Mfg Inc CA

Mixing, Equipment
- Advanced Machinery Inc MI
- Carolina Material Technologies NC
- Custom Processing Services PA

Pneumatic Systems
- Applicon Co IN
- Carolina Material Technologies NC
- Cyclonaire Corp NE
- Nol-Tec Systems Inc MN
- Reed Gunite & Shotcrete Equipment CA
- Velco GmbH Germany
- Young Industries Inc PA

Process Control Equipment
- Control Instruments Corp NJ
- Datapaq Inc NH
- General Glass Equipment Co NJ
- Ingredient Masters Inc OH
- Nol-Tec Systems Inc MN
- Norcross Visco-Shear Controls MI
- Ram Products Inc OH
- Rockwell Automation Inc WI
- Siemens Process Industries and Drives GA

Pulverizers
- Advanced Machinery Inc MI
- Applicon Co IN
- Basic Machinery Co Inc NC
- Fritsch GmbH - Milling and Sizing Germany
- Fritsch Miling & Sizing Inc NC
- Glen Mills Inc NJ
- Mixer Systems Inc WI
- Nol-Tec Systems Inc MN
- Williams Patent Crusher & Pulverizer Co Inc MD
- Wyssmont Co NJ

Pumps
- ER Advanced Ceramics Inc OH
- Ram Products Inc OH
- Reed Gunite & Shotcrete Equipment CA

Pumps Concrete
- Reed Gunite & Shotcrete Equipment CA

Scale Systems
- CSC Force Measurement Inc MA
- Mettler-Toledo Inc OH
- Nol-Tec Systems Inc MN

Screens & Screening Equipment
- Advanced Machinery Inc MI
- Basic Machinery Co Inc NC
- Cleveland Vibrator Co OH
- Control Instruments Corp NJ
- Detroit Process Machinery MI
- Fritsch GmbH - Milling and Sizing Germany
- Fritsch Milling & Sizing Inc NC
- Glen Mills Inc NJ
- Midwestern Industries Inc OH
- Mohr Corp MI
- Sicco Engineering Works India

Separators
- Fritsch GmbH - Milling and Sizing Germany
- Midwestern Industries Inc OH
- Williams Patent Crusher & Pulverizer Co Inc MD

Shredders
- Basic Machinery Co Inc NC
- Fritsch GmbH - Milling and Sizing Germany
- Glen Mills Inc NJ
- Nol-Tec Systems Inc MN
- Williams Patent Crusher & Pulverizer Co Inc MD

Single-Wafer Packs
- Tempo Plastic CA

Nozzles
- CerCo LLC OH
- Dunhua Zhengxing Abrasive Co Ltd China
- H.C. Starck GmbH Germany
- Maryland Ceramic & Steatite Co Inc MD

Packaging
- Tempo Plastic CA

Packaging Equipment
- Basic Machinery Co Inc NC

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- Custom Processing Services PA
- Erich Machines Inc IL
- ER Advanced Ceramics Inc OH
- Fluid Energy Processing & Equipment Co PA
- Fritsch GmbH - Milling and Sizing Germany
- Glen Mills Inc NJ See ad page 115
- Lancaster Products PA
- Netzsch Premier Technologies LLC PA
- Raymond Bartlett Snow
- Stedman Machine Co IN
- Union Process OH
- Williams Patent Crusher & Pulverizer Co Inc MO
- Wyssmont Co NJ See ad page 115

Spray Dryers
- Advanced Machinery Inc MI
- Arch Maintenance Services GA
- AVEKA MN
- Detroit Process Machinery MI
- Dorst America Inc PA
- Elan Technology GA See ad page 77
- Euro Support Advanced Materials The Netherlands
- Mohr Corp MI See ad page 87
- Spray Drying Systems Inc MD

Storage Equipment
- Basic Machinery Co Inc NC
- Cyclonaire Corp NE

Substrate Wafer Trays
- Tempo Plastic CA

Used Equipment
- Advanced Machinery Inc MI
- American Isostatic Presses OH

Fabrication Shops
- Maryland Ceramic & Steatite Co Inc MD

Glass Production
- Celsian Glass & Solar BV The Netherlands
- General Glass Equipment Co NJ
- RISE Research Institutes of Sweden RISE Glass Sweden
- Schott North America Inc NY
- Tri-Mer Corp MI

Inspection Systems
- CSC Force Measurement Inc MA
- Fosbel Inc OH
- Rockwell Automation Inc WI
- Siemens Process Industries and Drives GA

Laboratories
- Activation Laboratories Ltd Canada

Optical-Fiber Production
- Ocean Optics Inc FL

Refractory Production
- ER Advanced Ceramics Inc OH
- Fosbel Inc OH
- Laeis GmbH Luxembourg
- Laguna Clay Co CA
- Swindell Dressler Intl Co PA
- TevTech LLC MA See ad page 99

Structural Ceramics Production
- CerCo LLC OH
- Maryland Ceramic & Steatite Co Inc MD
- Swindell Dressler Intl Co PA
- Takasago Industry Co Ltd Japan

Tile Production
- LAIXL Corporation Japan
- Ram Products Inc OH
- Swindell Dressler Intl Co PA

Whiteware Production
- LAIXL Corporation Japan
- Ram Products Inc OH
- Swindell Dressler Intl Co PA

Porcelain Enamel
- Appliances
  - Roca Sanitario SA Spain
  - Zenith China

Architectural Units
- Roca Sanitario SA Spain
- Zenith China

Ceramic Coatings, Thermal Protection
- Cerinnov France
- Cerlase France
- Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD

Environmental Control
- Cyclonaire Corp NE
- Mixer Systems Inc WI
- Nol-Tec Systems Inc MN
- RoboVent MI
- Rockwell Automation Inc WI
- Saint-Gobain NorPro OH
- Tri-Mer Corp MI

Weighing Equipment
- Carolina Material Technologies NC
- CSC Force Measurement Inc MA
- Cyclonaire Corp NE
- Mettler-Toledo Inc OH
- Nol-Tec Systems Inc MN
- Rockwell Automation Inc WI
- Siemens Process Industries and Drives GA

Wire Cloth
- Midwestern Industries Inc OH

PLANT CONSTRUCTION DESIGN & ENGINEERING

Brick Production
- Basic Machinery Co Inc NC
- Laeis GmbH Luxembourg
- Swindell Dressler Intl Co PA

 Casting Plants
- Dorst America Inc PA
- ER Advanced Ceramics Inc OH

Ceramic Production
- Cerinnov France
- Cerlase France
- GrainBound LLC PA See ad page 111
- Lucideon UK
- Maryland Ceramic & Steatite Co Inc MD
- Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD
- Virdi3D LLC MA See ad page 75

Combustion Systems
- Air Products PA
- Swindell Dressler Intl Co PA

Decals & Decorating
- Cerinnov France
- Cerlase France
- Gwent Electronic Materials Ltd UK

Drying & Firing
- Basic Machinery Co Inc NC
- Ceramic Services Inc PA

Environmental Control
- Cyclonaire Corp NE
- Mixer Systems Inc WI
- Nol-Tec Systems Inc MN
- RoboVent MI
- Rockwell Automation Inc WI
- Saint-Gobain NorPro OH
- Tri-Mer Corp MI

Electronic Materials Production
- Haiku Tech Europe BV The Netherlands
- Haiku Tech Inc FL
- Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD

Vacuum Cleaning Systems
- Carolina Material Technologies NC

Ventilating Equipment
- American Art clay Co Inc IN

Vibrators
- Carolina Material Technologies NC
- Cleveland Vibrator Co OH
- Rockwell Automation Inc WI

Vibrators, Bin
- Carolina Material Technologies NC
- Cleveland Vibrator Co OH
- Cyclonaire Corp NE
REFRACTORIES

Acid
Allied Mineral Products Inc OH
Magneco Metrel Inc IL
Pacific Refractories Ltd India
Vitcas Ltd UK

Aggregate
Christy Minerals LLC MO
Furnace Products & Services Inc PA
Magneco Metrel Inc IL
Maryland Refractories Co OH

Alumina
Advanced Ceramic Technology CA
Allied Mineral Products Inc OH
Associated Ceramics & Technology Inc PA
Astral Material Industrial Co Ltd China
Baikowski Malaioff Inc NC
Bucher Emhart Glass SA Switzerland
Ceramco Inc NH
CeramTec-ETEC Germany
Dalma Inst of Scientific & Industrial Research India
Du-Co Ceramics Company PA
ER Advanced Ceramics Inc OH
Fosbel Inc OH
GrainBound LLC PA
IPN Ceramics LTD UK
Ipsen Ceramics IL
Magneco Metrel Inc IL
Maryland Refractories Co OH
Missouri Refractories Co (MORCO) MO
Pacific Refractories Ltd India
Plibrico Company IL
Precision Ferrites and Ceramics Inc CA
Rath Inc DE
Refractory Minerals Co Inc PA
RHUS Ltd NY
Riverside Refractories Inc AL
Selee Corp NC
Sunrock Ceramics Co IL
Tessers Technical Ceramics Inc Canada
Wistra GmbH Germany
Xiamen Innovacera Advanced Materials Co Ltd China
ZIRCAR Ceramics Inc NY
Zircar Refractory Composites Inc NY

Anchors
Associated Ceramics & Technology Inc PA
Magneco Metrel Inc IL

Arches, Suspended
Fosbel Inc OH
Ipsen Ceramics IL
Merkle International Inc IL

AZS
Bucher Emhart Glass SA Switzerland
Fosbel Inc OH
Magneco Metrel Inc IL
Missouri Refractories Co (MORCO) MO

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Backwalls
- Monofrax LLC NY
- RHI US Ltd NY

Basic
- Allied Mineral Products Inc OH
- Furnace Products & Services Inc PA
- Magneco Metrel Inc IL
- Missouri Refractories Co (MORCO) MO
- RHI US Ltd NY

Blankets
- Associated Ceramics & Technology Inc PA
- Morgan Thermal Ceramics GA
- Thermal Products Co Inc GA
- Unifrax I LLC NY
- ZIRCAR Ceramics Inc NY
- Zircar Refractory Composites Inc NY
- Zircar Zirconia Inc NY

Boards
- Agni Fiber Boards Pvt Ltd India
- Morgan Thermal Ceramics GA
- RHI US Ltd NY
- Saint-Gobain Ceramics & Plastics MA
- Thermal Products Co Inc GA
- Unifrax I LLC NY

Brick
- AF Recycling Inc OH
- Cancarb Limited Canada
- General Material Industrial Co China
- HarbisonWalker Intl PA
- Insulating Firebrick Inc PA
- Morgan Thermal Ceramics GA
- Pacific Refractories Ltd India
- RHI US Ltd NY
- Sunrock Ceramics Co IL
- Wistra GmbH Germany

Brick, Acid-Resisting
- Pacific Refractories Ltd India
- Vitcas Ltd UK

Brick, Fireclay
- Allied Mineral Products Inc OH
- Alsey Refractories Co MO
- Pacific Refractories Ltd India
- RHI US Ltd NY
- Vitcas Ltd UK

Carbon
- Astral Material Industrial Co Ltd China

Castable
- Allied Mineral Products Inc OH
- Alsey Refractories Co MO
- Aremco Products Inc NY
- Cancarb Limited Canada
- Capital Refractories Ltd UK
- Furnace Products & Services Inc PA
- HarbisonWalker Intl PA
- Industrial Ceramic Products Inc OH
- Magneco Metrel Inc IL
- Missouri Refractories Co (MORCO) MO
- Pacific Refractories Ltd India

Cements
- Allied Mineral Products Inc OH
- Aremco Products Inc NY
- Capital Refractories Ltd UK
- Daimia Inst of Scientific & Industrial Research India
- Furnace Products & Services Inc PA

Clay Flux
- Furnace Products & Services Inc PA
- Peter Pugger Mfg Inc CA
- RHI US Ltd NY

Coatings
- Allied Mineral Products Inc OH
- Aremco Products Inc NY
- Fusil GPE Inc OH
- Furnace Products & Services Inc PA
- Fusion Ceramics Inc OH
- Gwent Electronic Materials Ltd UK
- Indoceramic Canada
- Magneco Metrel Inc IL
- Plibrico Japan Co Ltd Japan
- Rath Inc DE
- Riverside Refractories Inc AL
- Starfire Systems Inc NY
- Thermal Products Co Inc GA
- Unifrax I LLC NY
- Vitcas Ltd UK
- Zibo Guangtong Chemical Co Ltd China
- Zircar Refractory Composites Inc NY
- ZYP Coatings Inc TN

Cordierite
- Advanced Ceramic Technology CA
- Alcon Porcelain & Plastics OH
- Astral Material Industrial Co Ltd China
- CoorsTek CO
- Du-Co Ceramics Company PA
- ER Advanced Ceramics Inc OH
- Industrial Ceramic Products Inc OH
- IPS Ceramics LTD UK
- Maryland Refractories Co OH
- Rauschert Industries Inc GA
- Saint-Gobain Ceramics & Plastics MA

Crucibles
- AdValue Technology LLC AZ
- Allied Mineral Products Inc OH
- APC International Ltd PA
- Aremco Products Inc NY
- Blasch Precision Ceramics Inc NY
- Bucher Emhart Glass SA Switzerland
- Ceramco Inc NH
- CeramTec-ETEC Germany
- Furnace Products & Services Inc PA
- Industrial Ceramic Products Inc OH
- Ipsen Ceramics IL
- LECO Corp MI
- Magneco Metrel Inc IL
- McDaniel Advanced Ceramic Technologies LLC PA
- Progressive Technology Inc CA
- Selee Corp NC
- Silicon Carbide Products Inc NY
- Zhejiang Mission Ceramic Products Co Ltd China
- Zircoa Inc OH

Dead-Burned
- Fluid Energy Processing & Equipment Co PA

Fiber Products
- Allied Mineral Products Inc OH

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ZIRC CAR Ceramics Inc NY
- Zircar Refractory Composites Inc NY
- Zircar Zirconia Inc NY
High-Alumina
Advanced Ceramic Technology CA
Allied Mineral Products Inc OH
Applied Ceramics Inc CA
Astral Material Industrial Co Ltd China
Blasch Precision Ceramics Inc NY
Bucher Emhart Glass SA Switzerland
Ceram-Tec-ETEC Germany
Custom Processing Services PA
Dalmia Inst of Scientific & Industrial Research India
ER Advanced Ceramics Inc OH
Fosbel Inc OH
IPS Ceramics LTD UK
Ipsen Ceramics IL
LECO Corp MI
Magneco Metrel Inc IL
Maryland Refractories Co OH
Missouri Refractories Co (MORCO) MO
Monofrax LLC NY
Pibrico Company IL
Pibrico Japan Co Ltd Japan
Precision Ferrites and Ceramics Inc CA
Rath Inc DE
RHI US Ltd NY
Riverside Refractories Inc AL
Selee Corp NC
Sunrock Ceramics Co IL
Xiamen Innovacera Advanced Materials Co Ltd China
Zhengzhou Mission Ceramic Products Co Ltd China
ZIRCAR Ceramics Inc NY
Zircar Refractory Composites Inc NY

Insulating Brick
Dalmia Inst of Scientific & Industrial Research India

Fused Cast
Fosbel Inc OH
Furnace Products & Services Inc PA
Monofrax LLC NY
Saint-Gobain Ceramics & Plastics MA

Fused Spinel Refractories
Dalmia Inst of Scientific & Industrial Research India

Glass Furnace
Deltech Inc CO
See ad page 97
Fosbel Inc OH
Furnace Products & Services Inc PA
HarbisonWalker Int'l PA
Ipsen Ceramics IL
Magneco Metrel Inc IL
RHI US Ltd NY
RISE Research Institutes of Sweden RISE Glass Sweden
Vesuvius SC

Graphite
Agni Fiber Boards Pvt Ltd India
Applied Ceramics Inc CA
Furnace Products & Services Inc PA

Grog
Alsey Refractories Co MO
Maryland Refractories Co OH

Gunning
Allied Mineral Products Inc OH
Blastcrete Equipment Co AL
Capital Refractories Ltd UK
Fosbel Inc OH
Missouri Refractories Co (MORCO) MO
Pibrico Company IL
Pibrico Japan Co Ltd Japan
Reno Refractories Inc AL
Riverside Refractories Inc AL
Unifrax I LLC NY
Velco GmbH Germany

Furnace Products & Services Inc PA
General Material Industrial Co China
Insulating Firebrick Inc PA
Laguna Clay Co CA
PSH Kilns & Furnaces Canada
RHI US Ltd NY
Zircoa Inc OH

Insulation
Agni Fiber Boards Pvt Ltd India
Capital Refractories Ltd UK
Du-Co Ceramics Company PA
Furnace Products & Services Inc PA
General Material Industrial Co China
HarbisonWalker Int'l PA
Induceramic Canada
Pibrico Company IL
Pibrico Japan Co Ltd Japan
PSH Kilns & Furnaces Canada
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Liesentstraat 9f  
5405 AH Uden The Netherlands  
eurosupport@eurosupport.nl  
http://www.eurosupport.nl  

Euro Support Advanced Materials is an inorganic specialty material producer, a.o. catalysts, dielectrics, and customized materials, including tail manufacturing. Over 20 years experience producing high purity barium titanate for the electronics industry.

ETHER NDE  +44 1582 767912  
Endeavour House  
3 Roundwood Ln  
Harpenden Hertfordshire AL5 3BW UK  
sales@ethernde.com  
http://ethernde.de  

Manufacturer of eddy current instruments, probes, and accessories. Vantage handheld dual frequency inspection instrument; SigmaCheck eddy current electrical conductivity meter; Vector USB-attached battery-operated eddy current instrument; and more.

EXOTHERMICS INC  603-821-5660  
14 Columba Dr  
Amherst NH US 03031  
exo.info@exothermicsinc.com  
http://www.exothermicsinc.com  

Advanced materials company that specializes in the development of ultrahigh temperature refractory compounds and ceramics for demanding aerospace, defense, and other niche applications.

FCT INGENIEURKERAMIK GMBH  +49 3676 888-0  
Frankenbergpark 11  
Frankenbluff Thuringia Germany D-96526  
k.berroth@fct-keramik.de  
http://fct.de  

Produce customized components made of silicon nitride-based ceramics, sintered silicon carbide, C/C-SiC composites, and zirconia. Major applications are in light-metal casting, wear protection, chemical and mechanical process engineering, electronics, precision optics, testing equipment, metal forming, and brake pads.

FCT SYSTEME GMBH  49 3676 824-0  
Gewerbepark 16  
Frankenbergpark 11  
Frankenbluff Thuringia Germany D-96526  
info@fct-systeme.de  
http://www.fct-systeme.de  

Develop and manufacture sintering systems, such as hot presses and systems for spark plasma sintering, gas-pressure sintering, and vacuum sintering up to ultrahigh temperatures for engineering ceramics, powder metallurgy, photovoltaics, and more.
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Topsfeld MA US 01983
sales@gellermicro.com
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http://www.gfschemicals.com

GFS Chemicals is a specialty chemicals manufacturer of bulk inorganics, organic intermediates, and analytical reagents including perchlorates, chlorates, nitrates, iodates, periodates, oxides, lithium salts, heavy metal, and precious metal compounds.

GLASS MFG INDUSTRY COUNCIL
504 Polaris Pkwy Ste 510
Westerville OH US 43082
bobpitz@gmic.org
http://gmic.org

A nonprofit trade association, the first organization to represent all sectors of the glass industry (container, flat, specialty and fiberglass). Dedicated to promoting the interests and economic growth, and sustainability of the glass industry.

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http://goceram.com

Develops, manufactures, and markets medium-pressure injection-molding systems, including low-cost mixers, injection-molding machines, and rate-controlled debinding furnaces as well as supercritical carbon dioxide binder extractors.

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+49 9287 8070
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mail@h-and-m-analytical.com
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Allentown NJ US 08501
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Analytical testing lab providing X-ray diffraction, X-ray fluorescence, particle size distribution, and SEM/EDS services. Provides litigation support, such as patent infringement and expert witness testimony.

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Hitachi High Technologies America, Inc. ("HTA") is a privately-owned global affiliate company that operates within the Hitachi Group Companies. HTA sells and services semiconductor manufacturing equipment, analytical instrumentation, scientific instruments, and bio-related products as well as industrial equipment, electronic devices, and electronic and industrial materials.

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We investigate refractory and ceramic failures, offer testing and analysis services to any standard or nonstandard method, prepare expert witness reports, independently compare materials from different supplier, and validate material properties.

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leico@leicoind.com  
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Established 1966. Supplies aluminium solid rod, tubing, and double- and four-bore insulators; calcia-stabilized, yttria-stabilized, and magnesium-stabilized zirconia; beryllium and thorium oxides in various forms; and clear fused quartz tubing.

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165 Jordan Rd Troy NY US 12180  
salien@lithoz-america.com  
http://www.lithoz.com/en

Lithoz is the system provider for additive manufacturing (3D-printing) of ceramics. As a technology provider, Lithoz covers the whole process chain, from the development of the material and the machine up to the application. Lithoz, based in Vienna, Austria, developed the LCM-technology, which is a slurry-based additive manufacturing-technology based on photopolymerisation with a very high resolution and very good reproducibility. It allows the production of very delicate structures and fine details directly from the CAD-data. Most sinterable powders can be processed by the LCM-technology. Additive manufacturing provides a new design freedom and allows geometries with nearly no limit.

LIXIL CORPORATION  
3-77 Minatocho  
Tokoname Aichi 479-8588 Japan  
global-site@lixil.co.jp  
http://www.lixil.co.jp

Established in 1924. Manufactures all types of tile, bathroom fittings and fixtures, sanitaryware, plastic bathtubs, prefabricated bathrooms, and vanity cabinets.

LUCIDION  
Quares Rd Penkhill Stoke-on-Trent  
Staffordshire ST4 7LD UK  
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 enquiries@lucidion.com  
http://www.lucidion.com

Lucidion, formerly Ceram, is a leading international provider of materials development, testing, and assurance.

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Established 1926. Produces industrial and technical ceramics. A large extrusion and dry-pretty business. Product line includes steatite, cordierite, lava, plastics, and tape casting.

MARYLAND Refractories CO  
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Nutec Bickley designs and manufactures kilns to fire ceramics attending the following industries: sanitaryware, technical ceramics, electroceramic insulators, refractories, heavy clay, and special applications. The company’s kilns are designed in temperature ranges of 90–1,760°C (195–3,200°F).

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info@oceanoptics.com
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Hickory KY US 42051
info@oldhickoryclay.com
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North Rhine-Westphalia 42551 Germany
info@velco.de
https://www.velco.de

Produces gunning machines for dry and humid/plastic mixes, gunning robots for hot repair of EAF, ladle, RH, and more. Pneumatic injection machines for the steel industries. Using the patented GUNMIX system, it is possible to apply LC qualities in dry gunning with low dust and rebound.

VERDER SCIENTIFIC INC
11 Penns Trail Ste 300
Newtown PA US 18940
info-usDverder-scientific.com
http://www.verder-scientific.com

Verder Scientific Inc, comprised of the Retsch, Retsch Technology, Carbvette Gero, and ELTRA brands, sets the standard in high-tech scientific equipment, serving research institutions and analytical laboratories, as well as manufacturing companies, for decades. The company manufactures and supplies instruments for sample preparation and elemental analysis as well as heat treatment of solid materials.

VERITY TECHNICAL CONSULTANTS LLC
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http://www.verityconsultants.com

Verity provides manufacturing consulting, technical investigations, analysis, reports, and testimony for the resolution of litigation and claims involving failures of glass and ceramic materials, product liability, and industrial workplace accidents.

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VESUVIUS is a worldwide leader in advanced ceramics for the solar, glass-tempering, and glass-forming industry.

WIRSTRA GMBH
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WASHINGTON MILLS
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Fax: 716-276-6650

WASHINGTON MILLS ELECTRO MINERALS CO
1801 Buffalo Ave
Niagara Falls NY US 14302
info@washingtonmills.com
http://www.washingtonmills.com

Manufactures fused synthetic minerals for use in refractory raw materials, abrasives, ceramic raw materials, and industrial applications. Products include silicon carbide, brown fused alumina, white fused alumina, boron carbide, bubble alumina, and more.

WINNER TECHNOLOGY
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WILLIAMS PATENT CRUSHER & PULVERIZER CO INC
314-621-3348
Fax: 314-436-2639

WILLIAMS PATENT CRUSHER & PULVERIZER CO INC 2701 N Broadway St Louis MO US 63102
info@williamspulverizer.com
http://williamspulverizer.com

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WESBOND CORP
302-655-7917
Fax: 302-656-7685

WESBOND CORP 1135 E 7th St
Wilmington DE US 19801
sales@wesbond.com
http://wesbond.com

Established 1976. Develops and manufactures new binding and bonding systems for refractory-fiber shapes and ceramic composites as well as ceramic shell molds for investment castings. Products include colloidal alumina, silica and mullite binders.

WASHINGTON MILLS ELECTRO MINERALS CO
1801 Buffalo Ave
Niagara Falls NY US 14302
info@washingtonmills.com
http://www.washingtonmills.com

Manufactures fused synthetic minerals for use in refractory raw materials, abrasives, ceramic raw materials, and industrial applications. Products include silicon carbide, brown fused alumina, white fused alumina, boron carbide, bubble alumina, and more.

VERDER SCIENTIFIC INC
866-473-8724
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UNIMIN CORPORATION
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Fax: 203-966-3453

UNIMIN CORPORATION specializes in industrial minerals and chemical raw materials, abrasives, ceramic raw materials, and more.

U.S. SILICA CO
800-345-6170
Fax: 304-258-8295

U.S. SILICA CO specializes in industrial minerals and chemical raw materials, abrasives, ceramic raw materials, and more.

UNION PROCESS INC.
330-329-3333
Fax: 330-329-3034

UNION PROCESS INC. specializes in industrial minerals and chemical raw materials, abrasives, ceramic raw materials, and more.

VIRIDIUS LLC
5890 Progress Dr Bldg E-001
Fax: 978-425-3031

VIRIDIUS LLC specializes in industrial minerals and chemical raw materials, abrasives, ceramic raw materials, and more.

Valley Design Corp
(708) 425-3030
Fax: 708-425-3031

Valley Design Corp specializes in industrial minerals and chemical raw materials, abrasives, ceramic raw materials, and more.

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302-655-7917
Fax: 302-656-7685

WESBOND CORP specializes in industrial minerals and chemical raw materials, abrasives, ceramic raw materials, and more.

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Niagara Falls NY US 14302
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XIAMEN INOVACERA ADVANCED MATERIALS CO LTD
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http://www.inovacera.com

With more than 20 years experiences in technical ceramic solutions, Inovacera manufactures products made of technical ceramics for customer-specific applications. Products include metalized ceramic components, alumina ceramic heater, ceramic pump components, and other ceramic components. All of our products are underpinned by the most rigorous quality accreditation.

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Unipretec is a professional manufacturer for advanced ceramics. Our main materials include alumina ceramic, zirconia ceramic, boron nitride, and machineable glass ceramic. We aim to provide high quality products and solutions for our customers.

XIETA INTERNATIONAL S.L.
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08006 Barcelona, Spain
www.xieta.com

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ZETRON Marketing Services Inc is a technical marketing company with an extensive database of technical files and pricing information on ceramic and refractory products worldwide. In addition, we provide technical brochures in Word Document format on request.

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Zenith Ceramics Inc. offers a complete line of superior quality engineered refractory products for the most demanding industrial applications. Our products include a unique granular zirconia; crucibles for investment casting; refractories for steel, powder metallurgy, glass, quartz, crystal growth, and carbon black; beads and grinding media for dispersion and milling; dies for extrusion of nonferrous metals and other forming methods; and components for oil and gas.

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1100 Main St
Midland TX 79703
Fax: 432-683-2790

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http://www.zhzhengheng.com

Zuoqing Zhengheng Co., Ltd. is a high-tech enterprise in the field of zirconia production. The company specializes in producing zirconia ceramic, zirconia zirconium dioxide, and zirconium oxide products.

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1510 V St NW
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Fax: 202-337-0123

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Fax: 81-3-3631-9906

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5618 Valley Rd
Park Ridge IL 60068
Fax: 630-432-9880

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