AMERICAN CERAMIC SOCIETY

bulletin

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DECEMBER 2019

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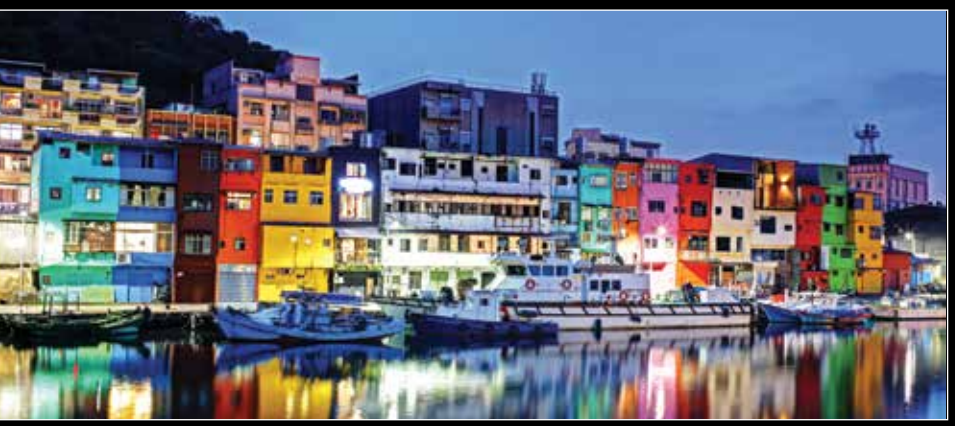

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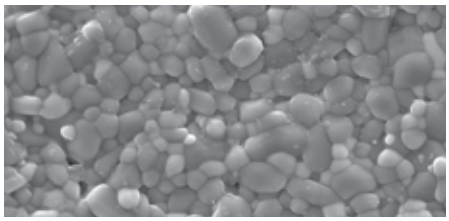

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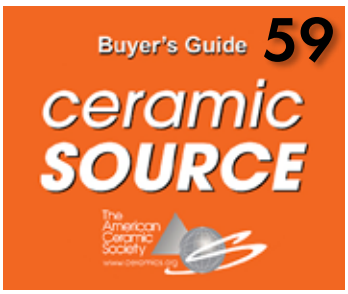

department

columns

meetings

resources

Correction to the October/November 2019 *ACerS Bulletin*

The company referred to on page 29 as "Abrasives.com" is "AbrasiveStocks.com." The *Bulletin* apologizes for the error.

AMERICAN CERAMIC SOCIETY
bulletin

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As seen on *Ceramic Tech Today*...

Credit: Thermal problem, Flickr (CC BY-NC-SA 2.0)

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.

Read more at www.ceramics.org/circuitarmor

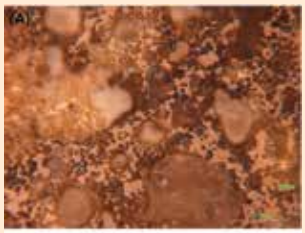
Also see our ACerS journals...

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. Martínez-Martínez, L. Pérez-Villarejo, D. Eliche-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
By Y. Yu, H. Su, J. Xiao, et al.
International Journal of Applied Ceramic Technology



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

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

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ACSBA7, Vol. 98, No. 9, pp 1– 148. All feature articles are covered in Current Contents.

Federal budget 2020—Science funding continues to rise

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.

Table 1. FY20 budget proposals ($ in millions)

	DOD S&T total	NSF	DOE Office of Science	NIST	NASA	NIH
FY19 appropriation	15,960	8,075	6,585	986	6,906	39,084
White House	14,059 (-12%)	7,066 (-12%)	5,546 (-16%)	687 (-30%)	6,394 (-7%)	34,368 (-12%)
House	14,843 (-7%)	8,636 (7%)	6,870 (4%)	1,040 (6%)	7,161 (4%)	41,100 (5%)
Senate	15,699 (-2%)	8,317 (3%)	7,215 (10%)	1,038 (5%)	6,906 (0%)	42,084 (8%)

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. ■

Business news

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).

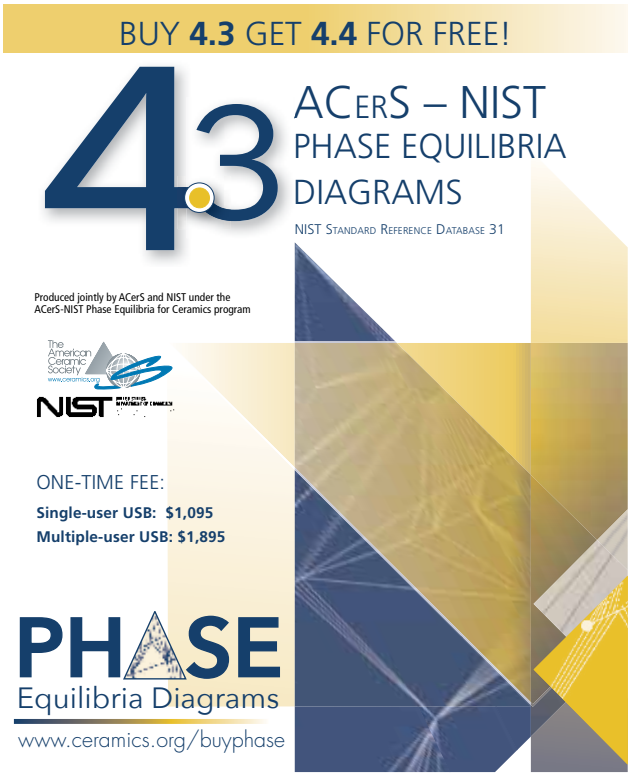
MARKET TRENDS

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. Specialty 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.

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

Battery technology	2018	2019	2024	CAGR% 2019–2024
Lithium-ion (rechargeable)	33,881	36,477	56,744	9.2
Lithium-polymer (rechargeable)	2,566	3,088	19,477	44.5
Alkaline and zinc-carbon (primary)	14,024	14,346	14,608	0.4
Nickel-metal hydride (rechargeable)	2,068	2,132	2,562	3.7
Specialty rechargeable batteries	63	68	870	66.5
Lithium (primary)	254	262	310	3.4
Nickel-cadmium (rechargeable)	23	23	16	-7.0
Other primary batteries	138	146	171	3.2
Total	2,462	3,021	11,208	30.0

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.

About the author

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

Resource

R. Eckard, "Portable battery-powered products: Global markets" BCC Research Report FCB023F, August 2019. www.bccresearch.com. ■

SOCIETY AND DIVISION NEWS

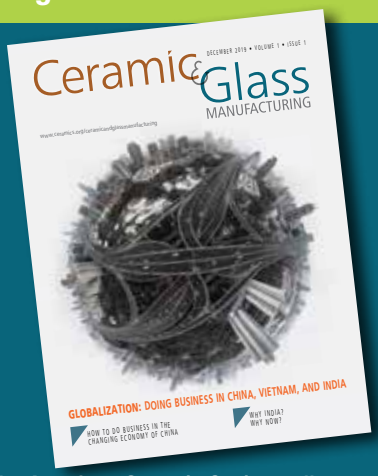
Corporate Partner news

We are pleased to welcome the following Corporate Partners:

- **Balai Besar Keramik**
- **Bullen Ultrasonics, Inc.**
- **Sandia National Laboratory**

For more details contact Kevin Thompson at 614-794-5894 or kthompson@ceramics.org. ■

ACerS launches new magazine for manufacturers!



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&GM 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.

Names in the news


Boccaccini

Aldo R. Boccaccini, professor and head of the Institute of Biomaterials at University of Erlangen-Nuremberg, Germany, was reelected for a second period of four years to the Council of the European Society for Biomaterials.


Du

Jincheng Du, professor in materials science and engineering department at the University of North Texas, received a Fulbright U.S. Scholar Award to conduct glass research in Brazil


Laurencin

Cato Thomas Laurencin, professor at the University of Connecticut Health Center, received the 2019 National Academy of Engineering Simon Ramo Founders Award. He also won the UNESCO-Equatorial Guinea International Prize for Research in the Life Sciences.


Madsen

Lynnette D. Madsen, program director of the U.S. National Science Foundation, received the 2020 Acta Materialia Inc. Hollomon Award for Materials & Society.


McCloy

John McCloy, professor in the school of mechanical and materials engineering at Washington State University, received a Fulbright award to study and conduct research in the United Kingdom.


Sreeram

A.N. Sreeram, senior vice president and chief technology officer at Dow Chemical, was appointed member of the President's Council of Advisors on Science & Technology by President Trump. Sreeram is also a member of Alfred University Board of Trustees.


Trolier-McKinstry

Susan Trolier-McKinstry, Steward S. Flaschen Professor of Ceramic Science and Engineering and Electrical Engineering at The Pennsylvania State University, delivered the John F. McMahon Memorial Lecture at Alfred University.

ACerS members in the ASM International 2019 Class of Fellows


Chandran

K.S. Ravi Chandran, professor at University of Utah.


Hoffman

Elizabeth N. Hoffman, program manager at the Savannah River National Lab.


Milligan

Walter William Milligan, Jr., professor at Michigan Technological University.


Rickman

Jeffrey Mitchell Rickman, professor at Lehigh University.

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

Society and Division news (continued)

Volunteer Spotlight

Kassner

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! ■

AWARDS AND DEADLINES

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.

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 microanalysis 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.

Credit: ACerS

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

Scanning Electron Microscopy

First place

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

Second place

Eutectic microstructures induced by flash sintering by **Yingjie Yang** and **Martha Mecartney**, University of California, Irvine

Third place

Solid state reaction and single crystal growth along interphase boundaries by **Kevin Anderson**, **Anit Giri**, **Richard P. Vinci**, 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 dewaxing by **Mayu Kato**, **Junichi Tatami**, **Motoyuki Iijima**, and **Takuma Takahashi**, Yokohama National University, Japan

Undergraduate Studies

First place

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

Second place

Microstructure of electrochromic NiO film by **Kristen Wong** and **Khalid Rafique**, University of California, Irvine ■

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STUDENTS AND OUTREACH

ACerS Annual Meeting and MS&T19 student contest winners

Credit: ACerS

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_3Ti particles in Al-Al_3Ti 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

Credit: ACerS

Undergraduate student speaking contest finalists. From left: Victoria Reichelderfer, Bailey Ricketts, Jose Mancias, and Shane Johnson.

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 ■

Credit: ACerS

CERAMICANDGLASSINDUSTRY FOUNDATION

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.*

Past attendees of Winter Workshop enjoying the Kennedy Space Center.

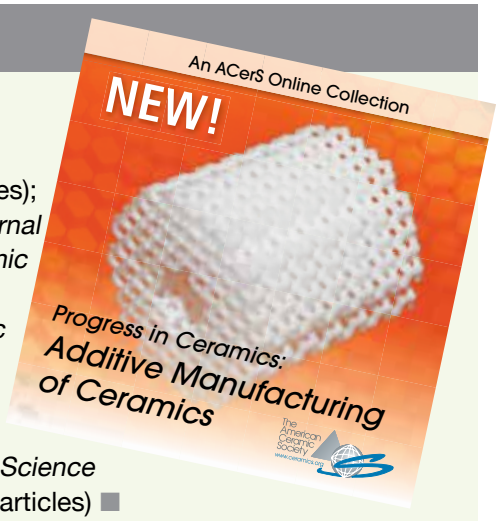
The afternoon session will feature speakers and activities on professional development. The Ceramics Career Panel will lead interactive discussions on career paths taken by successful members of the ceramics field, who will then be available to answer attendees' questions on a variety of topics.

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. ■

ACERS BOOKSHELF

Check out this new title from ACerS/Wiley



Check out a new collection from ACerS and Wiley. Available at https://bulletin-archive.ceramics.org/additive-manufacturing-of-ceramics.

Progress in Ceramics Series: Additive Manufacturing of Ceramics

In this Progress in Ceramics Series, we have compiled 94 articles on the topic of additive manufacturing. The articles were selected from five ACerS publications: *American Ceramic Society Bulletin* (5 articles); *Journal of the American Ceramic Society* (44 articles); *International Journal of Applied Ceramic Technology* (17 articles); *Ceramic Transactions* (10 articles); and *Ceramic Engineering and Science Proceedings* (18 articles) ■

Lasers weld ceramics at room temperature

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.

Credit: Garay lab, UC San Diego

Laser welded ceramic assembly consisting of a transparent cylindrical cap joined to a ceramic tube.

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 a UC San Diego press release.

When compared to metal-to-ceramic assemblies created through diffusion bonding, the UF laser-welded ceramics demonstrated comparable shear strengths, and required less than 50 watts of laser power to create.

The researchers foresee many applications of their UF laser welding technique, especially in terms of electronic assemblies. "Right now there is no way to encase or seal electronic components inside ceramics because you would have to put the entire assembly in a furnace, which would end up burning the electronics," Javier Garay, professor of mechanical engineering and materials science and engineering at UC San Diego, says in the 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). ■

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 (CO_2) 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 CO_2. 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 ($CaCO_3$, generally limestone) and then cooking it with sand and clay at high heat, produced by burning coal. The cooking process decarbonizes $CaCO_3$ and produces calcium oxide (CaO) and CO_2. The CaO is then reacted with silica (SiO_2) to produce alite, the major mineral phase in Portland cement.

Credit: Felice Frankel, MIT

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

Two parts of the process are responsible for CO_2 production: burning coal and heating $CaCO_3$.

One way to reduce emissions is to heat $CaCO_3$ 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 $CaCO_3$ decarbonation and $Ca(OH)_2$ precipitation and collection," the researchers write in the paper.

FROM BRICKS TO NANOS

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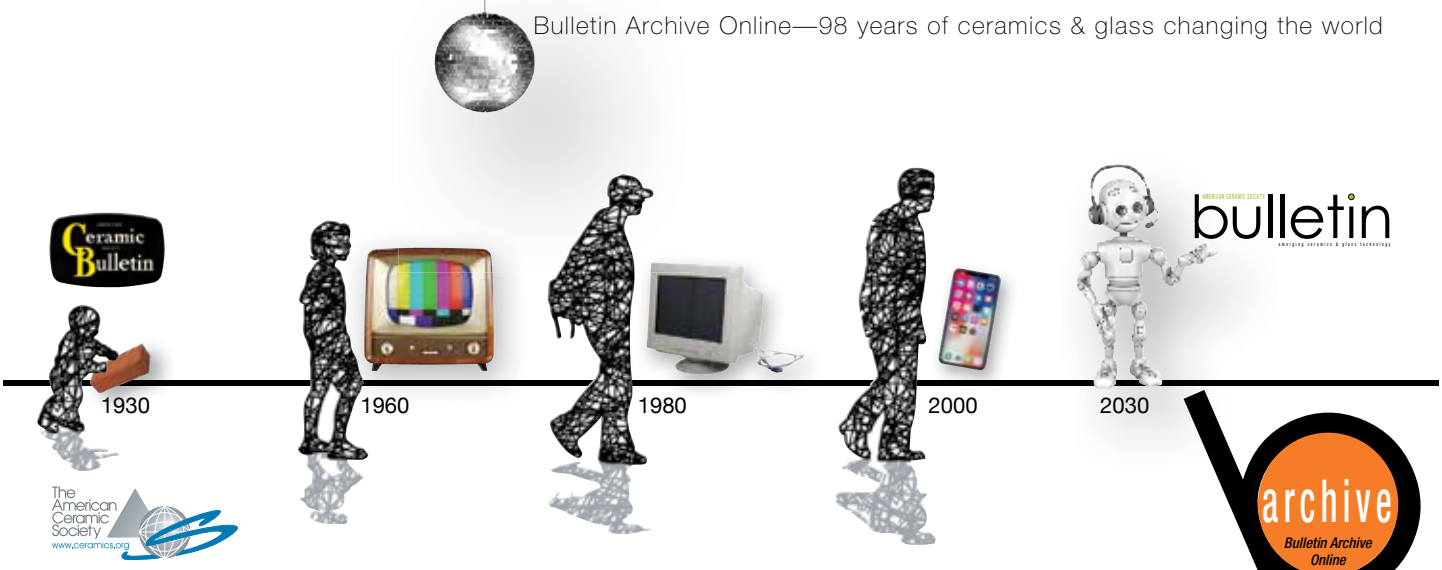

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The researchers, led by ACerS Fellow and Kyocera Professor of Materials Science and Engineering Yet-Ming Chiang and postdoc Leah Ellis, dissolved pulverized $CaCO_3$ in the acid at one electrode and calcium hydroxide [$Ca(OH)_2$] precipitated out as a solid at the other one. Though $Ca(OH)_2$ is slightly different from CaO, the material produced in a conventional cement manufacturing process, $Ca(OH)_2$ "readily reacts with silica to form alite while giving off only water," Chiang explains in an email.

In addition to $Ca(OH)_2$, dissolving $CaCO_3$ in acid produced a stream of O_2/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 CO_2 is delivered in a highly concentrated form mixed only with O_2 (and some H_2O vapor), direct capture using the same simple compression processes now used for purified and concentrated CO_2, could be used," they explain. That means the 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 H_2 and O_2/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 $CaCO_3$ 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

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

Across the globe, 230 billion m^2 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%).[3]

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.[4]

"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.[5] "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.[6] 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 CO_2 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.[7] "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,[8] 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 CO_2.[8] 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.[3]

"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.[2] "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 ft^2 (median price: $281,200).[9] However, that size varies significantly across the developed world, with an average for all homes closer to 1,200 ft^2.[10] 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

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

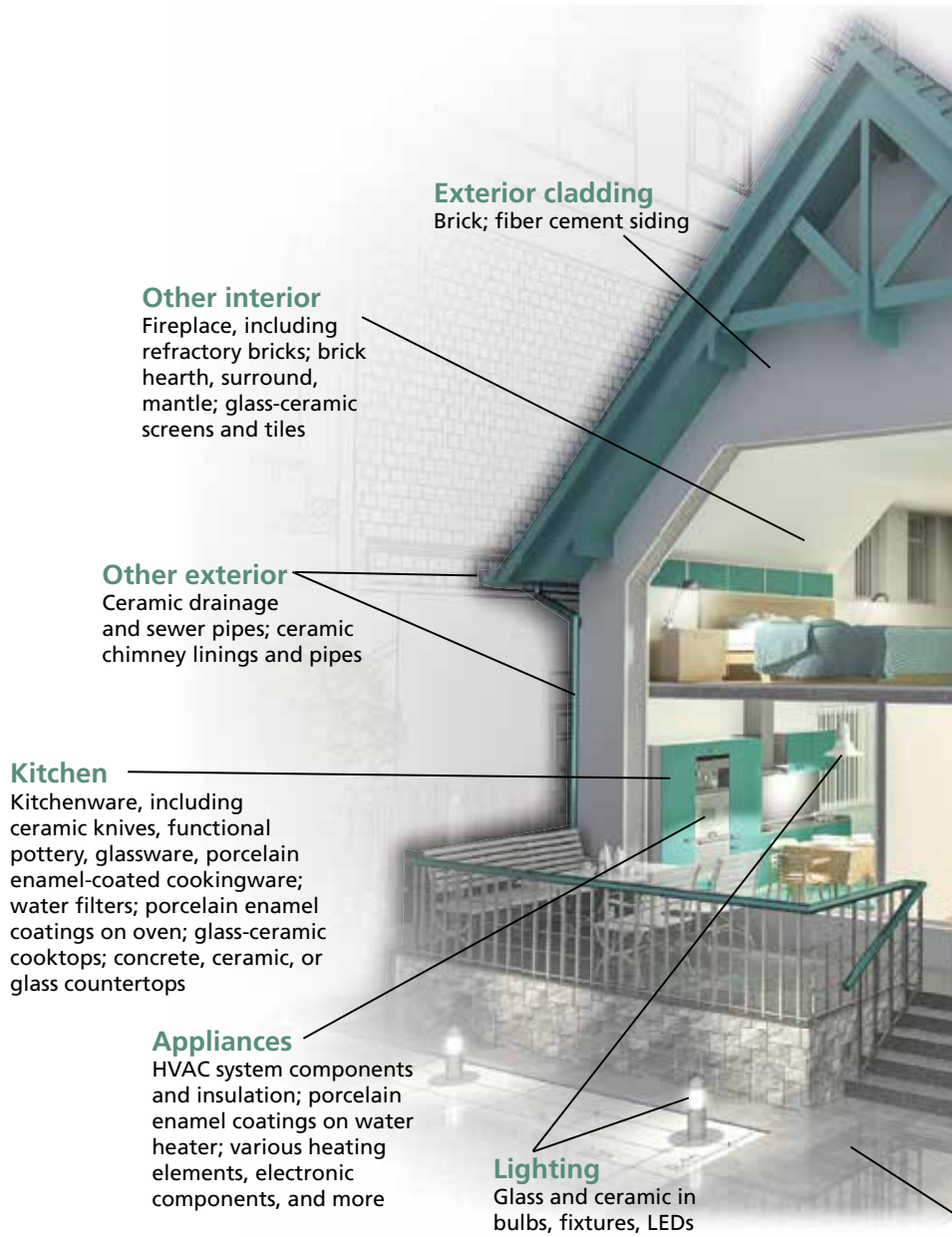
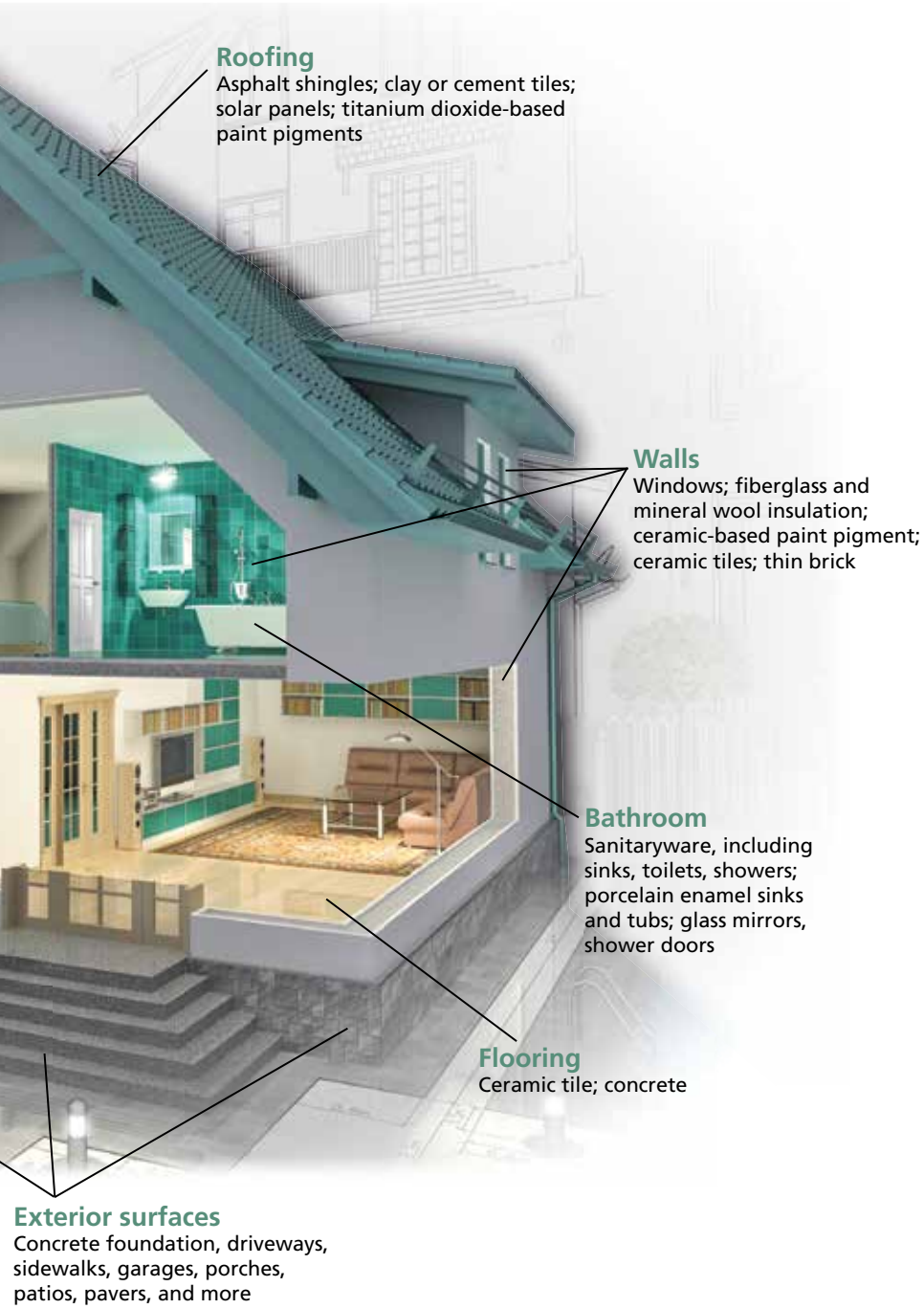


Figure 1. Ceramic and glass materials contribute function and beauty in every room and system in a home.

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

Credit: Owens Corning

Figure 2. Ceramic-coated granules can be manufactured in an array of colors and functionalities to provide dimensional effects and performance to asphalt shingles.

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 Tayler, 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

Table 1. Select companies that manufacture ceramic and glass building products

Company (location)	Annual revenue (millions)	Website	Role in value chain
Saint-Gobain (Courbevoie, France)	$46,670	www.saint-gobain.com	Various diverse products, including building glass, roofing, insulation, pigment materials for tiles
*CertainTeed, subsidiary of Saint-Gobain (Malvern, Pa.)	$4,000‡	www.certainteed.com	Roofing, insulation, siding, various building and construction products
LIXIL Group Corp. (Tokyo, Japan)	$16,900	www.lixil.com	Sanitaryware, as well as various other building materials and construction products
Mohawk Industries Inc. (Calhoun, Ga.)	$9984	www.mohawkind.com	Flooring (including ceramic tile), countertops
*Dal-Tile, subsidiary of Mohawk (Dallas, Texas)	$5.7‡	www.daltile.com	Ceramic tile, countertops
Kohler Co. (Kohler, Wisc.)	$7,727‡	www.kohlercompany.com	Sanitaryware; also manufactures diverse other products
Owens Corning (Toledo, Ohio)	$6,384†	www.owenscorning.com	Roofing, insulation
Boral (Sydney, Australia)	$5,869	www.boral.com	Various building products, including roof tiles, windows, drywall
Toto (Kitakyushu, Japan)	$5,407	www.toto.com	Sanitaryware
Carlisle (Scottsdale, Ariz.)	$4,600‡	www.carlisle.com	Various diverse products, including roofing, insulation, other construction materials
Johns Manville (Denver, Colo.)	$3100‡	www.jm.com	Roofing, insulation
GAF Materials (Parsippany, N.J.)	$3,000	www.gaf.com	Roofing
Schott AG (Mainz, Germany)	$2,325	www.schott.com	Various diverse products, including flat glass, ceramics, and glass-ceramics for various home applications
*Schott North America Inc. (Elmsford, N.Y.)	$56†	www.us.schott.com	Various diverse products, including flat glass, ceramics, and glass-ceramics for various home applications
Roca (Barcelona, Spain)	$2,009	www.roca.como	Sanitaryware, ceramic tile
Ferro Corp. (Mayfield Heights, Ohio)	$1,612	www.ferro.com	Various products in diverse industries, including porcelain enamel
IKO Industries (Calgary, Alberta, Canada)	$1188‡	www.iko.com	Roofing, insulation
Acme Brick Co. (Fort Worth, Texas)	$758†	www.brick.com	Brick
Knauf Insulation (Abu Dhabi, United Arab Emirates)	$406‡	www.knaufinsulation.com	Insulation
SCG Ceramics (Bangkok, Thailand)	$381	www.scgceramics.com	Ceramic tile, sanitaryware
Mansfield Plumbing LLC (Perrysville, Ohio)	$181†	www.mansfieldplumbing.com	Plumbingware

*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.

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

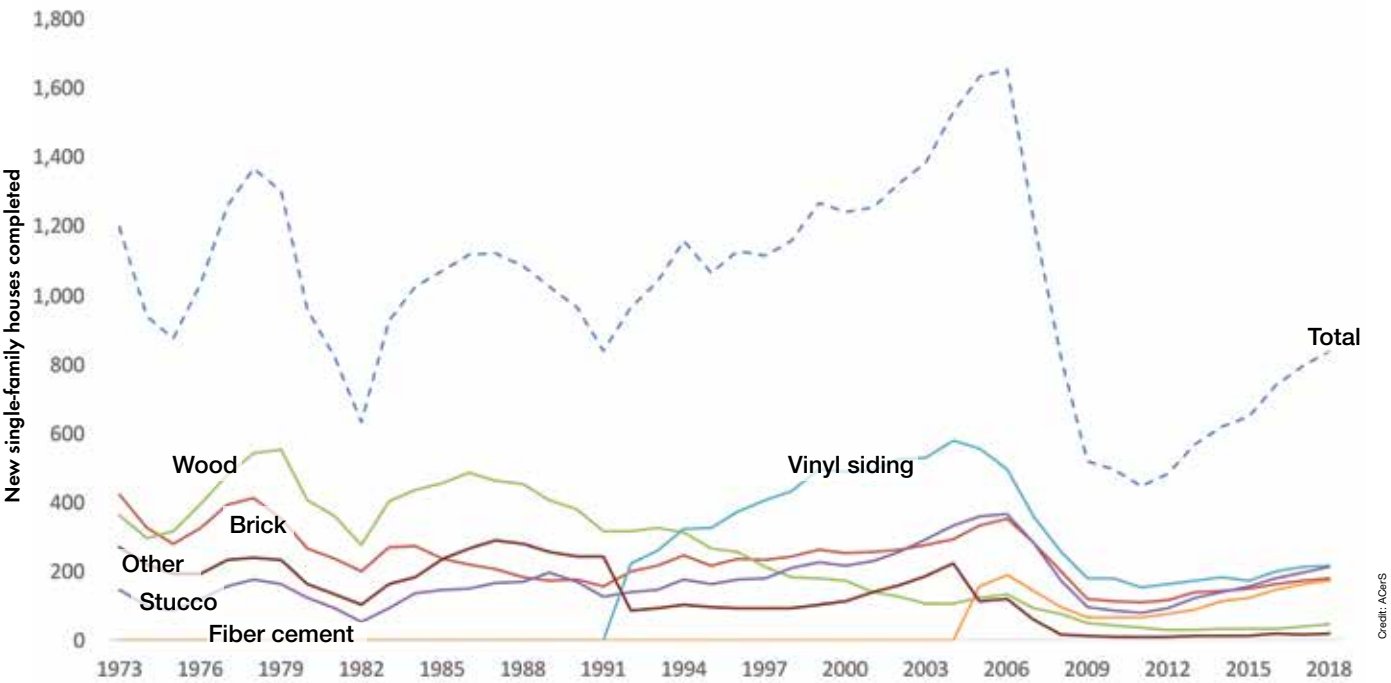


Figure 3. U.S. Census Bureau data showing total new single-family houses (dotted line) and houses by primary type of exterior wall material completed in the U.S., 1973–2018.

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.[17]

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.[15] 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.[18]

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.[19]

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.[20]

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.[18]

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).[21] 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,[22] 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.[23]

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.

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 Schimmelpenningh, 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.

Sumi von Dassow's seven-cup muffin pan.

Those who create functional pottery are thinking about much more than the job at hand. "We put the thought, time, and care into making these useful objects with the hopes that the users will somehow connect with them beyond their intended purpose," Jennifer Harnetty, editor of Ceramic Arts Network (CAN), explains in a 2018 CAN article on functional pottery.

Lindsay Oesterritter's designed juicer.

CAN is the website for the International Ceramic Artists Network (ICAN), the membership organization of The American Ceramic Society that serves the international ceramic arts community. Its website, CeramicArtsNetwork.org, provides a wide array of tools for learning about and improving ceramic art skills, and a place for artists to share ideas and perspectives. *Ceramics Monthly* and *Pottery Making Illustrated*, two magazines published by ACerS, provide further resources and information.

Amy Roberson's functional vessels, oval-patterned, water-etched watering can.

For more information on functional pottery, the book "In the Potter's Kitchen," published by ACerS highlights the many ways beyond bowls and mugs in which clay products are used in cooking, including ovenware, stovetop ware, serving ware, preparation ware, and storage ware. ■

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, and feldspathic 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.

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

Rooms with a view—Dynamic window glazing

Dynamic glazing, often called smart glass, is another big area of development in windows. These advances include coatings on the glass or integrated technologies that can reversibly control glass tint to adjust how much light passes through.

By variably adjusting solar heat gain through the glass, these technologies allow differential control during different climates—using less tint to allow more solar energy to pass through the glass during colder climates, warming the building inside; and using darker tint to reflect more solar radiation when the outside climate is hotter, keeping the building inside cooler.

Dynamic glazing attempts to balance conflicting desires of wanting a view yet also needing to reduce solar energy gain through the windows, which can account for up to about 30% of heat loss in homes.[a]

"How can we provide comfort for the occupants, in the most energy efficient manner possible? That's what dynamic glazing does" says Julia Schimmelpenningh, industry technical manager of architectural customer applications and service lab manager at Eastman Chemical Co. (Kingsport, Tenn.).

There are several variations of dynamic glazing, including electrochromic glazing, which controls glass tint with an electrical current; photochromic glazing, which adjusts based on light; and thermochromic glazing, which adjusts based on temperature.

SageGlass, for instance, is Saint-Gobain's (Malvern, Pa.) electrochromic glass, which is already on the market for commercial applications.

The float glass is sputtered with five metal oxide layers that give SageGlass electrochromic abilities. Applying a low voltage to the glass causes ions to migrate among these ceramic layers, initiating a solid-state change that darkens the glass. The process is reversible, allowing glass to darker and lighten on demand to tint levels of 1%–60%.[b]

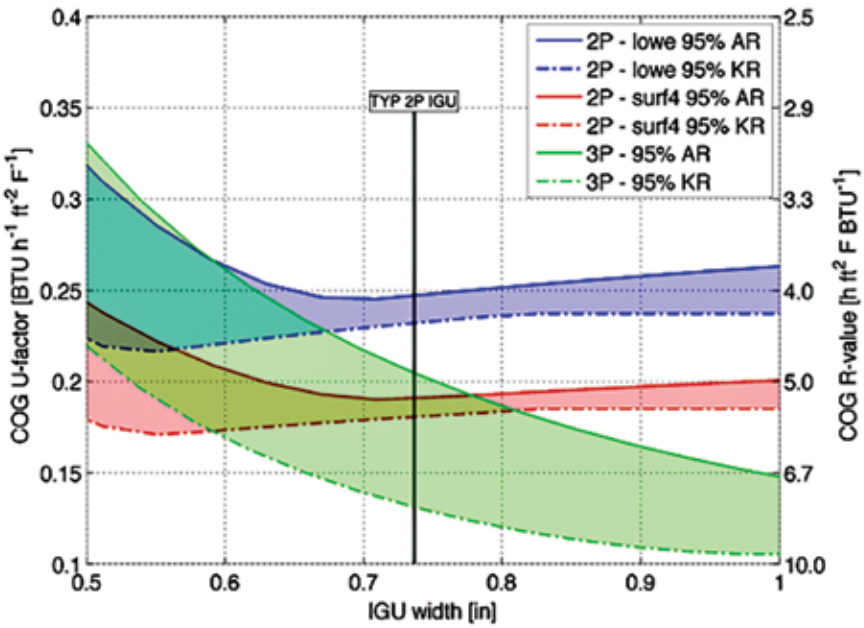
SageGlass's high-volume manufacturing plant in Faribault, Minn., is the largest electrochromic glazing plant in the world, capable of churning out millions of square feet of dynamic glass annually in a 324,000 ft^2 LEED-certified facility, which opened in 2012.

Still other developing window technologies go one step further than tailored energy control and also add energy harvesting to their abilities. Similar to roofs, building incorporated photovoltaics are another future direction for windows that directly integrate solar cells or energy harvesting technologies onto the glass.

While countless types of these technologies have been developed in prototypes or small scales, most all are currently cost-prohibitive or face manufacturing or commercial-scale barriers.

[a]US Department of Energy. "Update or replace windows." Accessed October 1, 2019. https://www.energy.gov/energysaver/design/windows-doors-and-skylights/update-or-replace-windows

[b]SageGlass by Saint-Gobain. "Dare to be Dynamic" press briefing. Downloaded October 1, 2019. https://www.sageglass.com/en/news ■



Credit: Lawrence Berkeley National Laboratory

Figure 4. Thermal performance of double glazing (2P) compared to triple glazing (3P) windows at various insulating glass unit (IGU) thickness and filled with argon (AR) or krypton (KR). Blue represents most windows currently on the market. Red represents windows with an additional low-E coating on the inside surface, indicating modest performance gains. Green indicates significant potential energy savings with triple-glazed units.

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 ft^2 per year.[29] Thirty years later, consumption reached 3.11 billion ft^2 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 manufactures 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,

Figure 5. Cross-section of a triple-glazed window unit, showing a thin panel of glass that separates the standard air space in a double-glazed unit.

Credit: Alpen

Credit: Mansfield Plumbing

Figure 6. A worker at Mansfield Plumbing loads a batch of slip cast washbasins on the transportation cart. Ceramic engineer manager Felipe Mejia says the sanitaryware industry is looking to automate the more labor-intensive steps of the manufacturing process.

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.[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 use.[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 a Lixil article,[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.[37] Watch a video of AquaCeramic in action at youtu.be/D9MSr-nfGQM.

Credit: Lixil

Figure 7. Lixil's Aquaceramic super-hydrophilic ceramic is engineered to use water to lift oils and substances off the surface, offering the ability to wash away potential stains with a flush.

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

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 self-cleaning 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.[38]

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.

Credit: Daniel Case; Wikimedia CC-SA 3.0

Figure 8. A porcelain enamel Lustron house still stands in Albany, N.Y. From 1948–1950, the Lustron Corporation used an assembly line in a former warplane manufacturing factory in Columbus, Ohio, to manufacture porcelain enamel houses as a quick and low-cost solution to the post-World War II housing crisis.

"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

Credit: Schott North America

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.[3]

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 windborne 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 9-lb 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.[39]

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.

"The combination of safety, lifespan, and thermal performance, when you look at the whole, makes ceramic materials really a no brainer"

– John Sanders (NBRC)

"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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January 22 – 24, 2020 | DoubleTree by Hilton Orlando at Sea World Conference Hotel | Orlando, Fla., USA

Electronic Materials and Applications (EMA 2020)

Organized by the ACerS Electronics and Basic Science Divisions

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

Rijnders

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

Dickey

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

DOUBLETREE by HILTON ORLANDO AT SEA WORLD

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407-352-1100

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

www.ceramics.org/ema2020

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-Conducting 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

AMERICAN CERAMIC SOCIETY bulletin
emerging ceramics & glass technology

CeramicTechToday
FROM THE AMERICAN CERAMIC SOCIETY

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

44TH INTERNATIONAL CONFERENCE AND EXPOSITION ON ADVANCED CERAMICS AND COMPOSITES

#ICACC20

January 26 – 31, 2020 | Hilton Daytona Beach Oceanfront Resort Daytona BeachDaytona Beach | Florida, USA

Award and Plenary Speakers

JAMES I. MUELLER AWARD

Weber

William J. Weber, Governor's Chair Professor, University of Tennessee, USA

Title: *Ion-beam modification and nanostructure evolution in ceramics*

BRIDGE BUILDING AWARD

Ishikawa

Toshihiro Ishikawa, Vice President, Tokyo University of Science, Japan

Title: *Development of precursor ceramics using organic silicon polymer*

PLENARY SPEAKER

Gray

George T. (Rusty) Gray III, Laboratory Fellow, Los Alamos National Laboratory, USA

Title: *Developing a pathway to microstructure-aware predictive capability for the shock / dynamic response of materials*

PLENARY SPEAKER

Balázsi

Katalin Balázsi, Head of Thin Film Physics Department, Institute for Technical Physics and Materials Science, Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary

Title: *Ceramic biomaterials: From traditional technologies to novel applications*

GLOBAL YOUNG INVESTIGATOR AWARD

Mhin

Sungwook Mhin, Senior Researcher, Korea Institute of Industrial Technology (KITECH), Korea

Title: *Advantageous crystalline–amorphous phase boundary for water oxidation*

ENGINEERING CERAMICS DIVISION JUBILEE GLOBAL DIVERSITY AWARD

Tallon

Carolina Tallon, Department of Materials Science and Engineering and Advanced Manufacturing Team, Virginia Polyechnic Institute and State University, USA

Title: *EMulti-scale thermal protective systems for extreme environments: Design, processing, properties and modeling*

Casalegno

Valentina Casalegno, Institute of Materials Physics and Engineering, Politecnico di Torino (POLITO), Italy

Title: *Ceramic and composite joints for nuclear applications*

Yun

Hui-suk Yun, Materials Processing Innovation Research Division, Korea Institute of Materials Science (KIMS), Korea

Title: *Current technological advances in multi-ceramic additive manufacturing*

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

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Exhibition Information

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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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Room rates are effective until **Dec. 20, 2019,** and are based on availability.

Exhibitor	Booth
3DCeram Sinto Inc.	318
AdValue Technology, LLC	216
Alfred University	315
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

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

www.ceramics.org/PACCFMAs

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

Submit your abstract before JANUARY 15, 2020

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).

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.

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)

FERROELECTRICS MEETING OF AMERICAS

Tentative Schedule of Events

Sunday, July 19, 2020	
Conference registration	3:30 – 7 p.m.
Welcome reception	5:30 – 7 p.m.
Monday, July 20, 2020	
Conference registration	7 a.m. – 5 p.m.
Opening awards ceremony & plenary session	8:30 – 11:30 a.m.
Lunch/Technology fair	11:30 a.m. – 1 p.m.
Concurrent technical sessions	1 – 5 p.m.
Coffee break	3 – 3:20 p.m.
Technology fair and poster session, including reception	5:30 – 7 p.m.
Tuesday, July 21, 2020	
Conference registration	7 a.m. – 5 p.m.
Concurrent technical sessions	8:30 – 11:30 a.m.
Lunch/Technology fair	11:30 a.m. – 1 p.m.
Concurrent technical sessions	1 – 5 p.m.
Coffee break	3 – 3:20 p.m.
Wednesday, July 22, 2020	
Conference registration	7:30 a.m. – Noon
Concurrent technical sessions	8:30 a.m. – Noon
Technology fair	8:30 a.m. – Noon
Afternoon on own	Noon – 5 p.m.
Conference dinner	7 – 9 p.m.
Thursday, July 23, 2020	
Conference registration	8 a.m. – Noon
Concurrent technical sessions	8:30 a.m. – Noon

Calendar of events

December 2019

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

11–12 83rd Annual Session of InCerS, entitled "National Conference on Innovations and Technologies for Ceramics (InTeC-2019)," at CSIR-NIIST – Thiruvananthapuram, Kerala, India; http://www.intec-2019.org

January 2020

22–24 EMA2020: Electronic Materials and Applications – DoubleTree by Hilton Orlando at Sea World Conference Hotel, Orlando, Fla.; www.ceramics.org/ema2020

26–31 ICACC20: 44th Int'l Conference and Expo on Advanced Ceramics and Composites – Daytona Beach, Fla.; www.ceramics.org/icacc20

March 2020

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

April 2020

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

May 2020

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

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

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

June 2020

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

July 2020

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

August 2020

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

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

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

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

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deciphering the discipline

A regular column offering the student perspective of the next generation of ceramic and glass scientists, organized by the ACerS Presidents Council of Student Advisors.

Yiqing Xia
Guest columnist

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:

$$m = (d\log\eta(T))/(d(T_g/T))_{T=T_g}$$

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.

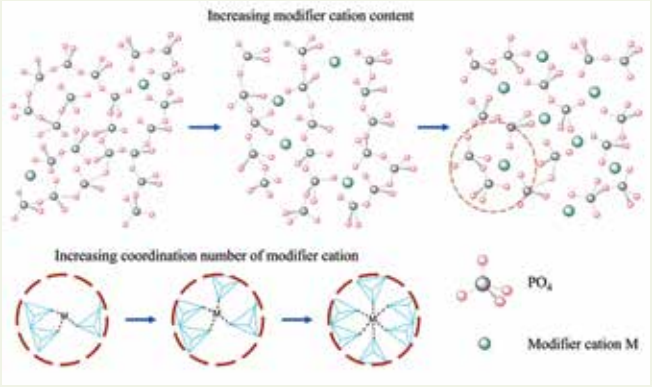

Figure 1. Structural connectivity in phosphate glasses modified by the content and coordination of modifier cation M.

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 ($m \approx 90$), 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

[1]Angell, C. A. Perspective on the glass transition. *J. Phys. Chem. Solids* **1988**, 49, 863.

[2]Xia, Y.; Marple, M. A. T.; Hung, I.; Gan, Z.; Sen, S. Network structure and connectivity in $SnO-P_2O_5$ glasses: Results from 2D 31P and 119Sn NMR spectroscopy. *J. Non Cryst. Solids* **2018**, 122 (29), 7416–7425.

[3]Xia, Y.; Zhu, W.; Lockhart, M.; Aitken, B.; Sen, S. Fragility and rheological behavior of metaphosphate liquids: Insights into their chain vs. network characters. *J. Non. Cryst. Solids* **2019**, 514, 77–82.

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. ■

Ceramic & Glass MANUFACTURING

DECEMBER 2019 • VOLUME 1 • ISSUE 1

www.ceramics.org/ceramicandglassmanufacturing

GLOBALIZATION: DOING BUSINESS IN CHINA, VIETNAM, AND INDIA

HOW TO DO BUSINESS IN THE CHANGING ECONOMY OF CHINA

WHY INDIA? WHY NOW?

WELCOME TO VOLUME 1, ISSUE 1

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.

Issue	Theme
December 2019	Globalization and the ceramic industry
April 2020	Breaking in: A small company guide to working with big companies
June/July 2020	Smart manufacturing: Good business practices for manufacturers
September 2020	Workforce development
December 2020	Standards: Guideposts to quality

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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Panel discussion with industry experts at Ceramics Expo 2019.

INDUSTRY NEWS

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.

Corning's Harrodsburg, Ky. facility is the home of its glass technology center.

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.

Kyocera's global headquarters in Kyoto, Japan.

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.

Glass packaging for food and beverages is O-I's leading product.

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

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.

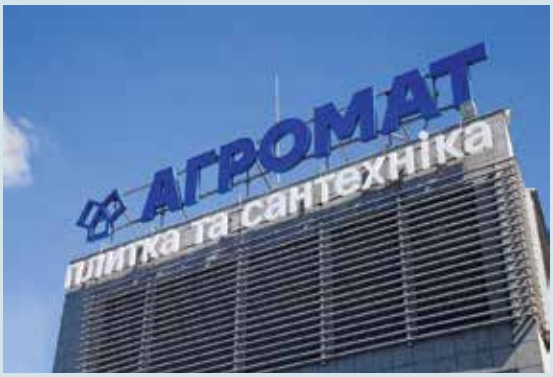
Saint-Gobain glass wool provides sound insulation at the Mogador Theatre in Paris.

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.



Agromat headquarters.

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.

Aerial view of the Oak Ridge National Laboratory

$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.

WVU's Rare Earth Extraction Facility produces highly concentrated rare earth products from coal mine drainage. This sample is 87 percent rare earth oxide. Credit: WVU Photo/ Chris Vass

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.

TRADE SHOWS

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 panels focused on new industrial opportunities for ceramics and additive manufacturing processes in the automotive, aerospace, electronics, and other sectors.

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.

www.ceramicsexpousa.com.

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.

https://www.worldofconcrete.com/en/register.html

MINERAL RECYCLING FORUM 2020
Pullman Hotel Aachen Quellenhof, 10-11 March 2020
Secondary raw material sources, supply, processing, and markets

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

IMFORMED Rendezvous
Grand Hotel Huis ter Duin (Noordwijk), Amsterdam
6-8 April 2020
The premier meeting place for the industrial minerals market

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 (Noordwijke) 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.

Michael Silver speaking at Ceramics Expo 2019 in Cleveland, Ohio.

"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

Vietnam—Shift to market economy creates opportunity for businesses and citizens

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.

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

American Elements' facility in Baotou, China.

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.

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.

Country	Year	Title
China	2019	China—Tradition and transformation
Israel	2018	Israel—Middle East Mavericks
Southeast Asia: Singapore, Malaysia, Thailand, and Indonesia	2017	Markets of magnitude
France	2016	Global groundbreaker: France innovates and collaborates to serve society
Korea	2015	Korea's core competencies
Australia	2014	Ceramics in Australia: Raw and advanced materials drive Land Down Under's global reach
Canada and Mexico	2013	Ceramics and glass: Canada and Mexico
India	2012	Ceramics and glass in India
Japan	2011	Ceramic advances in Japan: Achieving new breakthroughs, meeting new challenges
South America	September 2009	Ceramics in South America
China	2008	China: Ceramics world continues eastward shift

SAVE THE DATE

CERAMIC MANUFACTURING SOLUTIONS CONFERENCE

www.Ceramics.org/CeramicMfgCon

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

WHY INDIA? WHY NOW?

By Mike O'Driscoll

This article was written by Mike O'Driscoll, founder of IMFORMED Industrial Mineral Forums & Research Ltd. It was adapted with permission from his blog at Imformed.com.

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.

Minerals industry in India. *Credit: Imformed*

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, fluorspar, 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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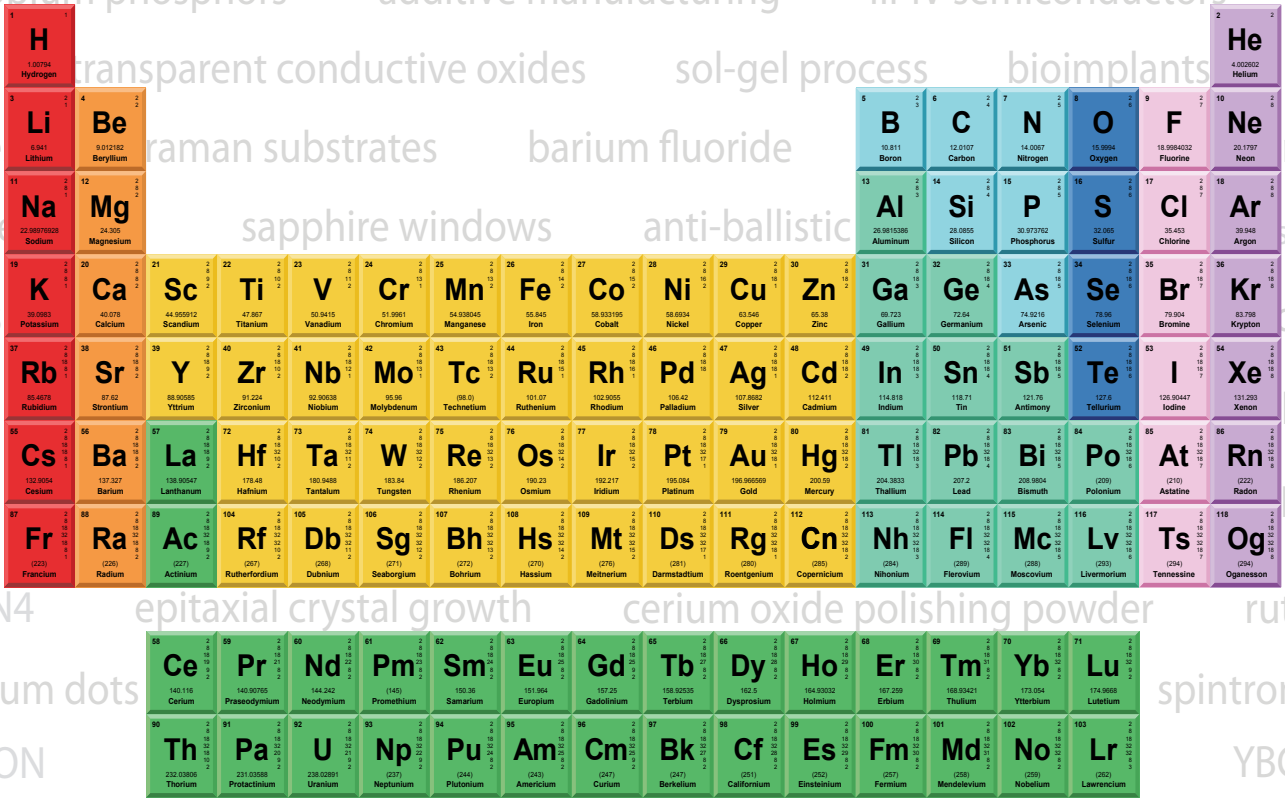

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PORTLAND OREGON

(Credit all images: ACerS)

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

ACerS 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.

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 Beautl, a junior scientist at the Austrian Institute of Technology.

◀ Winner of this year's most aesthetic mug.

▼ Competitors from the first-ever Humanitarian Pitch Competition.

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. ■

2018–2019 ACerS president Sylvia Johnson (left) and Alexandra Navrotsky (right) present Alexander Beautl with the first-ever Navrotsky Award for Experimental Thermodynamics of Solids.

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

View images from ACerS 121st Annual Meeting at MS&T19 at http://bit.ly/ACerSAnnualMeeting2019.

Dawn Bonnell, left, chats with Martin Harmer at the Annual Awards Banquet, where Bonnell received ACerS Distinguished Life Member award.

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Mo-Sci Corp MO **See ad page 107**
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Z-Systems USA Inc MA

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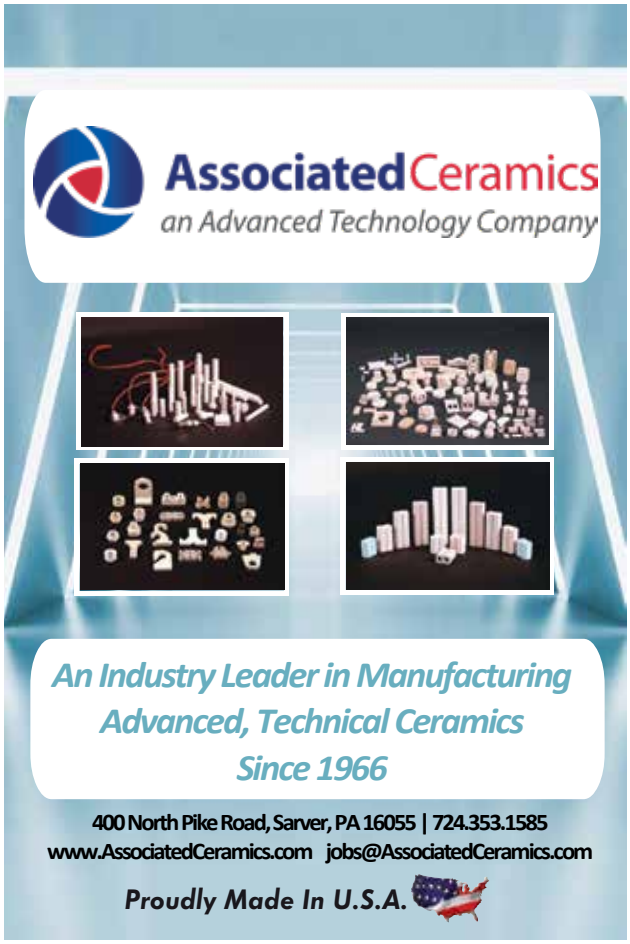

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Lighting
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McDanel Advanced Ceramic Technologies LLC PA **See ad page 65**
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Washington Mills Electro Minerals Co NY **See ad page 73**

Alumina, Fused Brown

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APF Recycling Inc OH
BassTech Intl NJ
Bosai Minerals Group Co Ltd China
Electro Abrasives Corp NY
GMA Industries Inc MI
Imerys Refractory Minerals GA
Washington Mills Electro Minerals Co NY **See ad page 73**

Alumina, Fused White

Alteo NA LLC OH
APF Recycling Inc OH
Electro Abrasives Corp NY
Imerys Refractory Minerals GA
Sauereisen Inc PA
Washington Mills Electro Minerals Co NY **See ad page 73**

Alumina, High-Purity

Alteo NA LLC OH
APF Recycling Inc OH
Applied Ceramics Inc CA
Associated Ceramics & Technology Inc PA **See ad page 67**
Baikowski Malakoff Inc NC
CoorsTek CO
Denka Corp NY
Ipsen Ceramics IL
Lithoz GmbH NY
Materion Advanced Materials NY
Nanoe France
Pred Materials International Inc NY
Prince Minerals Inc TX
Rauschert Industries Inc GA **See ad page 85**
Sauereisen Inc PA
Suntech Advanced Ceramics (Shenzhen) Co Ltd China
Valley Design Corp MA
Xiamen Unipretec Ceramic Technology Co Ltd China

Alumina, Hydrated

Almatis Inc PA
Alteo NA LLC OH
Denka Corp NY
Fusion Ceramics Inc OH
Hindalco Industries Limited India
Nanoe France
Prince Minerals Inc TX
RE Carroll Inc PA

Alumina, Other Grades

Almatis Inc PA
Alteo NA LLC OH
Associated Ceramics & Technology Inc PA **See ad page 67**
Baikowski Malakoff Inc NC
CoorsTek CO
Denka Corp NY

Elan Technology™
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Elan Technology GA **See ad page 77**
Hindalco Industries Limited India
Imerys Refractory Minerals GA
Nanoe France
Prince Minerals Inc TX
Trinity Ceramic Supply Inc TX
Wesbond Corp DE

Alumina, Reactive

Almatis Inc PA
Alteo NA LLC OH
Baikowski Malakoff Inc NC
Denka Corp NY
Hindalco Industries Limited India
Nabaltec AG Germany
Nanoe France
Prince Minerals Inc TX

Alumina, Single Crystal

Denka Corp NY
Nanoe France
Prince Minerals Inc TX

Alumina, Tabular

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Almatis Inc PA **See ad page 71**
Alteo NA LLC OH
APF Recycling Inc OH
Denka Corp NY
GrainBound LLC PA **See ad page 111**
Imerys Refractory Minerals GA
Nanoe France
Prince Minerals Inc TX
Sauereisen Inc PA

Alumina, Zirconia Toughened

Applied Ceramics Inc CA
Associated Ceramics & Technology Inc PA **See ad page 67**
CerCo LLC OH
Denka Corp NY
Innovnano - Advanced Materials SA Portugal
Nanocerox UT
Nanoe France
PicoParts Ltd Israel
Prince Minerals Inc TX
Rauschert Industries Inc GA **See ad page 85**
Sauereisen Inc PA
Washington Mills Electro Minerals Co NY **See ad page 73**
Xiamen Innovacera Advanced Materials Co Ltd China
Zircoa Inc OH

Aluminum & Compounds

Atlantic Equipment Engineers NJ
BassTech Intl NJ
Denka Corp NY
Hindalco Industries Limited India
Leico Industries Inc NJ
Refractory Minerals Co Inc PA
Valley Design Corp MA
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Pred Materials International Inc NY
Reade Advanced Materials RI
Surmet Corp MA **See ad page 77**
Toyal America Inc IL
Valley Design Corp MA

Aluminum Silicate

Goodfellow Corp PA
Sauereisen Inc PA

Antimony & Compounds

Alfa Aesar Johnson Matthey MA
Atlantic Equipment Engineers NJ
Goodfellow Corp PA
Pred Materials International Inc NY

Arsenic Oxide

Alfa Aesar Johnson Matthey MA

Barium & Compounds

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American Elements Inc CA **Outside back cover**
BassTech Intl NJ
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Ceramic Color & Chemical Mfg Co PA **See ad page 75**
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Barium Carbonate

BassTech Intl NJ
Fusion Ceramics Inc OH
Hexion Inc OH

Barium Titanate
AVX Corp SC
BassTech Intl NJ
Beijing Cerametek Materials Co Ltd China
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Euro Support Advanced Materials The Netherlands
Haiku Tech Inc FL
Hexion Inc OH
nGimat LLC KY

Bauxite Sintered
Alteo NA LLC OH

Beryllium & Compounds
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Centerline Technologies MA **See ad page 86**
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Materion Advanced Materials NY

Bismuth & Compounds
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nGimat LLC KY

Boric Acid
Sauereisen Inc PA

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Electro Abrasives Corp NY
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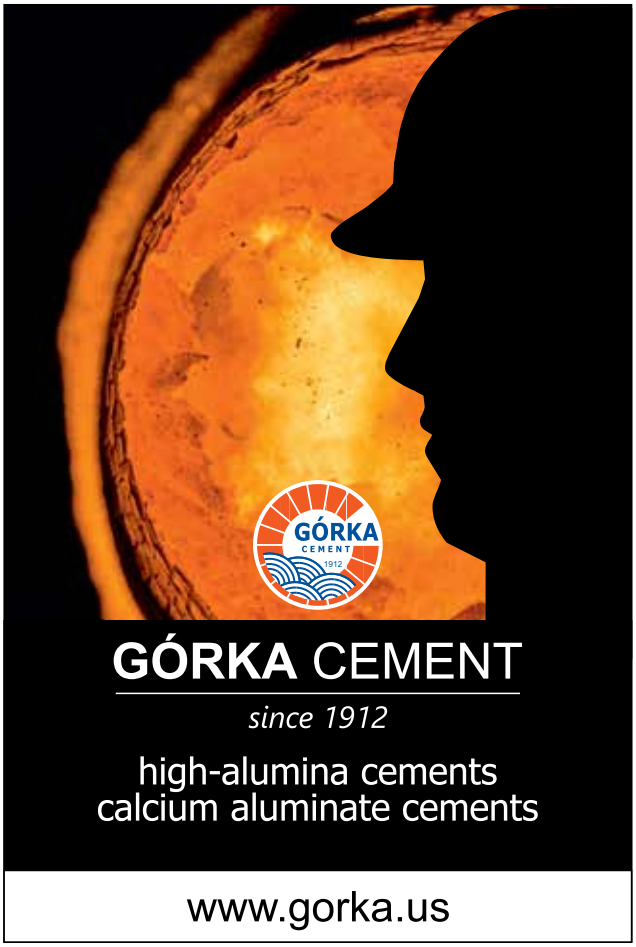
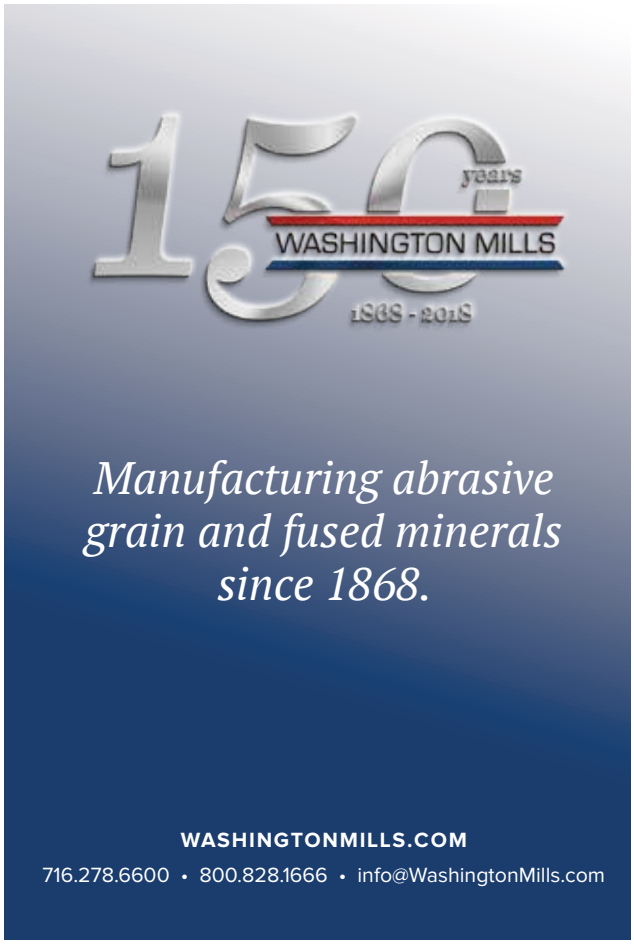
Precision Ceramics FL
Reade Advanced Materials RI
Saint-Gobain Ceramics & Plastics MA
Xiamen Unipretec Ceramic Technology Co Ltd China





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Hunter Chemical LLC PA

Calcium & Compounds
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Denka Corp NY
GFS Chemicals Inc OH
Prince Minerals Inc TX

Calcium Aluminates
Almatis Inc PA
CerPoTech AS Norway
Gorka Cement Poland **See ad page 73**
Mineral Research Processing France
nGimat LLC KY
Sauereisen Inc PA

Calcium Carbonate
Arkema Inc PA
Fusion Ceramics Inc OH
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Unimin Corp CT

Calcium Silicate
Fusion Ceramics Inc OH
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Carbon Fibers
Goodfellow Corp PA

Carbons, Carbon Black
Cancarb Limited Canada **See ad page 117**

Carbons, Diamond
Goodfellow Corp PA

Carbons, Graphite
APF Recycling Inc OH
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Semco Carbon OH
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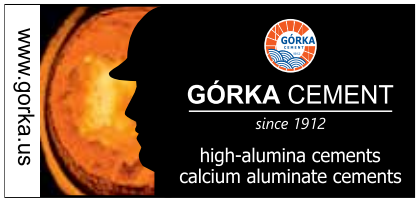
Aremco Products Inc NY
ESL ElectroScience PA
Gwent Electronic Materials Ltd UK

Cements Refractory


Almatis Inc PA **See ad page 71**
Aremco Products Inc NY
Diamorph AB UK



Gorka Cement Poland **See ad page 73**
Kerneos Inc VA
Mineral Research Processing France
Sauereisen Inc PA
Unifrax I LLC NY

Cerium & Compounds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Laguna Clay Co CA
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Tethon 3D NE
Unimin Corp CT

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Ceramic Color & Chemical Mfg Co PA **See ad page 75**
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Copper & Compounds
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APF Recycling Inc OH
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Ceramic Color & Chemical Mfg Co PA **See ad page 75**
CerPoTech AS Norway
Goodfellow Corp PA
Shoei Chemical Inc Japan

Dielectric Powders
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CerPoTech AS Norway
Euro Support Advanced Materials The Netherlands
Gwent Electronic Materials Ltd UK
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Dysprosium Oxide
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Leico Industries Inc NJ
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Electrically Conducting Powders
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CerPoTech AS Norway
Innovnano - Advanced Materials SA Portugal

Erbium Oxide
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CerPoTech AS Norway
FELDCO Intl CA
Leico Industries Inc NJ
MSE Supplies AZ
Treibacher Industrie AG Austria

Europium Oxide
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CerPoTech AS Norway
Leico Industries Inc NJ
MSE Supplies AZ
Treibacher Industrie AG Austria

Ferrites & Ferromagnetics
Centerline Technologies MA **See ad page 86**
Powder Processing & Technology LLC IN
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**

Fibers, Ceramic
MemPro Materials Corp
Thermal Products Co Inc GA

Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**
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Wesbond Corp DE
Zircar Zirconia Inc NY

Fibers, Glass
BassTech Intl NJ
Mo-Sci Corp MO **See ad page 107**
RISE Research Institutes of Sweden RISE Glass Sweden
Schott North America Inc NY
Unifrax I LLC NY

Fluorides
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Beijing Cerametek Materials Co Ltd China
Sauereisen Inc PA

Frit
Ceradyne Inc a 3M Co KY
Ceramic Color & Chemical Mfg Co PA **See ad page 75**
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RISE Research Institutes of Sweden RISE Glass Sweden
Trinity Ceramic Supply Inc TX
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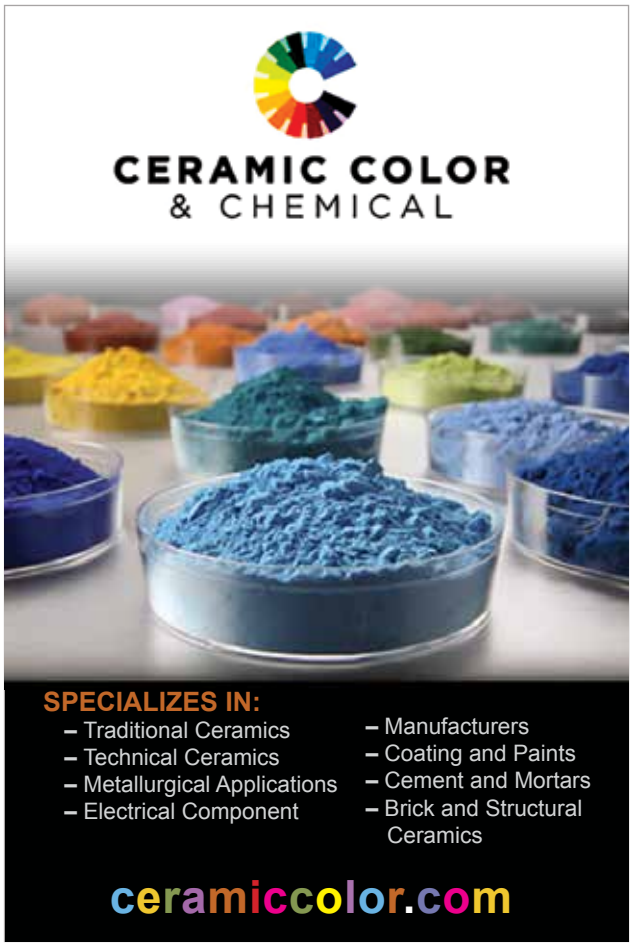

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Christy Minerals LLC MO
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Aremco Products Inc NY
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CoorsTek CO
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Semco Carbon OH
Superior Graphite Co IL
TevTech LLC MA **See ad page 99**

Indium & Compounds
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Goodfellow Corp PA
MSE Supplies AZ
Pred Materials International Inc NY

Iron & Compounds
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MSE Supplies AZ
nGimat LLC KY
Pred Materials International Inc NY
Trinity Ceramic Supply Inc TX

Magnesia, Fused
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Du-Co Ceramics Company PA
Fluid Energy Processing & Equipment Co PA
Washington Mills Electro Minerals Co NY **See ad page 73**

Magnesia-Alumina Sintered
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Microspheres Hollow
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Nyacol Nano Technologies Inc MA
Polymer Innovations Inc CA
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TevTech LLC MA **See ad page 99**

Neodymium Oxide
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Nickel & Compounds
American Chemet Corp IL
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Hunter Chemical LLC PA
Shoei Chemical Inc Japan

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Refractory Minerals Co Inc PA
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Piezoelectric Compositions
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Pigments
Arlimin Industries CO
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Wistra GmbH Germany

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Sheffield Pottery MA

Plaster, Industrial
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Potassium & Compounds
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Cancarb Limited Canada **See ad page 117**
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Pred Materials International Inc NY

Praseodymium Oxide
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Leico Industries Inc NJ
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Resins Molding
Hexion Inc OH
Starfire Systems Inc NY

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Sand, Foundry
Kyanite Mining Corp VA
U.S. Silica Co MD

Sand, Glass
Fusion Ceramics Inc OH
RISE Research Institutes of Sweden RISE Glass Sweden
U.S. Silica Co MD

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Covia **See ad page 81**
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Semiconducting Powders

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Denka Corp NY
Ipsen Ceramics IL
Maryland Refractories Co OH
Momentive Performance Materials Inc NY
Nanocerox UT
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Sauereisen Inc PA
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U.S. Silica Co MD

Silica, Fused
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BassTech Intl NJ
Bosai Minerals Group Co Ltd China
Centerline Technologies MA **See ad page 86**
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Ipsen Ceramics IL
Momentive Performance Materials Inc NY
Valley Design Corp MA

Silicates
Arkema Inc PA
BassTech Intl NJ
Denka Corp NY

Mineral Research Processing France
Nanocerox UT
Sauereisen Inc PA

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Silicon Carbide
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Beijing Cerametek Materials Co Ltd China
Bullen OH
Cancarb Limited Canada **See ad page 117**
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CoorsTek CO
Custom Processing Services PA
Electro Abrasives Corp NY
FELDCO Intl CA
Goodfellow Corp PA
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H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
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Momentive Performance Materials Inc NY
Ortech Inc CA
Pred Materials International Inc NY
Rauschert Industries Inc GA **See ad page 85**
Saint-Gobain Ceramics & Plastics MA
Starfire Systems Inc NY
Suntech Advanced Ceramics (Shenzhen) Co Ltd China
Superior Graphite Co IL
Texers Technical Ceramics Inc Canada
Treibacher Industrie AG Austria
Valley Design Corp MA

Washington Mills Electro Minerals Co NY **See ad page 73**

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McDanel Advanced Ceramic Technologies LLC PA **See ad page 65**
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Pred Materials International Inc NY
Rauschert Industries Inc GA **See ad page 85**
Suntech Advanced Ceramics (Shenzhen) Co Ltd China
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Spheres, Ceramic
Saint-Gobain NorPro OH
Zircar Zirconia Inc NY

Spheres, Glass

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Imerys Refractory Minerals GA
Mo-Sci Corp MO **See ad page 107**
RISE Research Institutes of Sweden RISE Glass Sweden

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Leico Industries Inc NJ

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H.C. Starck Surface Technology and Ceramic Powders GmbH Germany

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CerPoTech AS Norway
FELDCO Intl CA
Goodfellow Corp PA
Trinity Ceramic Supply Inc TX

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TAM Ceramics NY

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Dunhua Zhengxing Abrasive Co Ltd China
FELDCO Intl CA
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 **See ad page 77**

Titanium Dioxide
BassTech Intl NJ
Beijing Cerametek Materials Co Ltd China
FELDCO Intl CA
Fusion Ceramics Inc OH
Nanocerox UT
nGimat LLC KY
Pred Materials International Inc NY

Titanium Nitride
Atlantic Equipment Engineers NJ
FELDCO Intl CA
H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
Pred Materials International Inc NY

Tungsten Carbide
Associated Ceramics & Technology Inc PA **See ad page 67**
Atlantic Equipment Engineers NJ
C&L Development Corp CA
Centerline Technologies MA **See ad page 86**
Custom Processing Services PA
FELDCO Intl 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 Intl CA
H.C. Starck North American Trading LLC MA

Uranium & Compounds
Wistra GmbH Germany

Vanadium & Compounds
Atlantic Equipment Engineers NJ
CerPoTech AS Norway
FELDCO Intl CA

Yttria
APF Recycling Inc OH
Associated Ceramics & Technology Inc PA **See ad page 67**
Bullen OH
CoorsTek CO
ESL ElectroScience PA
H.C. Starck North American Trading LLC MA

H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
Innovnano - Advanced Materials SA Portugal
Nanocerox UT
nGimat LLC KY
Pred Materials International Inc NY
Washington Mills Electro Minerals Co NY
Zircar Zirconia Inc NY

Yttrium & Compounds
Alfa Aesar Johnson Matthey MA

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GFS Chemicals Inc OH
Nanocerox UT
nGimat LLC KY

Zinc & Compounds
CerPoTech AS Norway
FELDCO Intl CA
Leico Industries Inc NJ
Prince Minerals Inc TX
RE Carroll Inc PA
Sauereisen Inc PA
TevTech LLC MA **See ad page 99**

Zinc Oxide
American Chemet Corp IL
FELDCO Intl CA
Fusion Ceramics Inc OH
nGimat LLC KY
Prince Minerals Inc TX
Sauereisen Inc PA

Zirconia
Applied Ceramics Inc CA
C&L Development Corp CA
Custom Processing Services PA
Innovnano - Advanced Materials SA Portugal
Leico Industries Inc NJ
Nanocerox UT
Nanoe France
nGimat LLC KY
Ortech Inc CA
PremaTech Advanced Ceramics MA
Rauschert Industries Inc GA **See ad page 85**
Saint-Gobain Ceramics & Plastics MA
Sauereisen Inc PA
Suntech Advanced Ceramics (Shenzhen) Co Ltd China
TAM Ceramics NY
Washington Mills Electro Minerals Co NY
Xiamen Unipretec Ceramic Technology Co Ltd China
Zibo Guangtong Chemical Co Ltd China
Zircar Zirconia Inc NY
Zircoa Inc OH

Zirconia, Engineering-Grade
Innovnano - Advanced Materials SA Portugal
Leico Industries Inc NJ
McDanel Advanced Ceramic Technologies LLC PA **See ad page 65**
Nanoe France
Zibo Guangtong Chemical Co Ltd China
Zircoa Inc OH

Zirconia, High-Purity
APF Recycling Inc OH
Applied Ceramics Inc CA
CoorsTek CO
Innovnano - Advanced Materials SA Portugal
Nanocerox UT
Nanoe France
Sauereisen Inc PA
Zibo Guangtong Chemical Co Ltd China

Zirconia, Refractory-Grade
McDanel Advanced Ceramic Technologies LLC PA **See ad page 65**
Nanoe France
Washington Mills Electro Minerals Co NY
Zircoa Inc OH

Zirconium & Compounds
Atlantic Equipment Engineers NJ
C&L Development Corp CA
CerPoTech AS Norway
FELDCO Intl CA
Goodfellow Corp PA
H.C. Starck North American Trading LLC MA
H.C. Starck Surface Technology and Ceramic Powders GmbH Germany
Innovnano - Advanced Materials SA Portugal
Luxfer MEL Technologies NJ
Monofrax LLC NY
Saint-Gobain Ceramics & Plastics MA
Zibo Guangtong Chemical Co Ltd China

Zirconium Carbide
Cancarb Limited Canada **See ad page 117**
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

CLAY & NATURAL MINERALS

Bauxite
APF Recycling Inc OH
Bosai Minerals Group Co Ltd China
Fluid Energy Processing & Equipment Co PA
Hindalco Industries Limited India
Imerys Refractory Minerals GA
Prince Minerals Inc TX

Bentonite
Custom Processing Services PA
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
Sibelco Benelux Belgium
Trinity Ceramic Supply Inc TX
Unimin Corp CT

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
Alsey
Refractories Co MO
Christy Minerals LLC MO
Endiccott Clay Products Company NE **See ad page XX**
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
Vanderbilt Minerals LLC CT

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

Cordierite
Maryland Ceramic & Steatite Co Inc MD
Mason Color Works Inc OH
Reade Advanced Materials RI
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**

Diatomaceous Earth
Reade Advanced Materials RI

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

Feldspar
Avalon 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
Avalon Advanced Materials Inc. Canada
Fusion Ceramics Inc OH

Magnesite
APF Recycling Inc OH
Bosai Minerals Group Co Ltd China
Fluid Energy Processing & Equipment Co PA
Imerys Refractory Minerals GA

Mica
Imerys GA

Montmorillonite
Reade Advanced Materials RI
Vanderbilt Minerals LLC CT

Mullite
Christy Minerals LLC MO
Imerys Refractory Minerals GA
Kyanite Mining Corp VA
Pred Materials International Inc NY
Reade Advanced Materials RI
Texers Technical Ceramics Inc Canada
Washington Mills Electro Minerals Co NY

Nepheline Syenite
Fusion Ceramics Inc OH
Sheffield Pottery MA
Sibelco Benelux Belgium
Trinity Ceramic Supply Inc TX

Olivine
Prince Minerals Inc TX
Sibelco Benelux Belgium

Pyrite
Kyanite Mining Corp VA
Washington Mills Electro Minerals Co NY

Pyrophyllite
Maryland Ceramic & Steatite Co Inc MD
Vanderbilt Minerals LLC CT

Quartz
Applied Ceramics Inc CA
Fusion Ceramics Inc OH
Goodfellow Corp PA
Imerys GA
Momentive Performance Materials Inc NY
Prince Minerals Inc TX
Sibelco Benelux Belgium

Rutile
Fusion Ceramics Inc OH
Prince Minerals Inc TX

Sapphire
Applied Ceramics Inc CA
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**

Covia **See ad page 81**
Imerys GA
Imerys Refractory Minerals GA
Maryland Refractories Co OH
Prince Minerals Inc TX
Sibelco Benelux Belgium
Trinity Ceramic Supply Inc TX
U.S. Silica Co MD

Soda Ash
Fusion Ceramics Inc OH
RE Carroll Inc PA

Spinels
Almatis Inc PA
Baikowski Malakoff Inc NC
Fluid Energy Processing & Equipment Co PA
GrainBound LLC PA **See ad page 111**
Pred Materials International Inc NY
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**
Washington Mills Electro Minerals Co NY

Spodumene
Avalon Advanced Materials Inc. Canada
Fusion Ceramics Inc OH
Prince Minerals Inc TX
Trinity Ceramic Supply Inc TX

Steatite
Du-Co Ceramics Company PA
Maryland Ceramic & Steatite Co Inc MD

Talc
Custom Processing Services PA
Fusion Ceramics Inc OH
Rio Tinto Minerals Australia
Trinity Ceramic Supply Inc TX

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

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

■ CONSTRUCTION CERAMICS

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

Brick & Paving
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Brick Industry Assn VA
Cancarb Limited Canada **See ad page 117**

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Roca Sanitario SA Spain
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Tile, Floor & Pavers
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Tile, Wall
Comtrust Architectural Mesh Co Ltd China

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Endiccott Clay Products Company NE **See ad page 56**
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Somany Ceramics Ltd India

■ CONSULTANTS & SERVICES

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Advanced Materials Associates CO
Bharat Heavy Electricals Ltd India
Cerakote Ceramic Coatings OR
CoorsTek CO
Delkic & Associates FL
Gwent Electronic Materials Ltd UK
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
CelSian Glass & Solar BV The Netherlands **See ad page 83**
CHEMIR - A Division of Evans Analytical Group MO
CMC Laboratories Inc AZ
CoorsTek CO
Edward Orton Jr Ceramic Foundation OH
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
Micromeritics 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

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Spectrochemical Laboratories XXXX PA
TA Instruments DE

Brick & Structural Clay Processing
Ceramitec Germany
Lucideon UK
Niokem Inc NC
OPF Enterprises TX
Peter Pugger Mfg Inc CA
Verity Technical Consultants LLC OH

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Advanced Materials Associates CO
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AVEKA MN
Bharat Heavy Electricals Ltd India

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Ceralink Inc NY
Elan Technology GA **See ad page 77**
GrainBound LLC PA **See ad page 111**
H&M Analytical Services Inc NJ
Hitech Materials Pty Ltd New South Wales
Imerys GA
Inst for Applied Materials-Ceramics in Mechanical Engineering Karlsruhe Inst of Technology Germany
Lithoz GmbH NY
Lucideon UK
MemPro Materials Corp
NSL Analytical Services Inc OH
O'Keefe Ceramics Inc CO **See ad page 87**

OPF Enterprises TX
P-Ker Engineering NY
Rauschert Industries Inc GA **See ad page 85**
Refrac Systems AZ
Rensselaer Polytechnic Inst NY
Schott North America Inc NY
Silicon Carbide Products Inc NY
Technology Assessment and Transfer Inc (TA&T) MD
Teeter Marketing Services LLC FL
Texers Technical Ceramics Inc Canada
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**
Verity Technical Consultants LLC OH
Viridis3D LLC MA

Chemistry

Activation Laboratories Ltd Canada
CelSian Glass & Solar BV The Netherlands **See ad page 83**
Chemical Abstracts Service OH
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H&M Analytical Services Inc NJ
Hitech Materials Pty Ltd New South Wales
NSL Analytical Services Inc OH

Combustion Systems

Air Products PA
CelSian Glass & Solar BV The Netherlands **See ad page 83**
Ceramic Services Inc PA

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Harrop Industries Inc OH **See ad page 91**

Compositions

Activation Laboratories Ltd Canada
Advanced Materials Associates CO
CelSian Glass & Solar BV The Netherlands **See ad page 83**
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Gwent Electronic Materials Ltd UK
Hitech Materials Pty Ltd New South Wales
NSL Analytical Services Inc OH

Decorating Processes & Materials

Cerlase France
Lucideon UK
OPF Enterprises TX

Design

Air Force Civil Engineer Center FL
CoorsTek CO
Deltech Kiln and Furnace Design LLC CO
General Glass Equipment Co NJ
I Squared R Element Co NY **See ad page 113**
Jenike & Johanson Inc MA
Missouri
Refractories Co (MORCO) MO
OPF Enterprises TX
RocCera LLC NY
Tethon 3D NE
Viridis3D LLC MA

Electronics & Electrical Materials

Advanced Energy CO
APC International Ltd PA
AVEKA MN
Centerline Technologies MA **See ad page 86**
Elan Technology GA **See ad page 77**
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Gwent Electronic Materials Ltd UK
Haiku Tech Europe BV The Netherlands
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I Squared R Element Co NY **See ad page 113**
Powder Processing & Technology LLC IN
Semiconductor Energy Laboratory Co Ltd Japan **See ad page 121**

Energy

A123 Systems Inc MI
Advanced Energy CO
Air Force Civil Engineer Center FL
CelSian Glass & Solar BV The Netherlands **See ad page 83**
Ceralink Inc NY
FCT Systeme GmbH Germany
Lucideon UK
Polymer Innovations Inc CA
Semiconductor Energy Laboratory Co Ltd Japan **See ad page 121**
Texers Technical Ceramics Inc Canada

Engineering

Advanced Materials Associates CO
Air Force Civil Engineer Center FL
CelSian Glass & Solar BV The Netherlands **See ad page 83**
Cerinnov France
Ceritherm France
Cyclonaire Corp NE
Deltech Kiln and Furnace Design LLC CO
FCT Systeme GmbH Germany
General Glass Equipment Co NJ
Hitech Materials Pty Ltd New South Wales
Jenike & Johanson Inc MA
Lithoz GmbH NY
Nol-Tec Systems Inc MN
Teeter Marketing Services LLC FL
Verity Technical Consultants LLC OH
Wistra GmbH Germany

Environmental

Activation Laboratories Ltd Canada
Air Force Civil Engineer Center FL
CelSian Glass & Solar BV The Netherlands **See ad page 83**
Lucideon UK
SEMTech Solutions Inc MA
Texers Technical Ceramics Inc Canada
Tri-Mer Corp MI

Expert Witness

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H&M Analytical Services Inc NJ

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Glass & Solar

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Process optimization
Training and R&D

Celsian's aim is to minimize the cost of making glass for end users and the environment. We have an agile team of glass experts using proven methods like furnace modelling, laboratory measurements and practical furnace health checks to optimize glass melting processes. We also train operators and glass technologists through our standard course, dedicated programs and various e-learning modules. We strive to be the best partner for optimization of glass production worldwide.

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JTF Microscopy Services Inc NY
Lucideon UK
Particle Technology Labs IL
Refrac Systems AZ
Refractory Consulting Services OH
Spontaneous Materials CO
Verity Technical Consultants LLC OH

Fabrication

Accuratus Corp NJ
Advanced Materials Associates CO
Bullen OH
Lithoz GmbH NY
O'Keefe Ceramics Inc CO **See ad page 87**
PremaTech Advanced Ceramics MA
Refrac Systems AZ
RocCera LLC NY
Technology Assessment and Transfer Inc (TA&T) MD
Thermal Products Co Inc GA
Verity Technical Consultants LLC OH

Furnaces

Advanced Materials Associates CO
American Isostatic Presses OH
CelSian Glass & Solar BV The Netherlands **See ad page 83**
Deltech Kiln and Furnace Design LLC CO
Fosbel Inc OH
General Glass Equipment Co NJ

Harper International
harperintl.com

Harper International Corp NY **See ad page 101**
I Squared R Element Co NY **See ad page 113**
JTF Microscopy Services Inc NY
Refrac Systems AZ
Technology Assessment and Transfer Inc (TA&T) MD
The Furnace Source LLC CT
Trent Inc PA
Winner Technology Korea

Glass Processes & Materials

Alfred University NY

CelSian Glass & Solar
www.celsian.nl

CelSian Glass & Solar BV The Netherlands **See ad page 83**
Ceradyne Inc a 3M Co KY
Elan Technology GA **See ad page 77**
JTF Microscopy Services Inc NY
NSL Analytical Services Inc OH
Rensselaer Polytechnic Inst NY
RISE Research Institutes of Sweden RISE Glass Sweden
Saxon Glass Technologies Inc NY
Schott North America Inc NY
Specialty Glass Inc FL
Tri-Mer Corp MI
Verity Technical Consultants LLC OH
Vesuvius SC

Glazes/Colorants

Cancarb Limited Canada **See ad page 117**
Ceradyne Inc a 3M Co KY
Laguna Clay Co CA
Lucideon UK
NSL Analytical Services Inc OH
OPF Enterprises TX
RISE Research Institutes of Sweden RISE Glass Sweden

High-Technology Ceramics

Advanced Materials Associates CO
APC International Ltd PA
ARBURG GmbH + Co KG Germany
Astro Met Advanced Ceramics Inc OH
Bharat Heavy Electricals Ltd India
Ceramitec Germany
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Gwent Electronic Materials Ltd UK
Hitech Materials Pty Ltd New South Wales
Lucideon UK
NSL Analytical Services Inc OH
OPF Enterprises TX
P-Ker Engineering NY
Silicon Carbide Products Inc NY
Technology Assessment and Transfer Inc (TA&T) MD
Viridis3D LLC MA
Wistra GmbH Germany
Zircoa Inc OH

Kilns

Ceritherm France
Deltech Kiln and Furnace Design LLC CO
FCT Systeme GmbH Germany
Lucideon UK
Nabertherm Inc DE
OPF Enterprises TX

Litigation

H&M Analytical Services Inc NJ
Lucideon UK
Particle Technology Labs IL
Refractory Consulting Services OH
Spontaneous Materials CO
Verity Technical Consultants LLC OH

Maintenance & Repairs After Sales

Cerinnov France

Management

OPF Enterprises TX
Teeter Marketing Services LLC FL

Manufacturing

Advanced Materials Associates CO
AVEKA MN
Ceramco Inc NH **See ad page 89**
CeramTec North America Corp SC
Cerinnov France
CoorsTek CO
Custom Processing Services PA
Cyclonaire Corp NE
Jenike & Johanson Inc MA
Laserage Technology Corp IL
Lucideon UK
Maryland Ceramic & Steatite Co Inc MD
O'Keefe Ceramics Inc CO **See ad page 87**
OPF Enterprises TX
P-Ker Engineering NY
Refrac Systems AZ
Semiconductor Energy Laboratory Co Ltd Japan **See ad page 121**
Technology Assessment and Transfer Inc (TA&T) MD
Verity Technical Consultants LLC OH
Wistra GmbH Germany

Markets

Advanced Materials Associates CO
OPF Enterprises TX
Teeter Marketing Services LLC FL
Texers Technical Ceramics Inc Canada

Materials Testing & Characterization

Advanced Materials Associates CO
Alfred University NY
ARBURG GmbH + Co KG Germany
AVEKA MN
Bharat Heavy Electricals Ltd India
BuzzMac Intl LLC ME
Ceramitec Germany
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CSC Force Measurement Inc MA
Cyclonaire Corp NE
Edward Orton Jr Ceramic Foundation OH
Elan Technology GA **See ad page 77**
Fluid Energy Processing & Equipment Co PA
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
Hysitron Inc MN
Inst for Applied Materials-Ceramics in Mechanical Engineering Karlsruhe Inst of Technology Germany
Jenike & Johanson Inc MA
JTF Microscopy Services Inc NY
Lucideon UK
Micromeritics Instrument Corp GA
Nol-Tec Systems Inc MN
NorECs AS Norway
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OPF Enterprises TX
Particle Technology Labs IL
P-Ker Engineering NY
Refractory Consulting Services OH
Semiconductor Energy Laboratory Co Ltd Japan **See ad page 121**

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Modeling

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CelSian Glass & Solar BV The Netherlands **See ad page 83**
CoorsTek CO
Lucideon UK
Ram Products Inc OH
Spontaneous Materials CO
Tethon 3D NE

Nuclear Materials

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Dunhua Zhengxing Abrasive Co Ltd China
NSL Analytical Services Inc OH

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

Professional Engineer
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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
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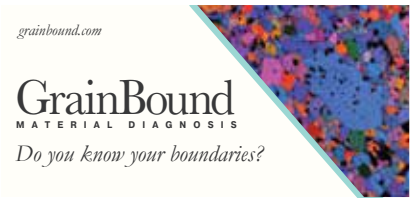
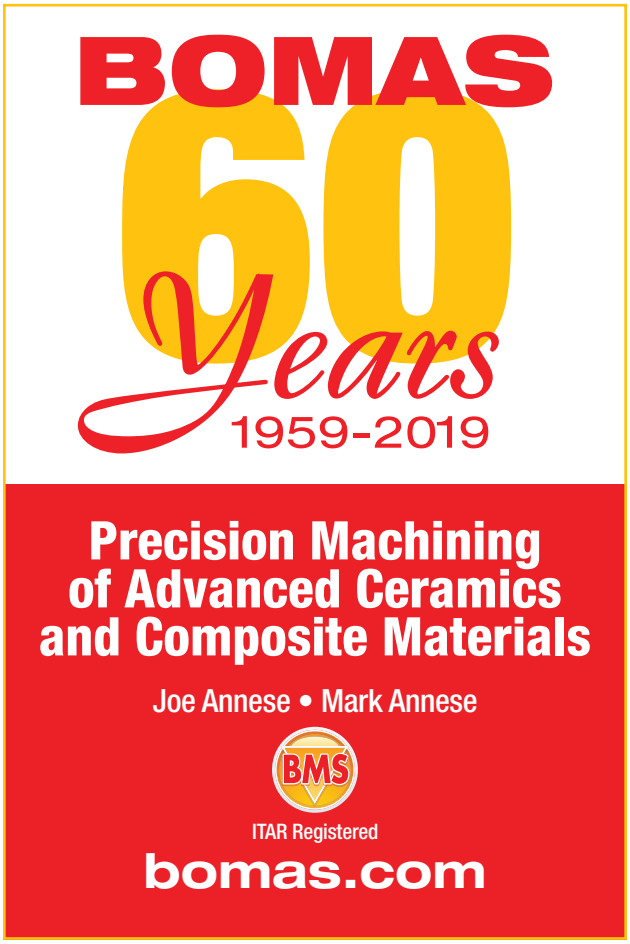
Alfred University NY
ARBURG GmbH + Co KG Germany
AVEKA MN
CelSian Glass & Solar BV The Netherlands
See ad page 83
Ceralink Inc NY
Cerlase France
CHEMIR - A Division of Evans Analytical Group MO



GrainBound LLC PA **See ad page 111**
Inst for Applied Materials-Ceramics in Mechanical Engineering Karlsruhe Inst of Technology Germany
Laeis 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



Software
Chemical Abstracts Service OH
General Glass Equipment Co NJ
Outotec Research Oy Finland
Rockwell Automation Inc WI
Throughput Bluestreak WI

Structural Ceramics
Advanced Materials Associates CO
Astro Met Advanced Ceramics Inc OH
Bharat Heavy Electricals Ltd India
Ceramitec Germany
CeramTec North America Corp SC
FCT Ingenieurkeramik GmbH Germany
Hitech Materials Pty Ltd New South Wales
OPF Enterprises TX
Rauschert Industries Inc GA **See ad page 85**
Silicon Carbide Products Inc NY
Technology Assessment and Transfer Inc (TA&T) MD

Superconductors
NSL Analytical Services Inc OH

Technical Writing
Advanced Materials Associates CO
Bharat Heavy Electricals Ltd India
CelSian Glass & Solar BV The Netherlands **See ad page 83**
Hitech Materials Pty Ltd New South Wales
JTF Microscopy Services Inc NY
Spontaneous Materials CO
Teeter Marketing Services LLC FL

Technology Transfer
CelSian Glass & Solar BV The Netherlands **See ad page 83**
Ceralink Inc NY
Cerlase France
Gwent Electronic Materials Ltd UK
Lucideon UK
Particle Technology Labs IL
Spontaneous Materials CO
Technology Assessment and Transfer Inc (TA&T) MD
Teeter Marketing Services LLC FL
Viridis3D LLC MA

■ CUSTOM CERAMICS FABRICATION & ENGINEERING SERVICES

Advanced Ceramics, Structural
Accuratus Corp NJ
AdTech Ceramics TN
AdValue Technology LLC AZ **See ad page 69**
Advanced Ceramic Technology CA
Advanced Ceramics Manufacturing AZ
Astro Met Advanced Ceramics Inc OH

Bomas Machine Specialties Inc MA **See ad page 85**
Bullen OH
CeramTec North America Corp SC
CeraNova Corp MA
CerCo LLC OH
CiDRA Precision Services LLC CT
CoorsTek CO
Custom Processing Services PA
Dunhua Zhengxing Abrasive Co Ltd China
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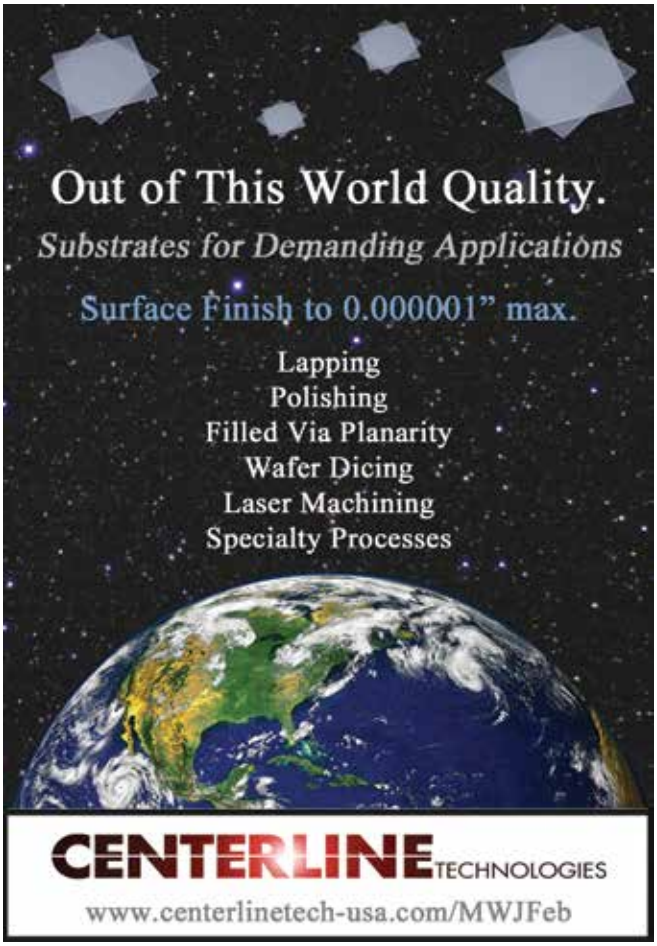

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Magneco Metrel Inc IL
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Verder Scientific Inc PA
Zircar Zirconia Inc NY

Furnaces, High-Temperature

Applied Test Systems Inc PA
Cancarb Limited Canada **See ad page 117**
Carbolite Gero UK
Centorr Vacuum Industries NH **See ad page 95**
Ceritherm France
CM Furnaces Inc NJ
Cober Muegge LLC CT
Dalmia Inst of Scientific & Industrial Research India
Deltech Inc CO **See ad page 97**
Detroit Process Machinery MI
FCT Systeme GmbH Germany
Furnace Products & Services Inc PA
Gasbarre Products Inc PA
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
HED INtl Inc NJ
Lucifer Furnaces Inc PA
Materials Research Furnaces Inc NH **See ad page 79**
Nabertherm Inc DE

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Quintus Technologies LLC OH
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Thermcraft Inc NC **See ad page 95**
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Winner Technology Korea
Zircar Zirconia Inc NY

Furnaces, Laboratory

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FCT Systeme GmbH Germany
Harper International NY **See ad page 101**
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**
RD Webb Company Inc MA
RocCera LLC NY
The Furnace Source LLC CT
Verder Scientific Inc PA
Winner Technology Korea
Zircar Zirconia Inc NY

Furnaces, Vacuum

Applied Test Systems Inc PA
AVS Inc MA
Centorr Vacuum Industries NH **See ad page 95**
Cober Muegge LLC CT
FCT Systeme GmbH Germany
Gasbarre Products Inc PA
Goceram AB Sweden
Materials Research Furnaces Inc NH **See ad page 79**
Nabertherm Inc DE

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Lucifer Furnaces Inc PA
Materials Research Furnaces Inc NH
Oxy-Gon Industries Inc NH **See ad page 94**
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PSH Kilns & Furnaces Canada
Recco Furnaces CA
Seco/Warwick Corp PA
Thermal Products Co Inc GA
Thermcraft Inc NC **See ad page 95**
Trent Inc PA
Verder Scientific Inc PA
Winner Technology Korea

Humidification Systems

CM Furnaces Inc NJ

Kilns

Applied Test Systems Inc PA
Carbolite Gero UK
Ceramic Services Inc PA
Ceritherm France
Detroit Process Machinery MI
FCT Systeme GmbH Germany
Fives North American Combustion Inc OH
Furnace Products & Services Inc PA
Harper International NY **See ad page 101**
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HED INtl Inc NJ
Keith Co CA
L&L Kiln Mfg Inc NJ

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Laguna Clay Co CA
Lucifer Furnaces Inc PA
Mohr Corp MI **See ad page 87**
Nutec Bickley Mexico
PSH Kilns & Furnaces Canada
RD Webb Company Inc MA
Recco Furnaces CA
RocCera LLC NY
Swindell Dressler Intl Co PA
Takasago Industry Co Ltd Japan
Thermcraft Inc NC **See ad page 95**
Wistra GmbH Germany

Kilns, Bell

Carbolite Gero UK
Ceramic Services Inc PA
Ceritherm France
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
HED INtl Inc NJ
Keith Co CA
L&L Kiln Mfg Inc NJ
L&L Special Furnace Co Inc PA **See ad page 101**
Lucifer Furnaces Inc PA
Nabertherm Inc DE
PSH Kilns & Furnaces Canada
Recco Furnaces CA
Swindell Dressler Intl Co PA
Takasago Industry Co Ltd Japan
Thermcraft Inc NC **See ad page 95**

Kilns, Box

Aadvanced Machinery Inc MI
American Art clay Co Inc IN
Applied Test Systems Inc PA
Carbolite Gero UK
Ceramic Services Inc PA
Ceritherm France
CM Furnaces Inc NJ
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
HED INtl Inc NJ
Keith Co CA
L&L Kiln Mfg Inc NJ
L&L Special Furnace Co Inc PA **See ad page 101**
Lucifer Furnaces Inc PA

Nabertherm Inc DE
Paragon Industries LP TX
PSH Kilns & Furnaces Canada
Recco Furnaces CA
Swindell Dressler Intl Co PA
Takasago Industry Co Ltd Japan
Thermcraft Inc NC **See ad page 95**
Verder Scientific Inc PA

Kilns, Chamber

Carbolite Gero UK
Ceritherm France
Harrop Industries Inc OH **See ad page 91**
L&L Kiln Mfg Inc NJ
Lucifer Furnaces Inc PA
Nabertherm Inc DE
Takasago Industry Co Ltd Japan
Thermcraft Inc NC **See ad page 95**
Verder Scientific Inc PA

Kilns, Conveyor

Ceramic Services Inc PA
Ceritherm France
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
HED INtl Inc NJ
Keith Co CA
Lucifer Furnaces Inc PA
Nabertherm Inc DE
Recco Furnaces CA

Kilns, Elevator

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Ceramic Services Inc PA
Ceritherm France
CM Furnaces Inc NJ
Euro Support Advanced Materials The Netherlands
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
HED INtl Inc NJ
Keith Co CA
L&L Kiln Mfg Inc NJ
L&L Special Furnace Co Inc PA **See ad page 101**
Lucifer Furnaces Inc PA
Nabertherm Inc DE
Nutec Bickley Mexico
Recco Furnaces CA
Swindell Dressler Intl Co PA
Takasago Industry Co Ltd Japan

Kilns, Envelope

Ceritherm France
Harrop Industries Inc OH **See ad page 91**
HED INtl Inc NJ
Keith Co CA
L&L Kiln Mfg Inc NJ
L&L Special Furnace Co Inc PA **See ad page 101**
Nabertherm Inc DE
PSH Kilns & Furnaces Canada
Recco Furnaces CA
Swindell Dressler Intl Co PA

Kilns, Periodic (Batch)

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Ceramic Services Inc PA
Ceritherm France
CM Furnaces Inc NJ
Cober Muegge LLC CT
FCT Systeme GmbH Germany
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
HED INtl Inc NJ
Keith Co CA
L&L Kiln Mfg Inc NJ
L&L Special Furnace Co Inc PA **See ad page 101**
Lucifer Furnaces Inc PA
Nabertherm Inc DE
RD Webb Company Inc MA
Recco Furnaces CA
Swindell Dressler Intl Co PA
Takasago Industry Co Ltd Japan
Thermcraft Inc NC **See ad page 95**

Kilns, Pusher Plate

Ceritherm France
CM Furnaces Inc NJ
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
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Ipsen Ceramics IL
Keith Co CA
Lucifer Furnaces Inc PA
Recco Furnaces CA

Kilns, Roller Hearth

Ceramic Services Inc PA
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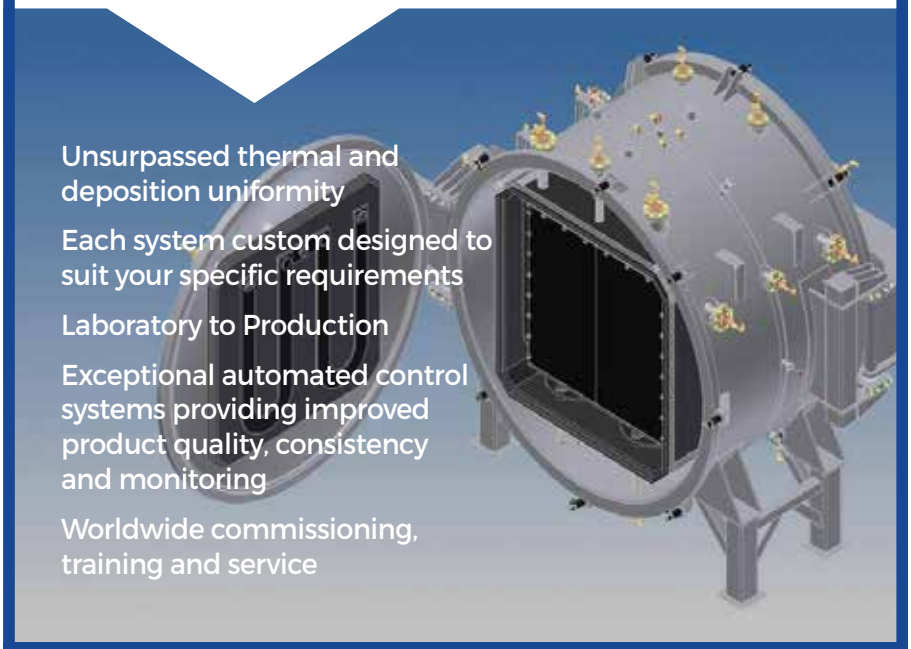

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Kilns, Rotary

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CM Furnaces Inc NJ
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Furnace Products & Services Inc PA
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
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Lucifer Furnaces Inc PA
Raymond Bartlett Snow
Thermcraft Inc NC **See ad page 95**
Verder Scientific Inc PA

Kilns, Shuttle

Basic Machinery Co Inc NC
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Ceritherm France
CM Furnaces Inc NJ
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
HED INtl Inc NJ
Keith Co CA
L&L Kiln Mfg Inc NJ
L&L Special Furnace Co Inc PA **See ad page 101**
Lucifer Furnaces Inc PA
Nabertherm Inc DE
Nutec Bickley Mexico
Recco Furnaces CA
Swindell Dressler Intl Co PA
Takasago Industry Co Ltd Japan
Thermcraft Inc NC **See ad page 95**
Wistra GmbH Germany

Kilns, Test/Lab

American Art clay Co Inc IN
Applied Test Systems Inc PA
Carbolite Gero UK
Ceramic Services Inc PA
CM Furnaces Inc NJ
Cober Muegge LLC CT
FCT Systeme GmbH Germany
Harper International NY **See ad page 101**
Harrop Industries Inc OH **See ad page 91**
Keith Co CA
L&L Kiln Mfg Inc NJ
L&L Special Furnace Co Inc PA **See ad page 101**
Lucifer Furnaces Inc PA
Nabertherm Inc DE
Paragon Industries LP TX
PSH Kilns & Furnaces Canada
RD Webb Company Inc MA
Recco Furnaces CA
Takasago Industry Co Ltd Japan
Thermcraft Inc NC **See ad page 95**
Verder Scientific Inc PA

Kilns Tunnel (Continuous)

Applied Test Systems Inc PA
Basic Machinery Co Inc NC
Ceramic Services Inc PA
Ceritherm France
CM Furnaces Inc NJ
Cober Muegge LLC CT
Deltech Inc CO **See ad page 97**
Euro Support Advanced Materials The Netherlands
Keith Co CA
Nutec Bickley Mexico
Recco Furnaces CA
Swindell Dressler Intl Co PA
Takasago Industry Co Ltd Japan
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Kilns, Tunnel

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Harper International NY **See ad page 101**

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Lehrs

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Recco Furnaces CA

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Bharat Heavy Electricals Ltd India
Ceralink Inc NY
Ceritherm France
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Zibo Guangtong Chemical Co Ltd China

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American Isostatic Presses OH
CM Furnaces Inc NJ
Datapaq Inc NH
Gasbarre Products Inc PA
Harrop Industries Inc OH **See ad page 91**
Keith Co CA
Leico Industries Inc NJ
Materials Research Furnaces Inc NH **See ad page 79**
McDanel Advanced Ceramic Technologies LLC PA **See ad page 65**
PSH Kilns & Furnaces Canada
Quintus Technologies LLC OH
Recco Furnaces CA
Verder Scientific Inc PA

EDUCATION & RESOURCES

Associations & Societies

Assoc of American Ceramic Component Manufacturers (AACCM) OH
Brick Industry Assn VA
Glass Mfg Industry Council OH
Indian Ceramic Society India
International Centre for Diffraction Data PA
Journal of the American Ceramic Society OH
SAMPE CA
The American Ceramic Society OH

Books

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Bharat Heavy Electricals Ltd India
Journal of the American Ceramic Society OH
SAMPE CA
Sheffield Pottery MA

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Arizona State University AZ
CelSian Glass & Solar BV The Netherlands **See ad page 83**
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Jenike & Johanson Inc MA
JTF Microscopy Services Inc NY
Spontaneous Materials CO
Tethon 3D NE

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Massachusetts Inst of Technology MA
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Arizona State University AZ
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Fraunhofer Institute for Ceramic Technologies and Systems IKTS Germany
Massachusetts Inst of Technology MA
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Rensselaer Polytechnic Inst NY

Employment Services
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Publications
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American Scientific Publishers CA
Chemical Abstracts Service OH
GrainBound LLC PA **See ad page 111**
Indian Ceramic Society India
Journal of the American Ceramic Society OH

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Antennas, Dielectric
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AVX Corp SC
Euro Support Advanced Materials The Netherlands
Induceramic Canada
Murata Manufacturing Co Ltd Japan **See ad page 103**
Polymer Innovations Inc CA

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MSE Supplies AZ
TevTech LLC MA **See ad page 99**

Dielectrics
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Centerline Technologies MA **See ad page 86**
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ENrG Inc NY
ESL ElectroScience PA
Euro Support Advanced Materials The Netherlands
Gwent Electronic Materials Ltd UK
Morgan Advanced Materials CA
NGK Spark Plug Co Ltd Japan
Pacific Ceramics Inc CA

Ferrites & Ferromagnetics
Advanced Ceramic Technology CA
Ferro Ceramic Grinding Inc MA
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Polymer Innovations Inc CA
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Spontaneous Materials CO

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Associated Ceramics & Technology Inc PA **See ad page 67**
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ENrG Inc NY
ESL ElectroScience PA
Euro Support Advanced Materials The Netherlands
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Ceramco Inc NH **See ad page 89**
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Du-Co Ceramics Company PA
Morgan Technical Ceramics CA
Precision Ferrites and Ceramics Inc CA
Xiamen Innovacera Advanced Materials Co Ltd China

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AVX Corp SC
Precision Ferrites and Ceramics Inc CA
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IC Packages
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Kyocera International Inc CA
NGK Spark Plug Co Ltd Japan

Insulators, Electrical/Electronic
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AdTech Ceramics TN
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CerCo LLC OH
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Magnets
Spontaneous Materials CO

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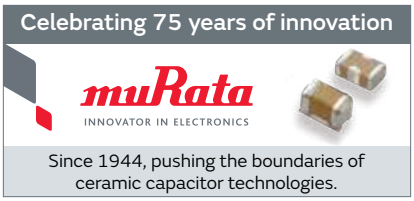
Kyocera International Inc CA
Precision Ferrites and Ceramics Inc CA

Multilayer Ceramic Capacitors
Euro Support Advanced Materials The Netherlands



Murata Manufacturing Co Ltd Japan **See ad page 103**
Polymer Innovations Inc CA

Multilayer Ceramics, AlN
AdTech Ceramics TN
NEVZ-Ceramics Close JSC Russia
Xiamen Innovacera Advanced Materials Co Ltd China

Multilayer Ceramics, Custom
AdTech Ceramics TN
EBL Products Inc CT
ENrG Inc NY
Euro Support Advanced Materials The Netherlands
Xiamen Innovacera Advanced Materials Co Ltd China

Piezoelectrics
APC International Ltd PA
AVX Corp SC
EBL Products Inc CT
Meggitt Piezo Technologies IN
Morgan Advanced Materials CA
Polymer Innovations Inc CA
Sparkler Ceramics Pvt Ltd India

Resistors, Thick-Film
ESL ElectroScience PA
Murata Manufacturing Co Ltd Japan **See ad page 103**
Polymer Innovations Inc CA

Resonators
AVX Corp SC
Murata Manufacturing Co Ltd Japan **See ad page 103**
NGK Spark Plug Co Ltd Japan
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**

RF Components
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Advanced Ceramic Technology CA
Advanced Energy CO
Murata Manufacturing Co Ltd Japan **See ad page 103**
Precision Ferrites and Ceramics Inc CA
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**

Semiconductors
Cancarb Limited Canada **See ad page 117**
Momentive Performance Materials Inc NY
NEVZ-Ceramics Close JSC Russia

Semiconductor Energy Laboratory Co Ltd Japan **See ad page 121**
Toto Ltd Japan

Sensors
AdTech Ceramics TN
AVX Corp SC
Bullen OH
CeramTec North America Corp SC
EBL Products Inc CT
ENrG Inc NY
Gwent Electronic Materials Ltd UK
Murata Manufacturing Co Ltd Japan **See ad page 103**
Neoptix Canada
Optocon AG Germany
Polymer Innovations Inc CA
Quality Thermistor Inc ID
Sparkler Ceramics Pvt Ltd India
Technisonic Research Inc CT

Spark Plugs
Associated Ceramics & Technology Inc PA **See ad page 67**
CerCo LLC OH
Federal-Mogul MI
Gwent Electronic Materials Ltd UK
NGK Spark Plug Co Ltd Japan

Substrates, Alumina
Accuratus Corp NJ
AdTech Ceramics TN
Bullen OH
Centerline Technologies MA **See ad page 86**
CeramTec North America Corp SC
CoorsTek CO
Du-Co Ceramics Company PA

Ferro Ceramic Grinding Inc MA
Laserage Technology Corp IL
NEVZ-Ceramics Close JSC Russia
NGK Spark Plug Co Ltd Japan
Ortech Inc CA
Saint-Gobain NorPro OH
Toto Ltd Japan
Valley Design Corp MA
Xiamen Innovacera Advanced Materials Co Ltd China

Substrates, Aluminum Nitride

Accuratus Corp NJ
AdTech Ceramics TN
Bullen OH
Centerline Technologies MA **See ad page 86**
CoorsTek CO
Laserage Technology Corp IL
MSE Supplies AZ
NEVZ-Ceramics Close JSC Russia
Ortech Inc CA
Starfire Systems Inc NY
Valley Design Corp MA
Xiamen Innovacera Advanced Materials Co Ltd China

Substrates, Glass

Accuratus Corp NJ
Bullen OH
Centerline Technologies MA **See ad page 86**
Laserage Technology Corp IL
RISE Research Institutes of Sweden RISE Glass Sweden
Saint-Gobain Recherche France
Valley Design Corp MA

Substrates, Other

Accuratus Corp NJ
Akron Porcelain & Plastics Co OH
Bullen OH
Centerline Technologies MA **See ad page 86**
CoorsTek CO
Du-Co Ceramics Company PA
ENrG Inc NY
MSE Supplies AZ
NGK Spark Plug Co Ltd Japan
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**
Valley Design Corp MA
Zircar Zirconia Inc NY

Substrates, Silicon Carbide

Bullen OH
Centerline Technologies MA **See ad page 86**
Ferro Ceramic Grinding Inc MA
Ortech Inc CA
Toto Ltd Japan
Valley Design Corp MA

Superconductors, High-Temperature

ENrG Inc NY
Xiamen Innovacera Advanced Materials Co Ltd China

Tapes

Du-Co Ceramics Company PA
ESL ElectroScience PA
Euro Support Advanced Materials The Netherlands
Haiku Tech Europe BV The Netherlands
Haiku Tech Inc FL
Maryland Ceramic & Steatite Co Inc MD
Polymer Innovations Inc CA

Thermistors

AVX Corp SC
Gwent Electronic Materials Ltd UK
Murata Manufacturing Co Ltd Japan **See ad page 103**
Polymer Innovations Inc CA
Quality Thermistor Inc ID

Transducers

APC International Ltd PA
CSC Force Measurement Inc MA
EBL Products Inc CT
Meggitt Piezo Technologies IN
Neoptix Canada
Sparkler Ceramics Pvt Ltd India
Technisonic Research Inc CT

Transformers

RoMan Manufacturing MI
Warner Power LLC MI

Ultrasonic Ceramics

APC International Ltd PA
EBL Products Inc CT
Meggitt Piezo Technologies IN

Murata Manufacturing Co Ltd Japan **See ad page 103**

Varistors

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Kyocera International Inc CA
Polymer Innovations Inc CA

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Reade Advanced Materials RI
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Sigmadiamant Spain
Stahli USA Inc WI
Suntech Advanced Ceramics (Shenzhen) Co Ltd China
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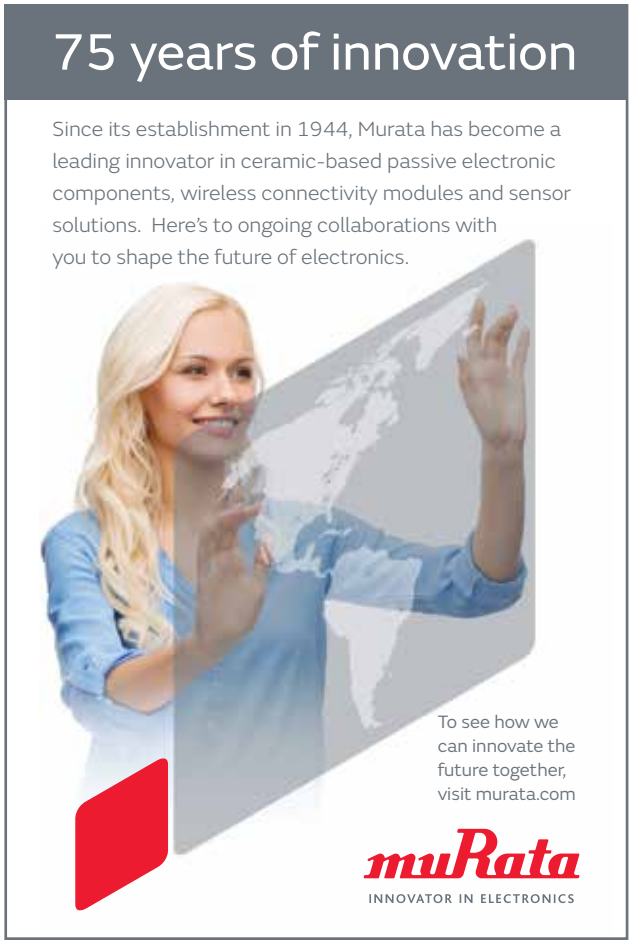
Cerlase France
Dorst America Inc PA
HED INtl Inc NJ
Laguna Clay Co CA
Maryland Ceramic & Steatite Co Inc MD

Casting Equipment, Tape

Haiku Tech Europe BV The Netherlands
Haiku Tech Inc FL



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Allied High Tech Products Inc CA
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Dynacut Inc PA
Haiku Tech Europe BV The Netherlands
Haiku Tech Inc FL
Liberty Machinery Co IL

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RISE Research Institutes of Sweden RISE Glass Sweden

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Dorst America Inc PA
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Laguna Clay Co CA
Rockwell Automation Inc WI

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General Glass Equipment Co NJ
Haiku Tech Inc FL
Jet Edge Waterjet Systems MN
Liberty Machinery Co IL
OptiPro Systems LLC NY
Sigmadiamant Spain
Suntech Advanced Ceramics (Shenzhen) Co Ltd China

Cutting Tools
Diacut Inc CO
Dynacut Inc PA
Engis Corp IL
Jet Edge Waterjet Systems MN
New Tech Ceramics Inc IA
Sigmadiamant Spain

CVD Equipment
Advanced Energy CO
Centorr Vacuum Industries NH **See ad page 95**
Liberty Machinery Co IL

Deburring Equipment
Engis Corp IL
Liberty Machinery Co IL
Mohr Corp MI **See ad page 87**

Diamond Drills
Diamond Industrial Tools Inc IL
Greenlee Diamond Tool Co IL

Diamond Hones
Diamond Industrial Tools Inc IL
Engis Corp IL
Greenlee Diamond Tool Co IL
Saint-Gobain Abrasives MA
Stahli USA Inc WI

Diamond Saw Blades
Allied High Tech Products Inc CA
Aremco Products Inc NY
Comtrust Architectural Mesh Co Ltd China
Diacut Inc CO
Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
LECO Corp MI
Liberty Machinery Co IL
Saint-Gobain Abrasives MA
Texers Technical Ceramics Inc Canada

Diamond Saws
Allied High Tech Products Inc CA
Aremco Products Inc NY
Diacut Inc CO
Dynacut Inc PA
Greenlee Diamond Tool Co IL
Liberty Machinery Co IL

Diamond Tools
Diamond Industrial Tools Inc IL
Engis Corp IL
Greenlee Diamond Tool Co IL
LECO Corp MI
Saint-Gobain Abrasives MA
Sigmadiamant Spain

Dicing Equipment
Aremco Products Inc NY
Diacut Inc CO
Diamond Industrial Tools Inc IL
Dynacut Inc PA
Liberty Machinery Co IL

Dies
Gasbarre Products Inc PA
Ram Products Inc OH

Dressing Wheels, Diamond
Diacut Inc CO
Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL

Electroplating Equipment
Haiku Tech Inc FL
Liberty Machinery Co IL

Extruders
Aadvanced Machinery Inc MI
American Art clay Co Inc IN
Basic Machinery Co Inc NC
Detroit Process Machinery MI
Dorst America Inc PA
Ipsen Ceramics IL
Laguna Clay Co CA
Mohr Corp MI **See ad page 87**
North Star Equipment Inc WA
Peter Pugger Mfg Inc CA

Feeders
Isoform Ltd UK
Mohr Corp MI **See ad page 87**
Wyssmont Co NJ

Forming Equipment
American Isostatic Presses OH
ARBURG GmbH + Co KG Germany
Dorst America Inc PA
HED INtl Inc NJ
Ipsen Ceramics IL
Isoform Ltd UK
Lithoz GmbH NY
Mohr Corp MI **See ad page 87**
Quintus Technologies LLC OH
Ram Products Inc OH

Glass Finishing Equipment
General Glass Equipment Co NJ
Liberty Machinery Co IL
Lithoz GmbH NY
OptiPro Systems LLC NY

Glass Forming Equipment
General Glass Equipment Co NJ

Glass Shear Spray
RISE Research Institutes of Sweden RISE Glass Sweden

Glass Supplies
Ipsen Ceramics IL

Grinders, Centerless
Diamond Industrial Tools Inc IL
Liberty Machinery Co IL
Precision Ferrites and Ceramics Inc CA
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Grinders, Cylindrical
Diamond Industrial Tools Inc IL
Liberty Machinery Co IL
Suntech Advanced Ceramics (Shenzhen) Co Ltd China

Grinders, Finished Product
DCM Tech MN
Ipsen Ceramics IL
Liberty Machinery Co IL
OptiPro Systems LLC NY
Stahli USA Inc WI

Grinding Wheels
Allied High Tech Products Inc CA
Diacut Inc CO
Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
Sigmadiamant Spain
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Goceram AB Sweden
Mohr Corp MI **See ad page 87**
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Suntech Advanced Ceramics (Shenzhen) Co Ltd China

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Cerinnov France
Ram Products Inc OH

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

Lapping Supplies
Allied High Tech Products Inc CA
Diamond Industrial Tools Inc IL
Dunhua Zhengxing Abrasive Co Ltd China
Engis Corp IL
FELDCO Intl CA
Stahli USA Inc WI

Laser Scribers
Centerline Technologies MA **See ad page 86**
Cerlase France
Mineral Research Processing France
Laserage Technology Corp IL

Machining Equipment
Dynacut Inc PA
Ferro Ceramic Grinding Inc MA
Liberty Machinery Co IL
Mineral Research Processing France
OptiPro Systems LLC NY
Penn Tool Co NJ **See ad page 111**
Stahli USA Inc WI

Mandrels, Diamond
Diacut Inc CO
Diamond Industrial Tools Inc IL
Engis Corp IL
Greenlee Diamond Tool Co IL

Molds, Case
Petro Mold Company PA
Ram Products Inc OH

Molds, Ceramic-Forming
Akron Porcelain & Plastics Co OH
Cerinnov France
Cerlase France
Goceram AB Sweden
Ipsen Ceramics IL
Isoform Ltd UK
Laeis GmbH Luxembourg
Laguna Clay Co CA
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

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Dynacut Inc PA
Engis Corp IL
LECO Corp MI
Liberty Machinery Co IL
OptiPro Systems LLC NY
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Gasbarre Products Inc PA
Mohr Corp MI **See ad page 87**
Quintus Technologies LLC OH

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

Presses, Extrusion
Dorst America Inc PA
Maryland Ceramic & Steatite Co Inc MD
Mohr Corp MI **See ad page 87**
Peter Pugger Mfg Inc CA

Presses, Hot
American Isostatic Presses OH
Centorr Vacuum Industries NH **See ad page 95**
FCT Ingenieurkeramik GmbH Germany
FCT Systeme GmbH Germany
Materials Research Furnaces Inc NH **See ad page 79**
Oxy-Gon Industries Inc NH **See ad page 94**
Refrac Systems AZ

Presses, Hot Isostatic
American Isostatic Presses OH
AVS Inc MA
FCT Ingenieurkeramik GmbH Germany
Quintus Technologies LLC OH

Presses, Hydraulic
Aadvanced Machinery Inc MI
ARBURG GmbH + Co KG Germany
AVS Inc MA
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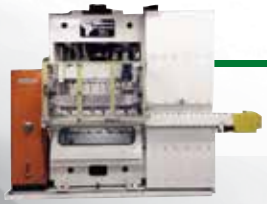
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Gasbarre Products Inc PA
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Haiku Tech Inc FL
Isoform Ltd UK
Mohr Corp MI **See ad page 87**
Quintus Technologies LLC OH
RocCera LLC NY
Suntech Advanced Ceramics (Shenzhen) Co Ltd China

Presses, Other
ARBURG GmbH + Co KG Germany
Isoform 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 Luxembourg

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

Presses, Tile (Ceramic)
Laeis GmbH Luxembourg
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Pug Mills
Aadvanced 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

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

Sputtering Equipment
Advanced Energy CO
FCT Ingenieurkeramik GmbH Germany

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Diamond Industrial Tools Inc IL
Dynacut Inc PA
Engis Corp IL
Greenlee Diamond Tool Co IL
Liberty Machinery Co IL
Teeter Marketing Services LLC FL

Surface Modification Systems
Teeter Marketing Services LLC FL

Tilemaking Equipment
Basic Machinery Co Inc NC
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Ram Products Inc OH

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Sheffield Pottery MA
Viridis3D LLC MA

Turning Machines, Insulator
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Ultrasonic Machining Equipment
Bullen OH
Liberty Machinery Co IL
OptiPro Systems LLC NY

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Dynacut Inc PA
Liberty Machinery Co IL
Ram Products Inc OH
Viridis3D LLC MA

Vibratory Finishing Equipment
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Rockwell Automation Inc WI

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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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Bullen OH
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
PremaTech Advanced Ceramics MA
Schott North America Inc NY
Specialty Glass Inc FL
StudioLX - Home Decor IL
TevTech LLC MA **See ad page 99**
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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**

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Vesuvius SC

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

Lenses
TevTech LLC MA **See ad page 99**

Lighting
Osram Sylvania Inc MA

Mirrors
Valley Design Corp MA

Optical & Optoelectronic Ceramics
NEVZ-Ceramics Close JSC Russia
Specialty Glass Inc FL
TevTech LLC MA **See ad page 99**
Vesuvius SC

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FELDCO Intl CA
Schott North America Inc NY
Specialty Glass Inc FL
Valley Design Corp MA
Vesuvius SC

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Schott North America Inc NY
TevTech LLC MA **See ad page 99**

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FELDCO Intl CA
Materion Ceramics AZ
TevTech LLC MA **See ad page 99**
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■ LABORATORY EQUIPMENT & SUPPLIES

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Nanofilm OH
RocCera LLC NY

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HunterLab VA

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

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

Dimension Measurement Instruments
CSC Force Measurement Inc MA

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Applied Test Systems Inc PA
Ceramic Services Inc PA
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Eirich Machines Inc IL
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Fiberoptic Illuminators
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Mo-Sci Corp MO **See ad page 107**
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Taber Industries NY

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Garg Process Glass India Pvt Ltd India
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Horiba Instruments Inc CA

Hardness Measurement Instruments
Allied High Tech Products Inc CA
Buehler Ltd IL
Carl Zeiss Mircolmaging Inc NY **See ad page 109**
LECO 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**
Ceramco Inc NH **See ad page 89**
CoorsTek CO
McDanel Advanced Ceramic Technologies LLC PA **See ad page 65**
Robocasting Enterprises LLC NM
Xiamen Innovacera Advanced Materials Co Ltd China
Zhengzhou Mission Ceramic Products Co Ltd China

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

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L&L Special Furnace Co Inc PA **See ad page 101**
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Spectronics Corp NY

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Buehler Ltd IL
BuzzMac Intl LLC ME
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Nanoscience Instruments AZ
Penn Tool Co NJ **See ad page 111**
TA Instruments DE
Taber Industries NY

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

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Buehler Ltd IL
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Microscopes, Other
See ad page 69


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Microscopes, Reflected Light
Allied High Tech Products Inc CA
Buehler Ltd IL
Carl Zeiss Mircolmaging Inc NY **See ad page 109**
LECO Corp MI

Microscopes, Scanning Electron

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Carl Zeiss Mircolmaging Inc NY **See ad page 109**
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SEMTech Solutions Inc MA

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

Mixers, Laboratory
Custom Processing Services PA
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Eirich Machines Inc IL
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Lancaster Products PA
Littleford Day Inc MI
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Ram Products Inc OH
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Ram Products Inc OH
Verder Scientific Inc PA

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Optocon AG Germany
Xiamen Innovacera Advanced Materials Co Ltd China

Viscosity Measurement Instruments
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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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Mettler-Toledo Inc OH
Rockwell Automation Inc WI
Siemens Process Industries and Drives GA

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Spectrochemical Laboratories PA

Auger Analysis
Evans Analytical Group LLC CA
High Temperature Materials Lab TN
Micron Inc DE

Chemical Analysis
Activation Laboratories Ltd Canada
CelSian Glass & Solar BV The Netherlands **See ad page 83**
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Dalmia Inst of Scientific & Industrial Research India
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Evans Analytical Group LLC CA
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Washington Mills Electro Minerals Co NY

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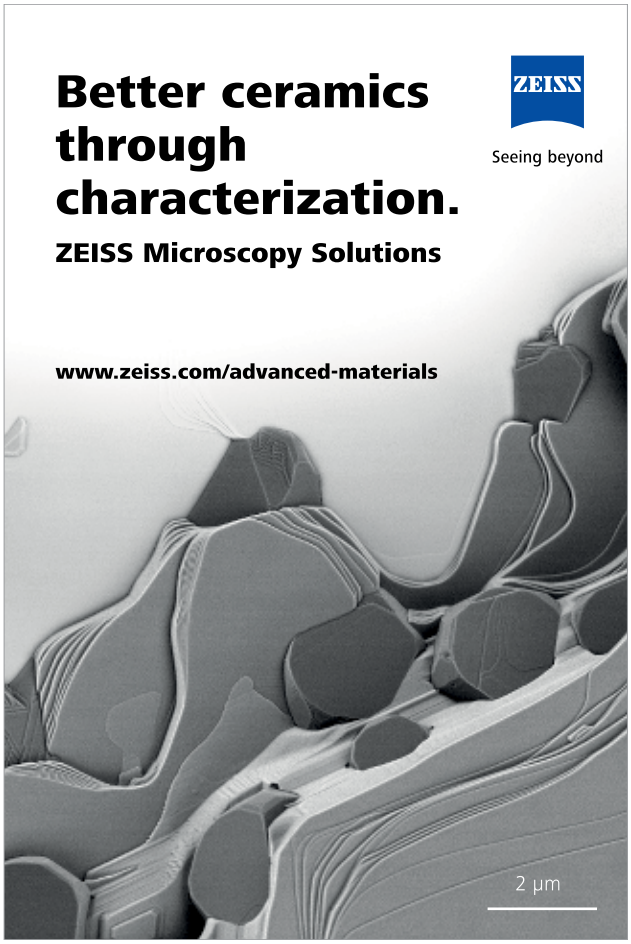
Imerys GA
Laguna Clay Co CA
Technology of Materials CA



Composition
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Alfred University NY
CelSian Glass & Solar BV The Netherlands **See ad page 83**
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Dalmia Inst of Scientific & Industrial Research India
Edward Orton Jr Ceramic Foundation OH
Japan Fine Ceramics Center Japan
P-Ker Engineering NY
Rauschert Industries Inc GA **See ad page 85**
Viridis3D LLC MA

Corrosion Testing
Activation Laboratories Ltd Canada
All Waste Matters UK
CelSian Glass & Solar BV The Netherlands **See ad page 83**
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Dalmia Inst of Scientific & Industrial Research India
Edward Orton Jr Ceramic Foundation OH
P-Ker Engineering NY
SEMTech Solutions Inc MA

Density Determination
Activation Laboratories Ltd Canada
AVEKA MN
CHEMIR - A Division of Evans Analytical Group MO
Cyclonaire Corp NE
Edward Orton Jr Ceramic Foundation OH
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
Activation Laboratories Ltd Canada
AVEKA MN
CHEMIR - A Division of Evans Analytical Group MO
Edward Orton Jr Ceramic Foundation OH
Evans Analytical Group LLC CA
High Temperature Materials Lab TN
Hindalco Industries Limited India
Japan Fine Ceramics Center Japan
Micron Inc DE
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

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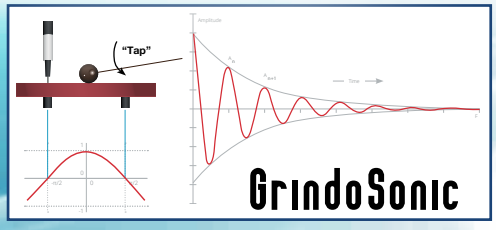

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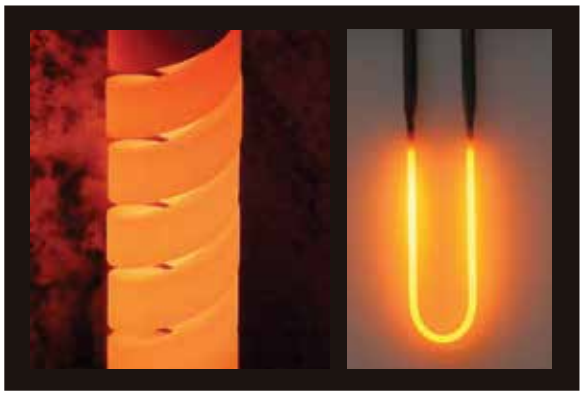

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Swindell Dressler Intl Co PA
Wistra GmbH Germany

Electronic Materials Production
Haiku Tech Europe BV The Netherlands
Haiku Tech Inc FL
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**

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

Fabrication Shops
Maryland Ceramic & Steatite Co Inc MD

Glass Production
CelSian Glass & Solar BV The Netherlands **See ad page 83**
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

Structural Ceramics Production
CerCo LLC OH
Maryland Ceramic & Steatite Co Inc MD
Swindell Dressler Intl Co PA
Takasago Industry Co Ltd Japan
TevTech LLC MA **See ad page 99**

Tile Production
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LIXIL Corporation Japan
Peter Pugger Mfg Inc CA

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

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Zenith China

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Cerinnov France
Cerlase France
Trans-Tech Inc, a subsidiary of Skyworks Solutions Inc MD **See ad page 75**
Zenith China

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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 **See ad page 67**
Astral Material Industrial Co Ltd China
Baikowski Malakoff Inc NC
Bucher Emhart Glass SA Switzerland
Ceramco Inc NH **See ad page 89**
CeramTec-ETEC Germany
Dalmia Inst of Scientific & Industrial Research India
Du-Co Ceramics Company PA
ER Advanced Ceramics Inc OH
Fosbel Inc OH
General Material Industrial Co China
GrainBound LLC PA **See ad page 111**
IPS 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
RHI US Ltd NY
Riverside Refractories Inc AL
Selee Corp NC
Sunrock Ceramics Co IL
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Ipsen Ceramics IL
Merkle International Inc IL

AZS
Bucher Emhart Glass SA Switzerland
Fosbel Inc OH
Magneco Metrel Inc IL
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Monofrax LLC NY
RHI US Ltd NY

Backwalls
Fosbel Inc OH
Merkle International Inc IL

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 **See ad page 67**
Morgan Thermal Ceramics GA
RHI US Ltd NY
Thermal Products Co Inc GA
Unifrax I LLC NY
ZIRCAR Ceramics Inc NY
Zircar Refractory Composites Inc NY
Zircar Zirconia Inc NY

Boards
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Morgan Thermal Ceramics GA
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Zircar Zirconia Inc NY

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Cancarb Limited Canada **See ad page 117**
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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
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Riverside Refractories Inc AL
Selee Corp NC
Vitcas Ltd UK
Zircar Refractory Composites Inc NY

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Vitcas Ltd UK
ZIRCAR Ceramics Inc NY
Zircar Zirconia Inc NY

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
Fosbel Inc OH
Furnace Products & Services Inc PA
Fusion Ceramics Inc OH
Gwent Electronic Materials Ltd UK
Induceramic 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
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Akron Porcelain & Plastics Co 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 **See ad page 85**
Saint-Gobain Ceramics & Plastics MA

Crucibles
AdValue Technology LLC AZ **See ad page 69**
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 **See ad page 89**
CeramTec-ETEC Germany
Furnace Products & Services Inc PA
Industrial Ceramic Products Inc OH
Ipsen Ceramics IL
LECO Corp MI
Magneco Metrel Inc IL
McDanel Advanced Ceramic Technologies LLC PA **See ad page 65**
Progressive Technology Inc CA
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Fosbel Inc OH
H.C. Starck GmbH Germany
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Ipsen Ceramics IL
LECO Corp MI
Magneco Metrel Inc IL
Missouri Refractories Co (MORCO) MO
Plibrico Company IL
Riverside Refractories Inc AL
Selee Corp NC
Silicon Carbide Products Inc NY
Zircar Refractory Composites Inc NY

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Monofrax LLC NY
Saint-Gobain Ceramics & Plastics MA

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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 Intl PA
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Magneco Metrel Inc IL
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RISE Research Institutes of Sweden RISE Glass Sweden
Vesuvius SC

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Maryland Refractories Co OH

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Fosbel Inc OH
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Plibrico Company IL
Plibrico Japan Co Ltd Japan
Reno Refractories Inc AL
Riverside Refractories Inc AL
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Plibrico Japan Co Ltd Japan
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Rath Inc DE
RHI US Ltd NY
Riverside Refractories Inc AL
Selee Corp NC
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Xiamen Innovacera Advanced Materials Co Ltd China
Zhengzhou Mission Ceramic Products Co Ltd China
ZIRCAR Ceramics Inc NY
Zircar Refractory Composites Inc NY

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

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Insulation Slabs, Vermiculite

Insulating Firebrick Inc PA

Insulation, Microporous

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Texers Technical Ceramics Inc Canada
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RHI US Ltd NY

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Plibrico Japan Co Ltd Japan
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Nozzles

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Paper

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Plibrico Company IL
Plibrico Japan Co Ltd Japan
RHI US Ltd NY
Riverside Refractories Inc AL
Selee Corp NC

Rods

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CerCo LLC OH
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Industrial Ceramic Products Inc OH
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Rollers

Keith Co CA
Recco Furnaces CA
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Setters

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RHI US Ltd NY
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Cancarb Limited Canada **See ad page 117**
CoorsTek CO
Custom Processing Services PA
Electro Abrasives Corp NY
Fosbel Inc OH
IPS Ceramics LTD UK
Magneco Metrel Inc IL
Missouri Refractories Co (MORCO) MO
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Zircon

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Zircoa Inc OH

Zirconia

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Ceramco Inc NH **See ad page 89**
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CerCo LLC OH
CoorsTek CO
Custom Processing Services PA
Dalmia Inst of Scientific & Industrial Research India
ENrG Inc NY
Fosbel Inc OH
Lithoz GmbH NY
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Precision Ferrites and Ceramics Inc CA
Refractron Technologies Corp NY **See ad page 69**

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Israel Ceramic & Silicate Inst Israel
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Lucideon UK

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Applied Research Center SC
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Israel Ceramic & Silicate Inst Israel
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Sandia National Laboratories NM

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Chemical Analysis Instruments

Ocean Optics Inc FL

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HunterLab VA
Lucideon UK

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Applied Test Systems Inc PA
CSC Force Measurement Inc MA
Dalmia Inst of Scientific & Industrial Research India

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Datapaq Inc NH
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Rockwell Automation Inc WI
Siemens Process Industries and Drives GA

Couplants Ultrasonic Instruments

James Instruments IL

Density Analyzers

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Quantachrome Instruments FL
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Linseis Inc NJ
Netzsch Instruments NA LLC MA **See ad page 123**
Particle Technology Labs IL
Setaram Instrumentation France
TA Instruments DE

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Neoptix Canada
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TA Instruments DE

Dilatometers

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Linseis Inc NJ
Netzsch Instruments NA LLC MA **See ad page 123**
TA Instruments DE

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Eddy-Current Testing Instruments

Ether NDE UK

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Haiku Tech Inc FL
Nanoscience Instruments AZ
Ocean Optics Inc FL

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CSC Force Measurement Inc MA
James Instruments IL
NorECs AS Norway

Electronic Analysis Instruments

Ether NDE UK
James Instruments IL

Flexural Analysis Instruments

Advanced Ceramics Manufacturing AZ
RocCera LLC NY
TA Instruments DE
Taber Industries NY

Gas Analysis Instruments

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Ocean Optics Inc FL
Setaram Instrumentation France

Image Analysis Instruments

Buehler Ltd IL
Carl Zeiss MircoImaging Inc NY **See ad page 109**
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Fritsch Milling & Sizing Inc. NC
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Particle Technology Labs IL
TA Instruments DE

Infrared Spectroscopy Instruments

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Ocean Optics Inc FL
Quantachrome Instruments FL

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American Stress Technologies Inc PA
BuzzMac Intl LLC ME
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Datapaq Inc NH
Ether NDE UK
James Instruments IL
Nanoscience Instruments AZ
Spectronics Corp NY
Thermal Wave Imaging Inc MI

Oxygen Analyzers

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Verder Scientific Inc PA

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http://dcm-tech.com

DCM designs and manufactures blanchard style rotary grinders for ceramic grinding applications. Servo drive, Z-axis, and programmable automatic feed provides process repeatability. DCM is a U.S. manufacturer that sells and services factory direct.

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Immokalee FL US 32004

International ceramic consultants specializing in energy-saving ceramic coatings and fiber modules.

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1007 E 75th Ave Unit E Fax: 303-433-2809
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mary@deltechfurnaces.com
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Manufacturer of standard and custom electric lab and production scale furnaces, including glass melt and rotary models for 1,500–2,000°C operation in air, inert atmospheres, and under positive pressures. ISO 9001:2015 certified. NQA-1 compliant. Control systems certified by Intertek UL508A compliant.

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rula@boroncarbide.cn
http://boroncarbide.cn

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DYNACUT INC 610-346-7386
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Elkem products that may be of interest in the advanced ceramics field are the Silgrain line of silicon powders. Silicon powder is often used as a raw material for manufacturing silicon nitride and silicon carbide ceramics.

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Manufactures six refractory cements with alumina content (purity level) ranging from 40–80%.

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A government research institute to help develop technologies for the domestic industry, with focus on export competitiveness and SMEs. Receives government and private funding; distributes its research grants to private companies.

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Greenville SC US 29607

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http://www.jtekt-na.com

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30 Willis Mountain Plant Ln Fax: 434-983-3579
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http://kyanite.com

Mines and markets raw and calcined kyanite (mullite), domestically and internationally. Available in grain sizes of 35, 48, 100, 200, and 325 mesh. Six plants in Virginia. Provides alumina silicate mineral.

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Produces high-performance hydraulic presses, dryers, and kilns, mainly for refractories, advanced and technical ceramics, fine ceramics, building material, and other applications.

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City Of Industry CA US 91746

info@lagunaclay.com
http://lagunaclay.com

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41-1 Yokomichi
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http://www.tytlabs.com

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RFCeramics@skyworksinc.com
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Skyworks Solutions, through its wholly-owned subsidiary Trans-Tech, is an industry leader in technical ceramic materials. With over 60 years of experience, the company offers a complete line of high-quality, low-cost, ceramic-based materials for many RF and microwave markets, including wireless communications, infrastructure, military, cable television, and bRdband access. Tightly controlled processes—from raw materials to forming, firing, finishing, assembling, and testing—produce the best and most consistently reproducible components available today for both low and high volume requirements. Product portfolio includes advanced materials (in both technical powder and ingot form) as well as dielectrics, ferrites, and magnetics.

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treibacher@treibacher.com
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trinityceramic@sbcglobal.net
https://trinityceramic.com

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sales@zircarceramics.com
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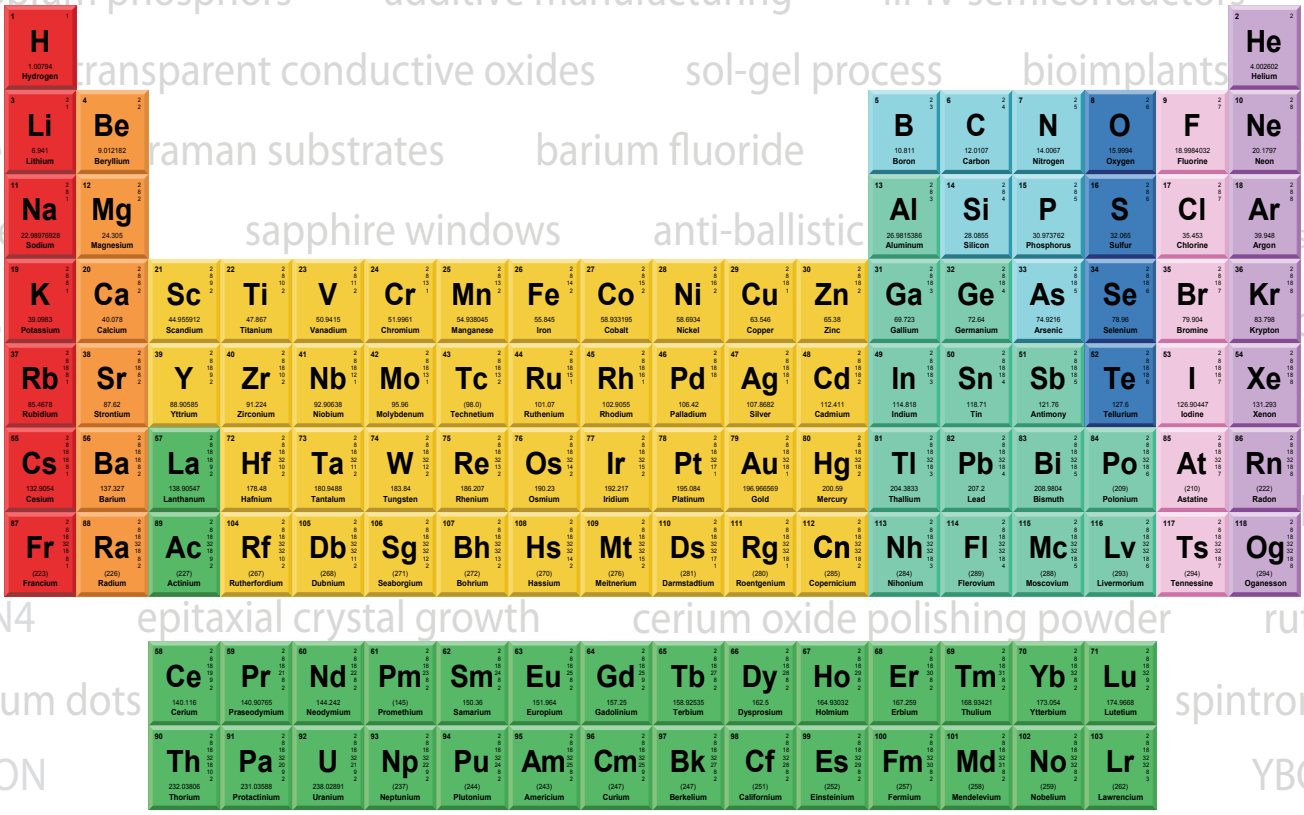

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