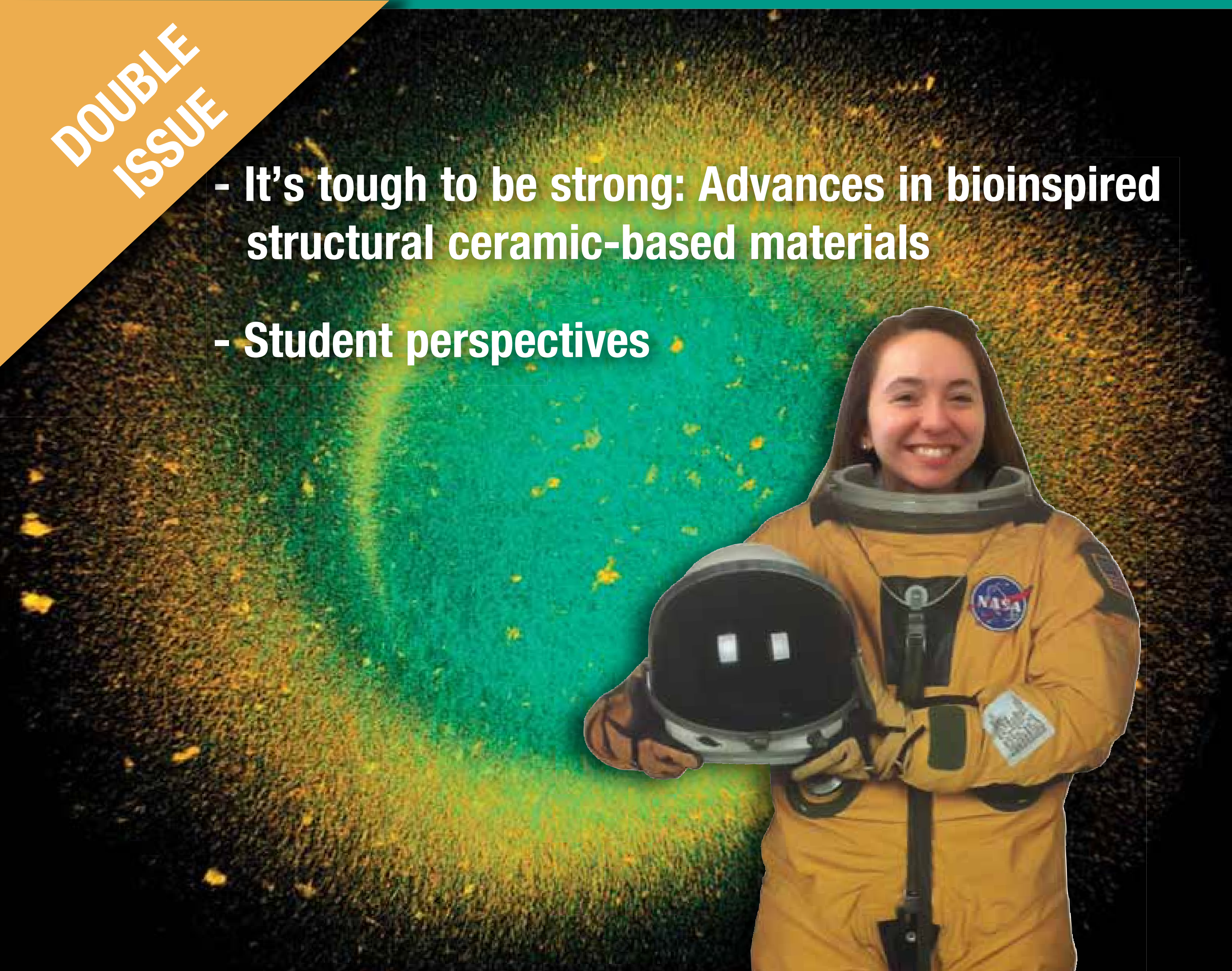
AMERICAN CERAMIC SOCIETY

bulletin

emerging ceramics & glass technology

JUNE/JULY 2014

DOUBLE ISSUE



- It's tough to be strong: Advances in bioinspired structural ceramic-based materials
- Student perspectives

ACerS announces new leaders •

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Engineering Ceramics Division
The American Ceramic Society

Organized by The American Ceramic Society and The American Ceramic Society's Engineering Ceramics Division

contents

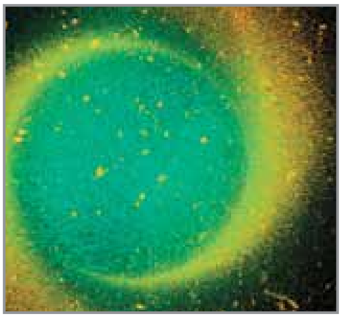
June/July 2014 • Vol. 93 No. 5

feature articles

meetings

columns

resources



cover story

It's tough to be strong: Advances in bioinspired structural ceramic-based materials

Credit: Porter; UCSD

– page 18

feature

Student perspectives

Credit: W. Gregory

– page 25

departments

AMERICAN CERAMIC SOCIETY
bulletin

contents

June/July 2014 • Vol. 93 No. 5

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Survey shows researchers are not tapping in to social media's powers of dissemination
http://bit.ly/1iHYAnQ

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Science-themed music videos may be able to boost scientific literacy
http://bit.ly/1kchS4Y

Concrete abstracts—Oxymorons describe longer-lasting, greener cement formulations
What can you build with recycled ceramics? Hint: It is not abstract!
http://bit.ly/1eQwli4

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. *American Ceramic Society Bulletin* (ISSN No. 0002-7812). ©2014. 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.ceramicbulletin.org). Editorial and Subscription Offices: 600 North Cleveland Avenue, Suite 210, Westerville, OH 43082-6920. Subscription included with The American Ceramic Society membership. Nonmember print subscription rates, including online access: United States and Canada, 1 year $95; 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 $75. Single issues, January–October/November: member $6.00 per issue; nonmember $7.50 per issue. December issue (*ceramicSOURCE*): member $20, nonmember $25. 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.

POSTMASTER: Please send address changes to American Ceramic Society Bulletin, 600 North Cleveland Avenue, Suite 210, Westerville, OH 43082-6920. Periodical postage paid at Westerville, Ohio, and additional mailing offices. Allow six weeks for address changes.

ACSBA7, Vol. 93, No. 5, pp 1–48. All feature articles are covered in Current Contents.

news & trends

Study shows impacts of US science funding felt beyond the lab

A new study published in *Science* indicates that university research and the funding that supports it are a "key component of the United States economic ecosystem."

Conducted by researchers from the American Institutes for Research, Committee on Institutional Cooperation, University of Michigan, University of Chicago, and Ohio State University, the study found that the economic impact of science funding extends far past the scientific community.

"The process of scientific research supports organizations and jobs in many of the high-skill sectors of our economy," write the researchers, who cite several reasons for the impact.

University research provides jobs to faculty members, but the study also found that fewer than one in five workers supported by federal research funds are faculty researchers. Instead, one in three is a student—graduate or undergraduate—and one in ten a postdoctoral fellow.

University research also provides spending that stretches beyond state lines. The new dataset used by the research team revealed that universities receiving federal research funds spend those dollars throughout the U.S., with almost 70 percent spent outside of the institution's home state. Expenditures with U.S. vendors and subcontractors in 2012 tallied almost $1 billion—15 percent of which was located in the university's home county, 15 percent in the home state, and the remaining 70 percent across the country.

University research provides spending that benefits companies of all sizes, with the impact reaching enterprises big and small. Many of the vendors were large companies, but the study's authors note, "we were struck by how many are small, niche, high-technology companies."


Credit: S. Leary; U. of Georgia; Flickr CC BY-NC 2.0

A new study shows that university research funding—and the work it supports—is vital to the U.S. economic ecosystem.

University research also provides scientific solutions to real world problems outside the research community. It is no secret that the work of scientists and engineers impacts everyday life, but that impact is not always recognized.

"Research universities are dedicated to the discovery of new knowledge," says coauthor Roy Weiss, deputy provost for research at the University of Chicago. "This study reports the first cooperative endeavor by multiple universities to evaluate the benefit of government investment in research. In addition to making the world a better place by virtue of these discoveries, we now have data to support the overall benefits to society."

The paper is "Science funding and short-term economic activity" (DOI: 10.1126/science.1250055). ■

DOE fuels US competitiveness in fuel cell market with $3M

In an ongoing effort to give United States businesses more cost-efficient and cleaner energy options, the Department of Energy recently awarded $3 million to strengthen the country's competitiveness in the fuel cell market.

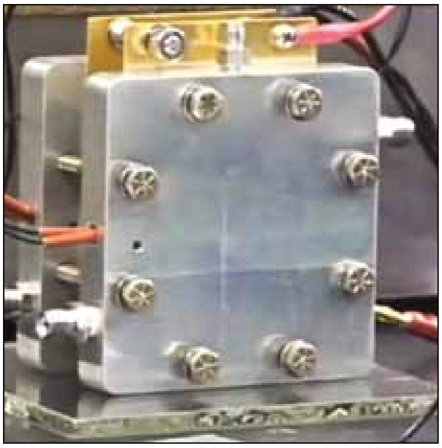
According to a DOE news release, FuelCell Energy (Danbury, Conn.) will use the monies to fund a project that will "enhance the performance, increase the lifespan, and decrease the cost of stationary fuel cells being used for distributed generation and combined heat and power applications.

"With support from the Energy Department, the private sector and the department's national laboratories have significantly reduced costs and improved performance in fuel cell and hydrogen technologies," says the release. "Building on this progress, the project awarded today will focus on developing an innovative carbonate fuel cell electrolyte matrix, which promises enhanced cell output and the doubling of service life, which will reduce the costs and enhance the market for efficient, clean fuel cell power. In addition, the project will look for more opportunities to reduce costs through greater production by incorporating manufacturing process improvements."

The fuel cell industry is a billion-dollar industry with market share to be gained. Countries in the Asian Pacific ship more than three-quarters of fuel cell systems worldwide, but the U.S. is quickly gaining ground with a series of strategic investments.

In 2012, industry revenues exceeded $1 billion worldwide, and U.S. companies received close to 80 percent of investment in the industry. America is among the top four dominant producers of stationary fuel cells, which account for half of all fuel cell shipments worldwide.

Since 2008, the DOE's efforts have reduced high-volume manufacturing costs for fuel cells by more than 30 percent, increased shipments from 1,000 units to 5,000 units annually,



Credit: HowStuffWorks; YouTube

Fuel cells, like this polymer exchange membrane cell, may gain ground in the U.S. with the help of $3 million in funding from the DOE.

and raised domestic manufacturing by more than 60 percent. Late last year, as part of the Obama administration's "all-of-the-above energy strategy," the DOE announced some $7 million for fuel cell projects.

According to the DOE's 2013 "Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Office" report, its R&D efforts have "helped manufacture about 40 new commercial technologies in the U.S., support 65 new technologies that are expected to reach commercial-scale within the next three to five years, and issue more than 450 U.S. patents." ■

Survey shows researchers are not tapping in to social media

Credit: J. Howie; Flickr CC BY 2.0

Findings suggest that academia has not yet embraced social media.

A new paper by a Michigan State University researcher suggests that university scholars have all but ignored social networks in distributing scientific findings and connecting with their tweet-happy, tech-savvy students.

What is a widely used channel for distributing content and making connections online in the business world just has not taken hold in academia. According to Christine Greenhow, assistant professor at MSU's College of Education, this is a concern because of a growing push to increase access to publicly funded research.

"Only a minority of university researchers are using free and widely available social media to get their results and published insights out and into the hands of the public, even though the mission of public universities is to create knowledge that makes a difference in people's lives," Greenhow says in an *MSUToday* report. "Simply put, there's not much tweeting from the ivory tower."

According to Greenhow, faculty are just beginning to dip toes in the social media waters to share research findings. She further suggests that higher education will not see widespread adoption unless "universities adopt policies for promotion and tenure that reward these practices."

Her survey of 1,600 researchers found that only 15 percent use Twitter, 28 percent use YouTube, and 39 percent use Facebook to connect with collaborators and distribute their work—not to engage or educate their students.

"Academia is not serving as a model of social media use or preparing future faculty to do this," says Greenhow, who believes the issue "is at the heart of largest discussions regarding accessibility, equal rights to education, transparency, and accountability."

The paper, appearing online in the *British Journal of Educational Technology*, is "Social scholarship: Reconsidering scholarly practices in the age of social media" (DOI: 10.1111/bjet.12150). ■

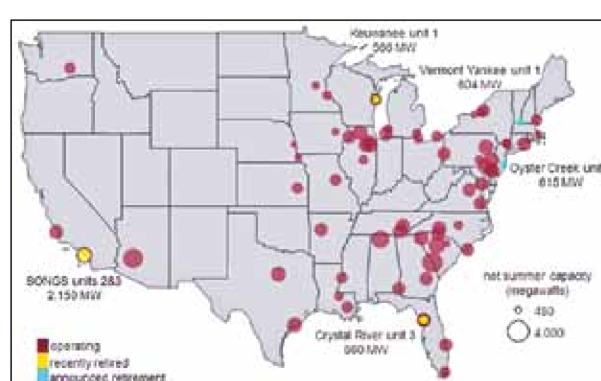
America uses more energy in 2013, struggles to reduce carbon emissions

Although Americans get 84 percent of total energy from oil, coal, and natural gas, a new report finds that, overall, Americans used more energy in all forms—renewable, fossil, and nuclear—in 2013.

According to new data from the Lawrence Livermore National Laboratory, Americans used 2.3 quadrillion thermal units (quads) more in 2013 than they did in 2012.

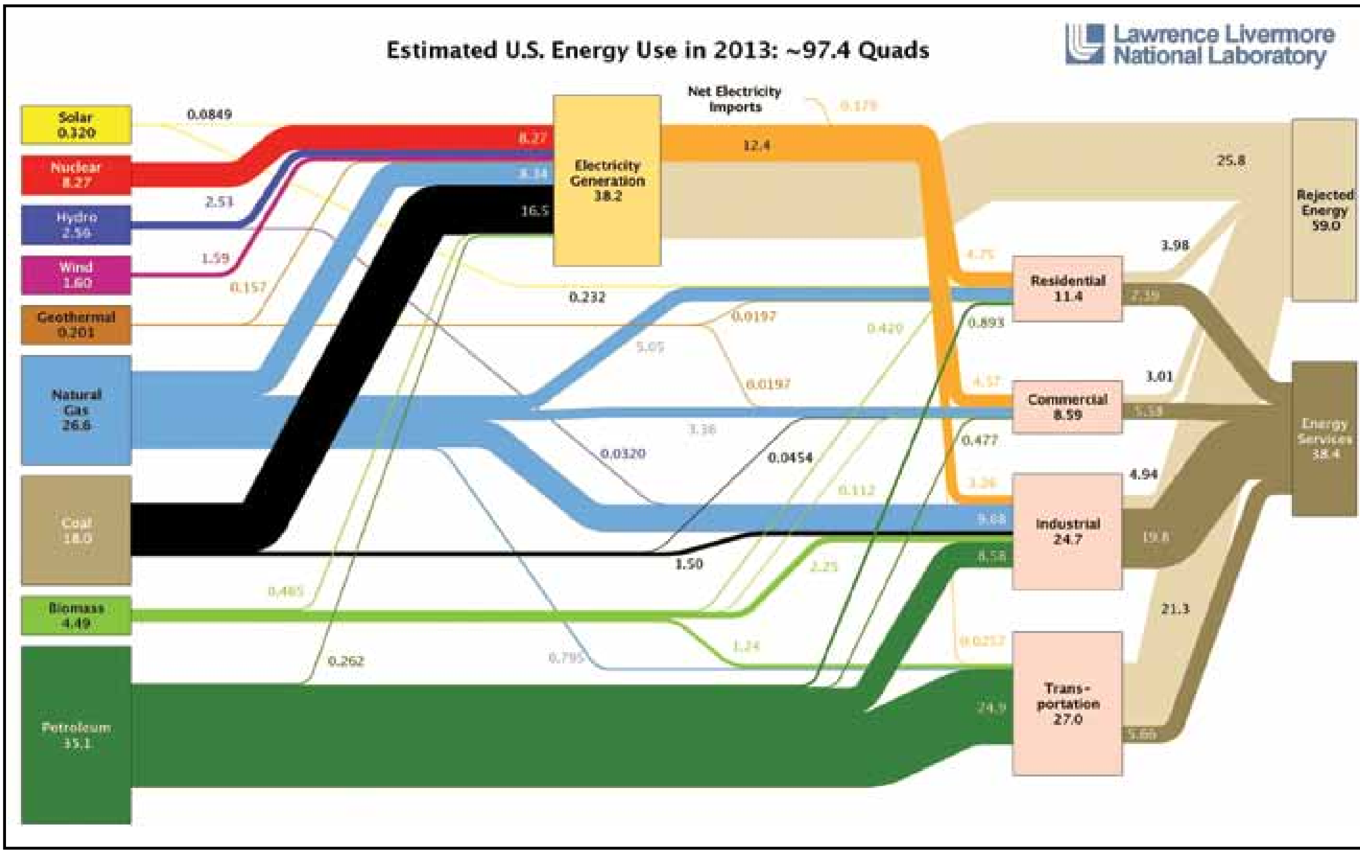
Wind energy showed a strong 18-percent growth, and natural-gas prices increased slightly in 2013. This resulted in a shift from the recent reliance on more costly coal to cheaper-to-produce natural gas. However, the move contributed to increased CO_2 emissions (a first since 2010).

Nuclear energy use also was up, despite the fact that a few reactors, including the San Onofre Nuclear



Credit: U.S. Energy Information Administration

Status of U.S. nuclear power plants as of September 2013.



Credit: Lawrence Livermore National Laboratory

A flowchart released by Lawrence Livermore National Laboratory of U.S. energy use.

Generating Station in Pendleton, Calif., were shut down.

The majority of the energy used in 2013 was for electricity generation—some 38.2 quads—followed by transportation, industrial, residential, and commercial, all of which increased slightly.

To view the data in full, visit www.llnl.gov.

However, new data suggests that the U.S.'s efforts, however earnest, to make its energy cleaner and greener may be impeding its ability to reduce harmful carbon emissions.

According to a policy brief by the Center for Climate and Energy Solutions (C2ES), which examines the role of nuclear power in the U.S., the closures or impending closures of U.S. nuclear facilities are making it more difficult to meet climate goals, including a 17-percent reduction in CO_2 emissions by 2020.

Nuclear power currently supplies more than 60 percent of zero-carbon electricity in the country.

"Losing more of our existing nuclear fleet will make it that much tougher to meet our carbon reduction goals," says C2ES President Eileen Claussen in a press release. "We need to keep ramping up renewables, but they can't meet our need for reliable power 24/7. Nuclear is a baseload source and it's carbon-free—two things we need."

Sixteen natural-gas combined cycle power plants would be needed to replace the energy generated from the five nuclear reactors retired since October 2012, according to the brief. Those 16 plants would provide baseload power, but also an added 12 million metric tons of CO_2 each year. Renewables, such as wind (7,600 turbines) and solar (3.7 million solar rooftop panels) could get the job done without increasing carbon emissions, but could not provide baseload power for the amount of electricity needed. According to C2ES, electricity accounts for almost a third of the country's total greenhouse gas emissions. ■

acers spotlight

Welcome to our newest Corporate Members!

ACerS recognizes organizations that have joined the Society as Corporate Members. For more information on becoming a Corporate Member, contact Tricia Freshour at tfreshour@ceramics.org, or visit www.ceramics.org/corporate.

Harper International
Buffalo, N.Y., USA
www.harperintl.com

Tethon 3D
Omaha, Neb., USA
www.tethon3d.com

MS&T14 Distinguished Life Member, Senior, Emeritus registration, student contests

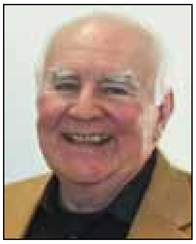
ACerS offers free MS&T14 registration for Distinguished Life members and reduced registration for Senior and Emeritus members. These offers are available only through ACerS. Registration forms are available at www.ceramics.org/annual meeting and should be submitted by **August 15, 2014**, to Marcia Stout at mstout@ceramics.org.

And students: You will not want to miss the Material Advantage contests. For more information, contact Tricia Freshour at tfreshour@ceramics.org. ■

Fellows nominations due September 1

Nominations for the ACerS 2015 Class of Fellows should be submitted by **September 1, 2014**. Fellows should have reached their 35th birthday and been members of the Society at least five years continuously. Visit www.ceramics.org/awards or contact Marcia Stout at mstout@ceramics.org. ■

Tribute to Warren W. Wolf, 1941–2014



Wolf

The Society learned with sorrow that former president Warren W. Wolf died April 25.

Wolf served as ACerS president from April 2005 to October 2006—the longest term in modern times—as a result of the transition of the Annual Meeting from April to October to align with MS&T. His succession through the three presidential offices (president-elect nominee, president-elect, and president) coincided with a financially precarious time at the Society.

Leading the Board through several bold steps to address the crisis, Wolf reported in a 2005 *Bulletin* interview that the Society had retired all of its debt and had a "bottom line … even further in the black than projected." The newfound fiscal stability allowed Wolf to implement the Society's 2005–2010 strategic plan, which included taking advantage of emerging opportunities, promoting ACerS' value to corporations and students, reinvigorating the *Bulletin* and its Editorial Advisory Board, and starting two new events. Those events remain active today—the International Conference on Ceramic Interconnect & Ceramic Microsystems Technologies, and the first International Congress on Ceramics.

The Society made what Wolf called "two major, future-setting decisions" during his tenure: establishment of the Ceramics Publishing Company to serve the art ceramics community; and investment in web-based infrastructure to create and power ceramics.org.

Wolf earned his B.S. in ceramic engineering from Pennsylvania State University, Ph.D. from Ohio State University, and MBA from Xavier University. He spent 33 years at Owens Corning, joining the company in 1968 as a senior scientist at the Science and Technology Center in Granville, Ohio. He retired in August 2001 as vice president and chief scientist of science and technology.

An innovative scientist, he holds 15 patents in the area of glass fiber manufacturing processes and compositions. Wolf's research into understanding the human health issues relating to glass fibers in lung tissue led the International Association on Research in Cancer to remove biosoluble glass fibers from its list of possible carcinogens. The glass industry recognized this work and his leadership in glass science with the Phoenix Award at a gala celebration in 2006.

David Green, ACerS president, speaking on behalf of all, says, "The Society extends its heartfelt condolences to Warren's family. Much of the success the Society enjoys today traces back to his leadership, not just as president, but also as a leader in industry. Those of us who had the honor to work with him will miss his insight, vision, and passion for the Society."

Wolf, of New Albany, Ohio, was 72 years old, and is survived by his wife Linda, seven children, grandchildren, and great-grandchildren. ■

Reflection from ACerS' past presidents

From time-to-time events occur that cause one to stop, look back, and reflect on the greater meaning of things long since gone by. For many members of the Society and the broader ceramics and glass community, the unexpected passing of Dr. Warren W. Wolf is such an occasion.

Much can be said of Warren's accomplishments as an industrial glass researcher and his contributions to the glass industry. As past presidents of The American Ceramic Society, we wish to acknowledge his outstanding leadership of the Society during a time of great challenge, which included his extended tenure as president in 2005–2006.

This period of change included the laudatory goals of providing greater financial stability for the Society; meeting the rapidly changing needs of industry; serving the ceramic art community; and perhaps, most important of all, reaching out nationally and internationally to better serve the Society's entire membership.

Those involved with the Society at the time were keenly aware of Warren's great sense of business and finance, his clear thinking on complicated issues, and his ability to envisage what could—indeed, must—be done for the good of the Society. Ever the optimist and totally committed to meeting the Society's challenges, he recognized the changing nature of the world in which we live and the obligation to serve it well, whether as an industrial scientist or engineer, educator, artist, government servant, or dedicated humanist, which he was.

It is sometimes remarked that no one knows where the influence of a great teacher really ends. The same cloth can be laid on Warren's shoulders as the Society traverses this new century. We bid him a fond farewell.

– John Wachtman, Dale Niesz, William Rhodes, William Payne, Robert Eagan, Dennis Readey, David Johnson, Delbert Day, Carol Jantzen, James McCauley, Stephen Freiman, Paul Becher, Robert Oxnard, James Houseman, Gary Messing, Kathryn Logan, John Marra, Katherine Faber, L. David Pye, John Kaniuk, Edwin Fuller, Marina Pascucci, George Wicks, and Richard Brow

To view an extended tribute to Wolf, visit www.ceramics.org/in-memoriam.

Ceramographic Exhibit & Competition entry open

Start working on those entries for the 2014 Ceramographic Exhibit & Competition, organized by ACerS Basic Science Division, to be held at MS&T14 in October. This annual exhibit promotes the use of microscopy and microanalysis as tools in the scientific investigation of ceramic materials. Visit www.ceramics.org/awards. ■

Potters Council and AACS: Where art and science connect

What do cutting-edge materials research and the investigation of ancient ceramics have in common? More than you might think, and the connections are the basis of a new ACerS membership type that allows members of Potters Council (a subsidiary of ACerS) to join the Art, Archaeology, and Conservation Science Division.

Thanks to a change made to the ACerS Constitution last October, Potters Council members who have an interest in cultural heritage and conservation science can participate as full AACS Division members by attending Division meetings, sharing ideas, exploring new developments in the field, and discovering the many connections between art and science, side-by-side with ACerS materials scientists and engineers.

Within the first 24 hours of being notified of this new opportunity, 26 Potters Council members had signed up—and more are joining every day.

"AACS is great for anyone working in or interested in cultural heritage and archaeology since by joining they will have at their fingertips the vast resources and educational experiences available through The American Ceramic Society," says AACS 2014 chair Marc Walton. "They will also be part of a dynamic and exciting community composed of chemists, materials scientists, and artists all working at the highest levels of their respective professions but united by the common goal of preserving and better understanding our material past."

ACerS members can add AACS to their membership for only $10 per year. To join, contact customer service at customerservice@ceramics.org, or 866-721-3322 (U.S.) or 240-646-7054 (outside U.S.). ■

PCSA science kits for sale

The new materials science and engineering outreach kits developed by ACerS's President's Council of Student Advisors are a great addition to your individual or organizational STEM outreach activities. Visit www.ceramics.org/pcsasciencekits. ■

Singh receives Toledo Glass and Ceramic Award

Janet Bailey (left) and Bill Walker (right) present Jay Singh with the 2014 Toledo Glass and Ceramic Award.

The ACerS Michigan/Northwest Ohio section awarded ACerS Fellow, director, and incoming president-elect Mrityunjay (Jay) Singh with its Toledo Glass and Ceramic Award at its annual award dinner in April, after which Singh provided remarks on "Human space exploration: Risks and challenges." ■

ACerS 2014 Society award winners announced

The 2014 Society award winners have been determined and the list of awardees and their affiliations is available at www.ceramics.org/awards. Biographies and photos of the 2014 winners will be posted over the next few months and featured in the September 2014 issue of the *Bulletin*. The awards will be presented October 13 at the ACerS Honors and Awards Banquet at MS&T14 in Pittsburgh, Pa. ■

ECD award, secretary nominations due July 1

The Engineering Ceramics Division invites nominations for the James I. Mueller, Bridge Building, and Global Young Investigator awards for 2015. The deadline for submitting nominations for all three awards is **July 1, 2014**. For details, visit www.ceramics.org/awards.

James I. Mueller Award

Recognizes individuals for long-term service to ECD and work in the area of engineering ceramics that has resulted in significant industrial, national, or academic impact.

Contact: Sujanto Widjaja, widjajas@corning.com.

Bridge Building Award

Recognizes individuals outside of the United States who have made outstanding contributions to engineering ceramics.

Contact: Mike Halbig, michael.c.halbig@nasa.gov.

Global Young Investigator Award

Recognizes an outstanding scientist who is conducting research in academia, in industry, or at a government-funded laboratory.

Contact: Soshu Kirihara, kirihara@jwri.osaka-u.ac.jp.

The ECD Nominating Committee invites nominations for the incoming division secretary candidate for 2014–2015. Nominations should be submitted by **August 15, 2014,** to James W. Zimmerman at zimmermaJW@corning.com, H.T. Lin at linh@ornlgov, or Sanjay Mathur at sanjay.mathur@uni-koeln.de. Visit www.ceramics.org/divisions/engineering-ceramics-division. ■

On the calendar

Southwest Section

2014 meeting, June 11–13, Omni Colonnade, San Antonio, Texas. For more information. Contact: Fred McMann, fredmcmann@comcast.net.

Gordon Research Conference

2014 Conference on Solid State Studies in Ceramics, July 20–25, at Mount Holyoke College in South Hadley, Mass. Topic: "Challenges around transport and reactivity in ceramics." Submit application by June 22 at www.grc.org. ■

JACerS recognizes authors

Congratulations to the following authors who have each published more than 30 high-impact papers in the *Journal of the American Ceramic Society* during the past 10 years (2003-2012): William G. Fahrenholtz; Lian Gao; Greg Hilmas; Hyoun-Ee Kim; Jing-Feng Li; Longtu Li; Sahn Nahm; Rishi Raj; Clive A. Randall; Jürgen Rödel; Jingyang Wang; Xiaohui Wang; and Yao Xi. ■

2014–2015 ACerS officers named

The new slate of ACerS officers has been determined. There were no contested offices and no write-in candidates, automatically making all nominees "elected." Because of a change to the ACerS constitution in October 2013, there is no need to prepare a ballot or hold an election when only one name is put forward for each office.

The new term will begin October 16, 2014, at the conclusion of MS&T.

ACerS President-elect

To serve a one-year term from October 16, 2014 to October 8, 2015

Mrityunjay (Jay) Singh

ACerS Board of Directors

To serve three-year terms from October 16, 2014 to October 2017

Michael L. Alexander
Geoff Brennecka
Hua-Tay (H.T.) Lin

Division and Class Officers

To serve a one-year term October 16, 2014 to October 8, 2015, unless otherwise noted

Art, Archaeology and Conservation Science

Chair: Glenn Gates
Vice chair: Pamela Vandiver

Secretary: Darryl Butt
Treasurer: John McCloy
Trustee: Katherine Faber

Basic Science Division

Chair: Eduardo Saiz
Chair-elect: Bryan Huey
Vice chair: Shen Dillon
Secretary: Xingbo Liu

Cements Division

Chair: Jeff Chen
Chair-elect: Tyler Ley
Secretary: Aleksandra Radlińska
Trustee: Joe Biernacki

Ceramic Education Council

President: Erica Corral
President-elect: Shen Dillon
Vice president: Yiquan Wu
Secretary: Ashley Hampton

Electronics Division

Chair: Tim Haugan
Chair-elect: Haiyan Wang
Vice chair: Geoff Brennecka
Secretary: Brady Gibbons
Secretary-Elect: Rick Ubic
Trustee: Winnie Wong-Ng

Engineering Ceramics Division

Chair: Michael C. Halbig
Chair-Elect: Soshu Kirihara
Vice chair/Treasurer:
Andrew L. Gyekenyesi
Secretary: Jingyang Wang
Trustee: Tatsuki Ohji

Glass & Optical Materials Division

Chair: Steve Feller
Chair-elect: Randy Youngman
Vice chair: Edgar Zanotto
Secretary: Pierre Lucas

National Institute of Ceramic Engineers

President: Kathy Lu
President-elect/Treasurer:
Ricardo Castro
Vice president: Chris Dosch
Secretary: Josef Matyas

Nuclear & Environmental Technology Division

Division chair: Josef Matyas
Vice-chair: Raghunath Kanakala
Secretary: Yutai Katoh
Trustee: Linda E. Jones

Refractory Ceramics Division

(term begins March 2015)

Chair: Jens Decker
Vice chair: Josh Pelletier
Secretary: Matt Lambert
Trustee: Louis J. Trostel, Jr.

Structural Clay Products Division

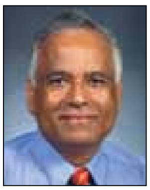
Chair: Bill Daidone
Chair-elect: John Hewitt
Secretary: John Dowdle

Whitewares & Materials Division

No nominations made ■

Meet the officers

President-elect statement



Singh

Mrityunjay (Jay) Singh, *Chief scientist, Ohio Aerospace Institute, NASA Glenn Research Center, Cleveland, Ohio*

I am honored to be nominated for president of The American Ceramic Society. A strong believer in the Society and its importance to our community, I want to help ensure that ACerS meets the needs of our members, attracts new members, nurtures new ideas, and has a strong foundation for the future.

ACerS should be the "first-stop" resource for technical information, knowledge, education and training, networking, mentoring, and professional development for its members and customers worldwide. It is critical that we promote interaction among these constituents through technical meetings, education and training, and web-based information delivery systems.

During more than two decades of Society membership and active involvement as director and past trustee and chair of the Engineering Ceramics Division, I have been fortunate to meet and work with very smart and talented people from all over the world, and an extremely hardworking and diligent staff at the headquarters. As a result, I have learned new insights to solve the various challenges that arise among the changing scope and landscape of professional societies.

In order to position ACerS as a technically viable and relevant global leader in the field of ceramics and glass science, we need to address many topics, including: capturing emerging opportunities and realigning and focusing existing capabilities; starting new volunteer-led initiatives and providing a platform for mentoring and growing of future leaders; growing membership and providing members new products and services; and growing ACerS' global presence by making strategic alliances.

As president-elect, I will promote mentoring and volunteer recognition activities along with strong interaction among our members, industry, students and young professionals, and future leaders. I envision strategic alliances with other international societies and outlets that will capitalize on our strengths, extraordinary information resources, and help in developing new products and services to serve our community.

Biography: M.S., *physical chemistry, Gorakhpur University, India; Ph.D., metallurgical engineering, Banaras Hindu University, India*

Singh is chief scientist at the Ohio Aerospace Institute, NASA Glenn Research Center in Cleveland, Ohio.

An ACerS Fellow and director, he also has served in various leadership positions in the Engineering Ceramics Division, and received the Division's James I. Mueller Award. ■

Director statements

Hua-Tay (H.T.) Lin, *Distinguished R&D staff and group leader of the Ceramic Science and Technology Group, Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.*

Lin

I feel very honored to be nominated for the Board of Directors of The American Ceramic Society. In my 25 years of membership, I have been fortunate to work together with talented colleagues from around the world and ACerS staff in organizing meetings and publications, as well as gaining insights and strategies to solve various problems in the constantly changing landscape of professional societies.

Through my service as editor-in-chief of the *International Journal of Applied Ceramic Technology* for 11 years and member and chair of the publications committee, involvement in various international ACerS conferences and meetings, and as a member of the Nominating, John Jeppson and Coble Award committees, the Panel of Fellows, and Engineering Ceramics Division (past chair), I have gleaned great insight into the importance of recognition for our members and how to work with others in making difficult decisions.

I strongly believe that ACerS must continue to be *the* resource for up-to-date scientific and technological information, education and training, networking, and professional development for its global members and customers. It is crucial that we promote interactions among various members and customers through technical conferences, topical education and training, and Internet-based information delivery systems and communications.

I will continue to strive to actively reach out to the growing membership and industrial sectors in Asia and to our industrial, academic, and government constituencies worldwide. I also will seek to establish strategic alliances with other international societies that will allow ACerS to capitalize on its strengths and abundant information resources to develop new products and services for the global ceramic community.

Biography: *B.S., physics, National Central University, Taiwan; M.S. and Ph.D., materials engineering, Auburn University*

Lin, distinguished R&D staff and group leader of the Ceramic Science and Technology Group at Oak Ridge National Laboratory, has served as a PI on numerous programs sponsored by the Department of Energy. The editor and coeditor of 27 peer-reviewed conference proceedings, author and coauthor of more than 145 peer-reviewed publications, he has sat on the international advisory boards of more than 39 international conferences and symposia and chaired or cochaired 60-plus prominent international conferences. ■

Brennecka

Geoff Brennecka, *Principal member of the Technical Staff, Sandia National Laboratories, Albuquerque, N.M.*

I am honored to be a candidate for the ACerS Board of Directors, and look forward to helping guide the future of the organization and associated community that has given me so many friends, colleagues, and opportunities.

My passion for electrical ceramics began in middle school when I first learned about superconductors, but it was my interactions with the Society via the local Student Branch (now Material Advantage) and the ACerS/NICE Student Congress while an undergraduate that introduced and welcomed me to the ACerS family.

Throughout the ensuing 17 years, many of my Society efforts have focused on promoting engagement and leadership opportunities for students and young professionals. I am particularly excited about the newly established Ceramic and Glass Industry Foundation and what it will mean for the continued vibrancy of our community and Society within the evolving materials landscape.

I am currently in the officer chain for the Electronics Division and have served the Society as chair of the Education Integration Committee, president of the National Institute of Ceramic Engineers, organizer of several technical symposia, member or chair of multiple award committees, and mentor to each after helping launch both the President's Council of Student Advisors and the Young Professionals Network.

I am proud to call ACerS my professional home, relish the opportunity to work with my colleagues on the Board, and would be interested in hearing your ideas about how ACerS can better serve all of our members.

Biography: *B.S. and M.S., ceramic engineering, University of Missouri-Rolla (now Missouri University of Science and Technology); Ph.D., materials science and engineering, University of Illinois at Urbana-Champaign*

Brennecka, the principal member of the technical staff at Sandia National Laboratories, was previously an adjunct professor at the New Mexico Institute of Mining and Technology and his alma mater (Missouri S&T).

He is the 2010 recipient of ACerS Emerging Leader Award. ■

Alexander

Michael L. Alexander, *Vice president–Research, Riverside Refractories Inc., Pell City, Ala.*

The ACerS bylaws state that the structure of the Board of Directors should be representative of the Society's diverse interests. As a manufacturer, I will bring this perspective to the Board. I am aware of the challenges that manufacturers face, from raw-material supply and cost, labor force availability, government regulations, and the need for technically trained support staff.

As a manufacturer with global interaction and as part of our long-term plan, there arises a need to develop synergy amongst academics, manufacturing, and societies. Promoting a cooperative spirit is important in order to increase participation, and move groups forward to accomplish a common goal.

In the past two decades, I have learned that getting involved is the best way to achieve the greatest good in belonging to ACerS. With the Refractory Ceramics Division, I have been participating in Materials Camp at MS&T to create an awareness of refractories engineering to young students.

I want to encourage others to get involved, and to pass along the passion to develop a career in ceramics, and hopefully, refractories.

Biography: *B.S., ceramic engineering, Alfred University*

Alexander, vice president of research at Riverside Refractories Inc., began his career there in 1988 as technical sales manager, and was promoted to his current position in 1995. He previously worked for Ferro Corp. and the Quigley Company.

Alexander has spent most of his career around blast furnaces, with a focus on trough and taphole materials. He is a member of the Refractory Ceramics Division and served as RCD chair from October 2007 to March 2009. Alexander also has served on the ACerS meetings and Jeppson Award committees, as well as on the Ceramic Leadership Summit Advisory Group and the international executive board for UNITECR. ■

Glass and ceramics make pavement markings more visible

Pavement markings are essential to road safety—they guide travellers along their journey from here to there. Many people get in their cars and drive to work every day, but seldom pay attention to one of the most important parts of the road.

Standard pavement marking paints used by the Ohio Department of Transportation, and similar departments in many other states across the United States, incorporate glass beads to achieve that easy-to-spot reflectivity, also called retroreflectivity.

ODOT incorporates glass beads into several of their pavement marking paints, with various bead specifications depending on the type of paint used. The beads are silicon dioxide glass (≥99 percent) containing some trace metals. They range in diameter from about one to two millimeters depending on the type of paint in which they are used, according to an email from Steven Loeffler of ODOT's chemical section.

The glass beads generally are incorporated into the paint, although they also can be applied on top of the paint. Incorporated beads contain a mixture of silane-coated and noncoated beads so that some sink within the paint and some float to the surface, allowing the paint to maintain reflectivity as the sunken beads are exposed with wear. Loeffler says that, depending on paint type, pavement marking paints contain 30–45 percent glass beads by weight.

Those glass beads are manufactured by Potter Industries (Malvern, Pa.), Weissker (Palestine, Texas), and Swarco Industries (Columbia, Tenn.), which mainly recycle cullet to produce the beads, says Loeffler.

ODOT's records cite $35 million in awarded contracts for pavement markings in 2013—a lot of money is spent on those humble lines. Many reports from DOTs across the country indicate the annual expenditures are so high partially because pavement mark-

Credit: S. Loeffler; ODOT

The Ohio Department of Transportation mixes glass beads with pavement paints.

ings need reapplication almost yearly, although wear does depend on the road surface, traffic volume, and local weather conditions.

Beyond the seemingly more-standard glass beads, some states have also explored ceramic additions to pavement markings.

Vermont's DOT performed an in-depth evaluation of how ceramic and glass bead mixtures stack up to solely glass beads in 2007. Although their tests showed that ceramics offer a five-fold increase in retroreflectivity, the effects do not last. And because the ceramic-incorporated paints cost substantially more, Vermont did not see value in using the paints unless, the report says, "ceramic beads can be protected from winter maintenance practices and other similar abrasion."

To that end, however, there may be a solution. Montana's DOT has just begun an experiment (and Minnesota has dabbled, as well) to assess the performance of pavement markings containing ceramic elements and glass beads incorporated into grooves carved into the road. Montana's ceramic clusters, produced by 3M and composed of a mixture of glass beads with silica, pigment, and a proprietary polymer, claim to improve durability and reflectivity. These efforts may be able to protect the more pricey ceramic-containing paints from wear, particularly from harsh scraping by snowplows. The experiment will run through 2018. ■

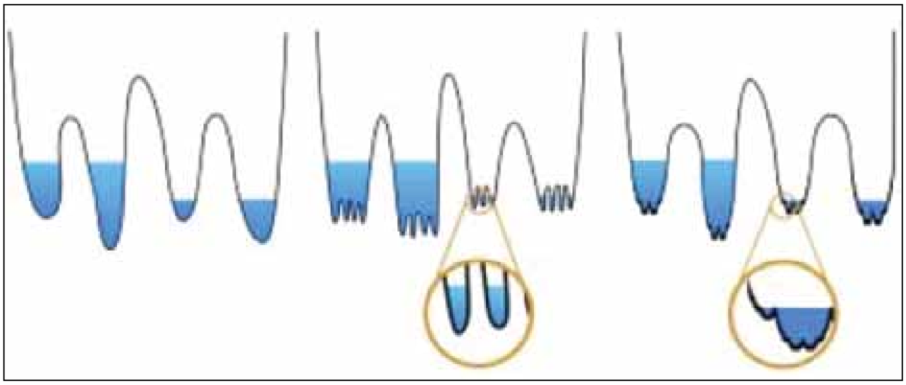
Glass energy landscapes have rough fractal basins

The thermodynamics of glass states are not described by a simple model. But research from Duke University offers insights that may be help to unlock these mysteries by providing a new energy landscape of glasses. The work shows that the landscape, which maps all possible energy positions of the glass molecules, is much rougher than previously believed.

According to a Duke press release, lead author Patrick Charbonneau says, "There have been beautiful mathematical models, but with sometimes tenuous connection to real, structural glasses. Now we have a model that's much closer to real glasses." Charbonneau, a professor of chemistry and physics at Duke, and a team of scientists used mathematical models and theory to analyze how glass molecules behave, complete with a new energy landscape and phase diagram.

The article, published in *Nature Communications*, establishes a model in which the molecules within a glass settle into fractal states within basins in the energy landscape. In the paper, the authors compare movement between the energy positions with boating on a system of lakes:

"In the liquid, all of the space can be explored. At lower water levels, each basin is a different glass. The free energy barriers hinder passing from one glass to another; the basin width allows for vibrational relaxation. The water level further determines what features of the landscape are experienced. Deep into the glass, the landscape roughness results in intrastate barriers that are associated with secondary relaxations. At very low water levels—deep into the fractal glass—lakes transform into a complex wetland with a hierarchy of small ponds. The very bottom of each of these ponds corresponds to a given realization of the force network, but the identification of the force contacts remains undetermined before the fractal regime is reached."



A new model of the energy landscape of glass shows that it contains fractal basins (far right) that are rougher than previously thought.

According to the press release, "The new description makes sense of several behaviors seen in glasses, like the property known as avalanching, which describes a random rearrangement of molecules that leads to crystallization."

The paper is "Fractal free energy landscapes in structural glasses" (DOI: 10.1038/ncomms4725). ■

Concrete abstracts describe improved concrete formulations

Researchers at the University of Wisconsin-Milwaukee have developed a durable, water-resistant, and malleable concrete formulation—called Superhydrophobic Engineered Cementitious Composite (SECC)—that they estimate could last more than 120 years.

They engineered the composite to resist cracking using two superior characteristics. First, they made the concrete superhydrophobic. "Additives in the hybrid change the concrete on a molecular level when the pavement hardens, creating a spiky surface that, although microscopic, causes the water to bead and roll off," states the university press release.

Second, the SECC gains some flexibility by mixing thin unwoven poly(vinyl alcohol) fibers into the concrete, which help prevent crack growth. By allowing small cracks to form, but not grow, the fibers help distribute stress loads through small spaces that water cannot penetrate.

"Our architecture allows the material to withstand four times the compression with 200 times the ductility of traditional concrete," says civil engineering and mechanics professor Konstantin Sobolev in the press release.

Although SECC is more expensive than standard concrete, the extended lifetime saves repair and replacement costs. The scientists speculate it will be most practical in applications that undergo continuous loading, such as bridge approach decks.

Another group of researchers from the Institute of Science and Concrete Technology at the Polytechnic University of Valencia (Spain), Jaume I University of Castellón (Spain), Imperial College London (United Kingdom), and São Paulo State University (Brazil) has been using ceramic wastes—namely, brick—to produce more environmentally friendly and waste-reducing concrete.

Using only ceramic residue, chemical activator, and water, the group produced a strong portland cement alternative. It has experimented with red brick clay, mixing it with sodium hydroxide or with sodium silicate and sodium hydroxide.

The team published those results in *Construction and Building Materials* last year. The paper is "Properties and microstructure of alkali-activated red clay brick waste" (DOI: 10.1016/j.conbuildmat.2013.01.031).

"The process to make cement in this case is very simple. First, grind the brick and mix with the activating solution. Immediately after kneading it together with the barren, the cement is ready to be placed in molds and subjected to a special hardening process at high temperature," says author María Victoria Borrachero in a press release.

The team is now experimenting with ceramic wastes, particularly bathroom ceramic or porcelain tile, and is working on replacing the activator with more sustainable replacements, too.

"We have already done tests with rice husk ash, and the results are very positive. Its use would yield an even more sustainable and cheaper final product, because it would be composed almost entirely of reused waste," says Borrachero. ■

Students at the University of Wisconsin-Milwaukee install a test slab of their Superhydrophobic Engineered Cementitious Composite.

Flexible glass-fabric thermoelectric generator converts body heat to electric energy


Credit: KAIST

A new flexible thermoelectric generator uses body heat to power wearable electronic devices.

A team from the Korea Advanced Institute of Science and Technology (KAIST) has developed an "extremely light and flexible" glass-fabric-based thermoelectric (TE) generator that moves with the human body and harnesses heat while doing so.

According to a KAIST press release, the technique employed by the team, headed by electrical engineering professor Byung Jin Cho, "minimizes thermal energy loss but maximizes power output."

Unlike previous TE generators that used polymers, Cho's concept has a self-sustaining structure sans the usual ceramic and alumina substrates that siphon off thermal energy. By employing a technique similar to screenprinting, the researchers printed "synthesized liquidlike pastes of *n*-type (Bi_2Te_3) and *p*-type (Sb_2Te_3) TE materials" onto a glass fabric.

"For our case, the glass fabric itself serves as the upper and lower substrates of a TE generator, keeping the inorganic TE materials in between," says Cho. "This is quite a revolutionary approach to design a generator. In so doing, we were able to significantly reduce the weight of our generator (~0.13 g/cm^2), which is an essential element for wearable electronics."

When worn as part of a wristband device, KAIST's small generator—which measures just 10 cm by 10 cm—can produce ~40 mW of electricity based on skin temperature.

"Our technology presents an easy and simple way of fabricating an extremely flexible, light, and high-performance TE generator. We expect that this technology will find further applications in scale-up systems such as automobiles, factories, aircrafts, and vessels where we see abundant thermal energy being wasted," adds Cho.

Their findings, "Wearable thermoelectric generator fabricated on glass fabric" (DOI: 10.1039/C4EE00242C), are published in *Energy & Environmental Science*. ■

Advanced ceramic materials may provide hydrogen storage for fuel cells

New research on advanced ceramics from the University of California, San Diego may offer a solution to the need for more effective solutions for hydrogen fuel storage.

Most fuel cells use hydrogen as fuel. But hydrogen has low energy content by volume, so a substantial volume of hydrogen is needed for a portable fuel cell. Hydrogen also diffuses easily through many materials and is the culprit responsible for hydrogen embrittlement of common engineering alloys, including steels, aluminum alloys, and other nonferrous alloys.

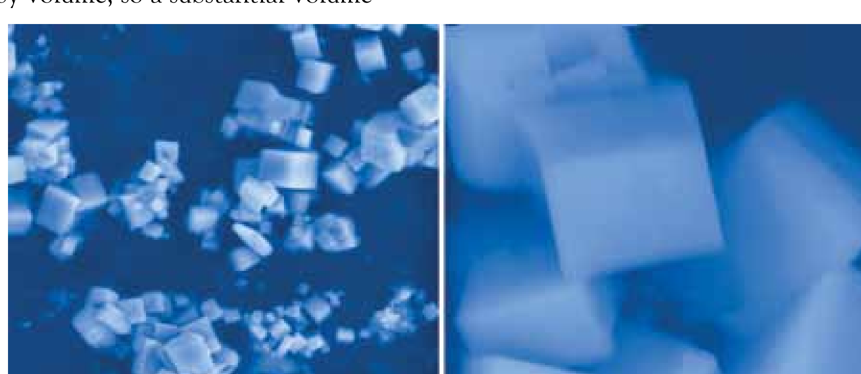
According to the United States Department of Energy's Office of Energy Efficiency & Renewable Energy, an automotive hydrogen fuel cell using current tank storage capabilities would require a hydrogen tank bigger than a standard car trunk to travel just 300 miles. These limitations make current technologies impractical for long-term solutions.

In addition to storage as compressed gas or as liquid in a tank, hydrogen also can be bound to advanced materials for storage. ACerS member Olivia Graeve has helped develop a new ceramic advanced material for just that purpose.

Graeve and a team of scientists synthesized compounds of calcium hexaboride, and strontium and barium hexaboride. They demonstrated that combustion synthesis is a simple, low-cost production technique for making the new compounds.

For combustion, they used a 750°F box furnace to heat boron with metal nitrates and organic fuels, which, when ignited, generates heat for the reaction. "It's a very simple, nice process," Graeve says in a UCSD press release.

The team used the process to synthesize cages of boron molecules contain-


Credit: UCSD

Scanning electron micrograph of hexaboride structures, at 5 μm (left) and 500 nm (right), that may provide a viable hydrogen storage solution.

ing crystals of the compounds, which can be swapped for hydrogen for an effective storage solution.

According to the press release, "The work is at the proof of concept stage and is part of a $1.2 million project funded by the National Science Foundation, a collaboration between UCSD, Alfred University in upstate New York, and the University of Nevada, Reno." ■

Coin-sized battery can power devices for a decade

A new battery prototype developed by researchers at Oak Ridge National Laboratory may help bid farewell to charging cables and USBs, thanks to a "new and unconventional battery chemistry" that can sustain a single charge for up to 10 years.

According to an ORNL press release, their findings, published in the *Journal of the American Chemical Society*, "challenged a long-held assumption that a battery's three main components—the positive cathode, negative anode, and ion-conducting electrolyte—can play only one role in the device."

The electrolyte in the new design pulls "double-duty"—serving as an ion conductor and cathode supplement—and is further enabled by ORNL's solid electrolyte, which boosts the battery's capacity and service life.

"This bifunctional electrolyte revolutionizes the concept of conventional batteries and opens a new avenue for the design of batteries with unprecedented energy density," says ORNL's Chengdu Liang in the release.

The ORNL team was able to demonstrate the concept in what is considered to be "one of the best single-use batteries because of its high energy density, stability, and long shelf life." The solid lithium thiophosphate (Li_3PS_4, LPS) electrolyte incorporated into a lithium–carbon fluoride battery resulted in a battery with an increased capacity of 26 percent.

"As the battery discharges, it generates a lithium fluoride salt that further catalyzes the electrochemical activity of the electrolyte," Liang said. "This relationship converts the electrolyte—conventionally an inactive component in capacity—to an active one."

The release notes that, depending on how the battery is engineered or used, the capacity improvement may equal years or decades of additional life. And given its small size, the battery would be particularly useful in devices where easy or desirable battery replacement or recharging is neither easy nor desirable (artificial cardiac pacemakers, radiofrequency identification devices, and remote keyless systems and sensors).

The paper is "Pushing the theoretical limit of Li-CF_x batteries: A tale of bifunctional electrolyte" (DOI: 10.1021/ja5026358). ■

advances in nanomaterials

Transparent ceramics produce stronger armor windows

The United States Naval Research Laboratory has developed a superior ceramic nanocrystalline spinel, highly transparent and strong, with ambitions to improve armor windows for military vehicles.

Using an enhanced high-pressure-sintering (EHPS) technique, NRL scientists increased spinel hardness by 50 percent over what is currently used in military armor windows.

"The EHPS approach uses high pressures (up to 6 GPa) to retard bulk diffusion rates, break powder agglomerates, and reposition nanoparticles very close to each other to help eliminate porosity in the sintered ceramic," states an NRL press release. "NRL researchers then can exploit the increased surface potential of nanoparticles for surface-energy-driven densification without coarsening."

Credit: U.S. Navy; General Dynamics

New and improved armor windows could find application in deckhouse windows in the new class of U.S. Navy destroyers, like the *USS Elmo Zumwalt*.

The new technique did not decrease density or fracture resistance, as has been previously observed because of residual porosity in nanocrystalline spinel. The spinel also retained high transparency, a must for optical equipment on military vehicles.

Although previous work has shown that the Hall–Petch relationship between strength and hardness falls apart for some ceramic materials sized less than 130 nm, the NRL research shows that grain sizes down to 28 nm maintain strength and hardness.

The paper, published in *Acta Materialia*, is "An extended hardness limit in bulk nanoceramics" (DOI: 10.1016/j.actamat.2014.01.030). ■

It's tough to be strong: Advances in bioinspired structural ceramic-based materials

By Michael M. Porter and Joanna McKittrick

Adapting biological processes to synthesize ceramic materials yields microstructures remarkably similar to natural materials with mechanical properties at least as good.

Biological materials science focuses on the structure–function–property–processing paradigm, a common theme in materials science. However, synthesis and growth of natural materials is quite different from that of synthetic materials. Almost all biological systems follow six fundamental design principles.[1–3]

- ***Water***. Although essential for biological systems, synthetic materials typically avoid water.
- ***Cyclic, green process***. The life and decomposition cycles of biological systems occur at about standard temperature and pressure—300 K and 1 atm. Ceramic and metal processing involves high pressures and temperatures.
- ***Local resources***. Biological systems use available organic (soft) and inorganic (hard) building blocks, made of carbon, nitrogen, oxygen, hydrogen, calcium, phosphorus, and sulfur, resulting in a vast array of hybrid systems. Synthetic materials require acquisition of resources.
- ***Self-assembly***. A "bottom-up" process builds structural hierarchy across nanolength to macrolength scales. Engineers build structures from the top down.
- ***Fitting form to function***. Biological systems grow, self-repair, and evolve as needed. Function dictates the organism's shape, not vice versa. This allows identification of the properties that have been optimized for a certain function.

Natural materials, such as nacre (top left), bone (top right), and narwhal tusk (bottom), suggest structures and processing approaches for new synthetic materials.

- ***Hierarchical structures***. Efficiency and multifunctionality are organized over a range of scale levels (nanoscale to macroscale). Structure confers distinct and translatable properties from one level to the next and may be optimized for more than one function. For example, bone supports the body, stores ions, and produces marrow.

The idea behind bioinspired materials is to adapt the apparent effortlessness of biological systems to produce complex, multifunctional materials to make synthetic materials. Biological systems adapt to changing ambient conditions, continually refining and adjusting shape through chemical, cellular, and mechanical signaling. This requires a systems approach with the expertise of engineers as well as life scientists to develop materials with complex, hierarchical structures.

Two model structural materials—abalone nacre and bone—have exceptional mechanical properties designed for body support, as well as impact resistance (nacre) or blood flow and joint movement (bone). These properties result from highly ordered, structural alignment in multiple directions across several length scales. Bioinspired design seeks to mimic the nanostructural and microstructural features of natural materials to fabricate high-performance, multifunctional materials.

This review focuses on the development of cellular solids, tough ceramics, and hybrid composites inspired by bone and abalone nacre. These materials may be useful for a variety of applications ranging from load-bearing bone implants and lightweight structural composites to separation filters and catalyst supports.

Learning from bone and nacre

Bone and nacre are natural ceramic-based materials, containing organic matter, with extraordinary mechanical properties given their lightweight composition from locally available elements—calcium, phosphorous, carbon, oxygen, and hydrogen. They are stiff, strong, and tough—mechanical properties usually considered mutually exclusive[4]. The Ashby plot in Figure 1 compares the stiffness and toughness of bone and

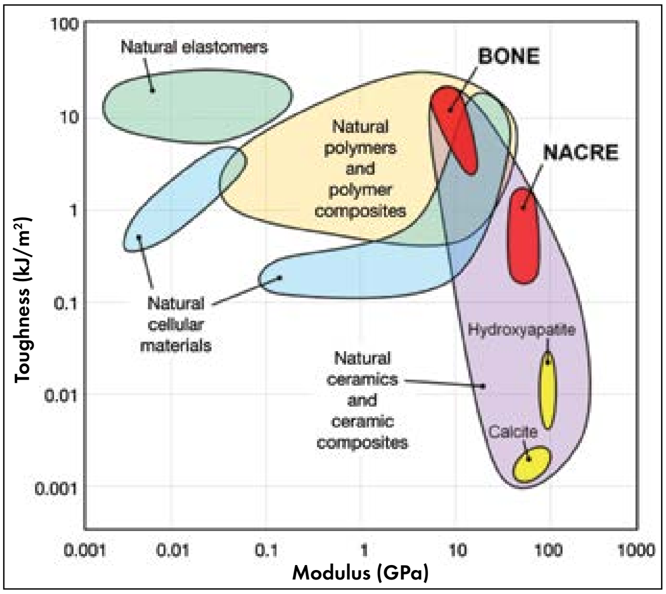


Figure 1. Ashby plot comparing toughness and modulus. Bone and nacre are tough materials despite their low density.[5]

nacre with several other natural materials.[5] The plot shows these materials are surprisingly tough, considering their low density, high strength, and stiffness. These properties result from a hybrid, hierarchical design built by self-assembly from the molecular level up, resulting in anisotropic, hierarchical architectures.

Bone is about 65 wt% hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) embedded in an organic matrix of type I collagen. Two main forms exist: cortical (or compact) and cancellous (or trabecular). At the microstructural level, osteons compose cortical bone and consist of dense (5–10 percent porosity), concentrically oriented lamellar sheets surrounding small vascular channels and lacuna spaces ~10–50 µm in diameter. Lamellar sheets, 3–7 µm thick, have a "twisted plywood" architecture with fibers oriented at various angles.[6] Each fiber is composed of several mineralized collagen fibrils ~150 nm in diameter and 5–10 µm long. Each fibril consists of tropocollagen proteins and periodically spaced hydroxyapatite minerals with a characteristic periodicity of 67 nm. Figure 2(a) shows how the microstructure of cortical bone consists of layers (or lamellae) of aligned fibers that are oriented in successive rotations of ~30°.[7–9]

Cancellous bone, on the other hand, has a cellular structure (75–85 percent porosity) of trabecular struts surrounding large pores 100–500 µm wide. Although morphologically similar to cortical bone at the submicrometer level, cancellous bone contains flat lamellar sheets, rather than cylindrical osteons. Mechanical loading mediates the growth of both bone types (i.e., bone grows in response to stress), which yields varying mechanical properties depending on location, age, sex, and physiology.

Compared with bone, nacre exhibits superior mechanical properties, primarily because it lacks porosity. Nacre is ~95 wt% crystalline aragonite ($CaCO_3$) platelets embedded in an organic matrix of chitin and proteins.[10] The inorganic-platelets and organic-matrix structure resembles a "brick-and-mortar" structure, with stacked aragonite "bricks" ~0.5 µm thick by 8–10 µm wide "mortared" by organic layers 20–50 nm thick (Figure 2(b)).[10] Mineral bridges 25–55 nm in diameter connect the platelets.[11] This organization of successive layers is a consequence of the nucleation and growth of aragonite crystals, leading to the formation of tiles aligned about the *c*-axis.[12] The platelets have a characteristic surface roughness caused by asperities ~50 nm wide and 30 nm high.[13] However, the platelets are not discrete tiles dispersed in a continuous organic matrix. Similar to bone, the organic and inorganic constituents are continuous, interpenetrating phases that grow concurrently.[12] Additional growth bands of organic layers ~20 µm thick, corresponding to periods of growth interruption, separate mesolayers ~300 µm wide.[12]

Several mechanisms across various length scales contribute to the excellent strength and toughness of bone and nacre. In cortical bone, extrinsic toughening occurs behind the crack tip at length scales >1 µm,[4,14] including crack deflection and twisting around osteons, uncracked-ligament bridging, collagen-fibril bridging, and constrained microcracking. Intrinsic toughening mechanisms in bone occur ahead of the crack tip at length scales <1 µm[4,14] and include hidden length sacrificial bonding, microcracking, fibrillar sliding, and molecular uncoiling. In nacre, the brick-and-mortar structure deflects crack propagation, leading to failure via delamination, tile pullout, or tile fracture.[15,16] As stress accumulates, the organic matrix dissipates energy, acting as a tough, viscoelastic glue.[13,17] The mineral bridges resist intertile shearing (tile pullout) and tensile failure (tile fracture), acting as reinforcing struts to give nacre its strength and stiffness. The surface asperities prevent excessive sliding between adjacent platelets, further protecting nacre from fracture by delamination or tile pullout.[13,17] Other toughening mechanisms in nacre include platelet interlocks (waviness) as well as rotation, sliding, and organic bridging between nanograins.[15,16]

On a more fundamental level, the microstructural anisotropy found in cortical bone and nacre provides these materials their high mechanical properties (Table 1). The high, yet anisotropic, compressive strengths relate directly to the

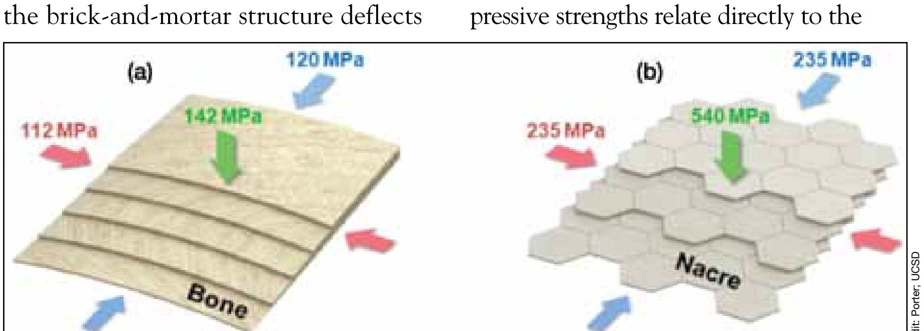


Figure 2. Compressive strengths reflect microstructural anisotropies. (a) Cortical bone has a "twisted plywood" lamellar microstructure. (b) Abalone nacre microstructure follows a "brick-and-mortar" morphology.[8,9]

orientation, alignment, and uniformity of the layered microstructures in bone and nacre (Figure 2).

Engineering bioinspired materials

The natural world provides many examples of cellular structures: trabecular bone, plant stems (e.g., wood), cuttlefish bones, corals, sponges, sea urchin spines, horseshoe crab exoskeletons, feathers, porcupine quills, and bird beak interiors. An interconnected network of struts and plates form the faces of the cell walls in cellular solids. The cells tend to align for maximum mechanical efficiency. Therefore, many cellular solids develop anisotropically as they respond to load orientations. For example, the compressive strength of a trabecular femur head is much higher in the direction of maximum load than in the transverse directions.[18] Research shows that the elastic modulus and strength of an open cell porous material are strong functions of density.[18] Cellular solids are of interest in the biomedical field as scaffolds for bony (osseointegration) or cellular ingrowth. Therefore, mechanical integrity is important.

Emulating the intricate organization of the molecular, nano-, micro-, and macrostructures found in nature may be the key to developing higher performance synthetic materials. Using advanced synthetic materials, such as alumina, zirconia, polymethylmethacrylate (PMMA), and epoxy, rather than nature's relatively weak constituents, such as hydroxyapatite, aragonite ($CaCO_3$), collagen, and chitin, it becomes possible to engineer bioinspired materials with hybrid, hierarchical architectures that outperform their biological counterparts. For example, according to the rule of mixtures, the global mechanical properties (X) of a hybrid composite material depend on the properties (X_i) and fractions (ϕ_i) of the individual parts (i):

$$X=\sum \phi_i Xi.$$

However, most biological materials do not follow the rule of mixtures and exhibit higher than expected mechanical properties.[19] For instance, two common modes of failure in platelet-reinforced composites are platelet fracture (brittle failure) and platelet pullout (ductile failure).[20] Both bone and nacre have optimized interfacial adhesion between the stiff inorganic platelets and ductile organic matrix, such that ductile failure occurs just before brittle failure. This adaptation, combined with structural hierarchy, provides bone and nacre extremely high flaw tolerance and fracture toughness[20,21]—better than most synthetic materials.

Bioinspired ceramic-based materials

Drawing inspiration from hard biological materials, many research groups in the past decade have engineered extremely strong, stiff, and tough ceramic-based materials by various nature-inspired processes to produce thin films, porous scaffolds, or bulk composites. Table 1 compares the properties of bone and nacre with selected bioinspired materials, which were selected because they mimic, or draw inspiration from, one or more of the nanostructural or microstructural features that provide bone and nacre their extraordinary mechanical properties.

Thin films

Inspired by nacre, thin film bottom-up fabrication techniques exploit chemical, physical, electrical, or mechanical forces to drive assembly of synthetic building blocks. Methods include layer-by-layer self-assembly, enzyme- and peptide-mediated synthesis, biomineralization, centrifugation, evaporation or vacuum filtration, solution casting, chemical bath or electrophoretic deposition, ion beam sputtering, and morphosynthesis. Most of these syntheses occur near room temperature and in an aqueous environment.

Organic constituents control and regulate size, morphology, orientation, texture, and organization of mineral crystals in biological systems. Langmuir–Blodgett films, reverse micelles, liquid crystals, and self-assembled monolayers (SAMs) have mimicked successfully chemistries of biological proteins that promote nucleation of inorganic crystals. The SAM approach has been most effective for nucleating crystals with controlled orientation and polymorph. SAM molecules have the general formula $RSiX_3$, where R is an organic functional group and X is typically an alkoxide or halide. One end of the SAM molecule attaches to the substrate and the other functional end promotes nucleation of inorganic crystals. Tailoring the functional group allows for deposition of continuous or pattered ceramic thin films.[22] Crystalline single-metal oxides can be deposited at temperatures <100°C, making this an attractive method for further development. However, crystalline multiconstituent metal oxides are difficult to produce using this method.

Enzymes catalyze chemical reactions such as hydrolysis, reduction–oxidation, and elimination of specific functional groups in living matter. They also can be used for site selective oxide, hydroxide, carbonate, and phosphate deposition at low temperatures. For example, the enzyme silicatein-α promotes biosynthesis of SiO_2 in sponges and diatoms and can be isolated and cloned from glass sponges. It also can catalyze nucleation of ceramic films, particles, and nanowires of TiO_2, ZrO_2, SnO_2, and $CaTiO_3$.[23] Peptides, proteins, polyamides, and amino acids—acting as a catalyst or template to control the morphology, polymorph, and orientation—induce nucleation of TiO_2. Catalyzed hydrolysis of phosphate esters by alkaline phosphatase produces patterned thin films of hydroxyapatite on collagen substrates.[24] The above methods produce a thin layer, prompting researchers to pursue other methods to attempt to duplicate the layered microstructure to macrostructure of bone and nacre films.

A significant early attempt to develop nacre-like films deposited sequential layers of montmorillonite (MTM) clay platelets and poly(diallydimethylammonium chloride) polyelectrolytes using a surfactant-mediated self-assembly approach.[25] The films had ultimate tensile strengths up to 109 MPa and Young's moduli up to 13 GPa, similar to the properties of nacre and cortical bone, respectively. A similar layer-by-layer approach fabricated MTM/poly(vinyl alcohol) nanocomposites closely resembling nacre's brick-and-mortar microstructure and formed optically transparent multilayer composites with an unsurpassed stiffness compared with similar nanocomposite films.[26] A sequence of Al_2O_3/chitosan films produced with a bottom-up spin-coating technique produced more ductility and flaw tolerance than prior works, with observed ultimate tensile strains up to 21 percent.[21] An alternative approach used ecofriendly vacuum filtration, similar to papermaking, to fabricate high-strength and high-stiffness MTM/PVA composites with varying optical transparencies, as well as gas barrier and fire-resistant properties.[27] (See Table 1 for property data.)

Thin films have outstanding mechanical properties and unique functionalities, but they are, in fact, thin—less than 1 mm. Although they are impractical for many structural applications, films can be used as hard coatings, displays, sensors, and optical equipment.

Porous scaffolds

Porous scaffolds that mimic bone are ideal for tissue engineering applications, such as load-bearing bone implants that promote tissue ingrowth or other applications requiring high porosity and reasonable mechanical strength. Researchers report many different methods to emulate the trabecular architecture of cancellous bone including direct foaming[28] and polymer sponge replication.[29] However, mimicking cancellous bone is not ideal for load-bearing applications because of its high porosity, near isotropic structure, and poor mechanical properties. Instead, highly anisotropic scaffolds with unidirectionally aligned pores have shown great potential for load-bearing applications.[30,31] For example, researchers made porous scaffolds by dipping polyurethane foams repeatedly into ZrO_2 or hydroxyapatite slurries, drying, and then burning out the foam. The ZrO_2 scaffold achieved high compressive strength (35 MPa), whereas the strength of the hydroxyapatite scaffold was ~4 MPa.[29] Another interesting method uses the unidirectional porosity of wood as a template to fabricate anisotropic hydroxyapatite scaffolds, following a series of chemical treatments.[32] The method achieved optimal pore-size distribution (100–300 μm) required for the migration and proliferation of osteoblasts (bone synthesizing cells). However, the mechanical properties were poor compared with other unidirectionally aligned porous scaffolds (Table 1).

The advent of additive manufacturing enables fabrication of a variety of porous scaffolds with designer architectures. This technique has gained tremendous attention in the medical industry as an efficient means to customize scaffolds for biomedical implants. Direct ink–write assembly has been used to form bioactive glass scaffolds with regular pore spacing of 500 μm and cell walls 100 μm thick.[31] High compressive strength and modulus were reached (136 MPa and 2 MPa) with a porosity of 60 percent, which is within the range of cancellous bone (Table 1). The scaffolds promoted nucleation of hydroxyapatite after soaking in simulated body fluid for two weeks, indicating that the material is ideal for osseointegration. However, the mechanical properties of 3D-printed parts depend on the formation and resolution of the layers (highest resolutions are ~10 μm). Ultimately, the interface between layers is the weakest point of the structure and may lead to catastrophic crack initiation, propagation, and subsequent failure. Because of its high cost, high energy consumption, extended fabrication times, limited material availability, restricted workspace, and poor material properties, 3D printing is not the most economical means to develop high-performance scaffolds.

Until additive manufacturing technologies improve, other methods to fabricate high-strength, porous scaffolds are preferable. Currently, one of the best methods for forming aligned porous scaffolds is freeze casting from a (usually) aqueous-based slurry. Adding surfactants and binders improves particle dispersion and as-cast strength. With this method, the slurry is poured into a mold set on a freezing surface. The freezing surface is controlled, such that a thermal gradient leads to the directional solidification of the slurry. Constitutional supercooling sets up instabilities on the liquid–solid interface as the freezing front advances in the slurry. These perturbations (instabilities) crystallize into ice dendrites that shoot out into the liquid. The ice crystals expel particles between dendrites, thereby forming a lamellar structure. Finally, the frozen slurry is freeze-dried and sintered to form a structurally robust scaffold. Processing variables include volume fraction of solid powder, cooling rate, and liquid properties, such as viscosity. A polymer or metal can be infiltrated into these scaffolds to form lamellar composites.

Bulk composites

Because of their large macrostructures and scalability, bulk ceramic-based composites are, quite possibly, the most versatile and high performance bioin-

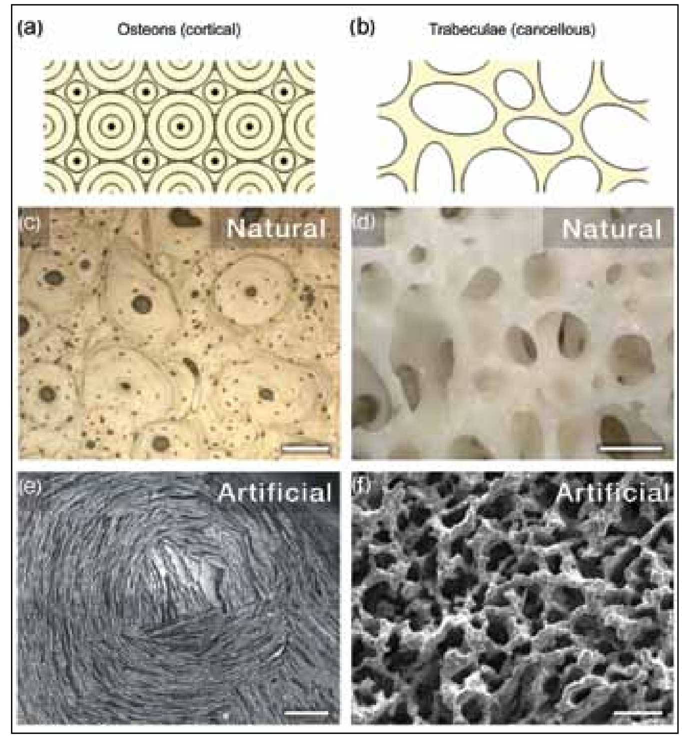
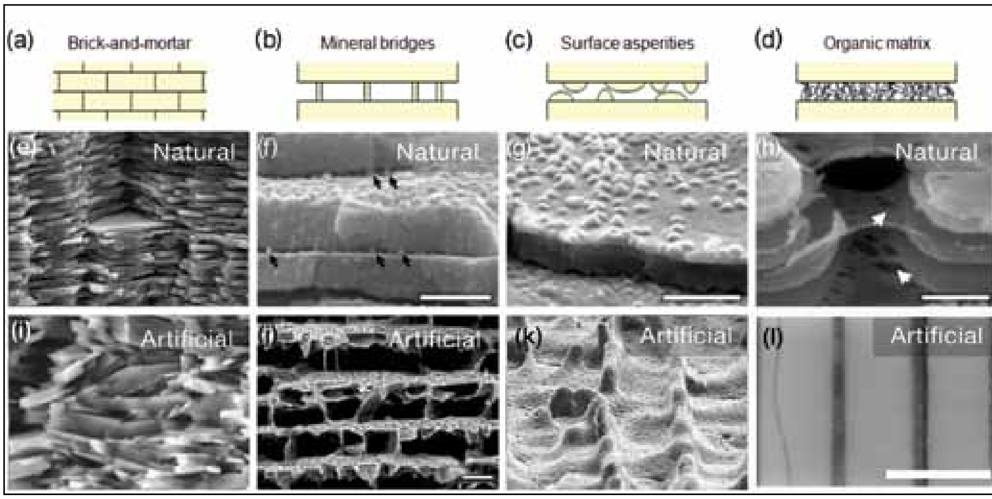


Figure 3. Natural and artificial osteonal and trabecular bone structures. (a-b) Schematic osteonal and trabecular bone architectures; (c) natural osteons in cortical bone; (d) natural trabecular struts in cancellous bone; (e) aligned freeze cast microstructure mimics osteonal bone architecture.[38] (f) artificial scaffold mimics trabecular bone architecture. Scale bars: (c) 100 μm; (d) 500 μm; (e) 500 μm; (f) 25 μm.



Credit: (e) Wikipedia. (f, g, h, l) Porter; UCSD. (i) Deville and Bouville; LSFC. (j) Deville; Wiley. (k) Ritchie, LBL

Figure 4. Nacre microstructure types and schematics show different architectures. The middle row shows natural nacre microstructures. The bottom row shows artificial nacre microstructures. (a, e, i) brick-and-mortar; (b, f, j) mineral bridges; (c, g, k) surface asperities; and (d, h, l) organic matrix. Scale bars: (f) 500 nm; (g) 500 nm; (h) 1 μm; (j) 20 μm; (l) 1 μm.

spired materials. Promising techniques for making composites with enhanced mechanical properties include infiltrating ceramic scaffolds with polymers or metals and aligning ceramic microstructures with external forces. Variations of polymer or metal infiltration techniques into ceramic scaffolds include melt immersion, solvent evaporation, in-situ polymerization, particle centrifugation, and chemical vapor deposition.

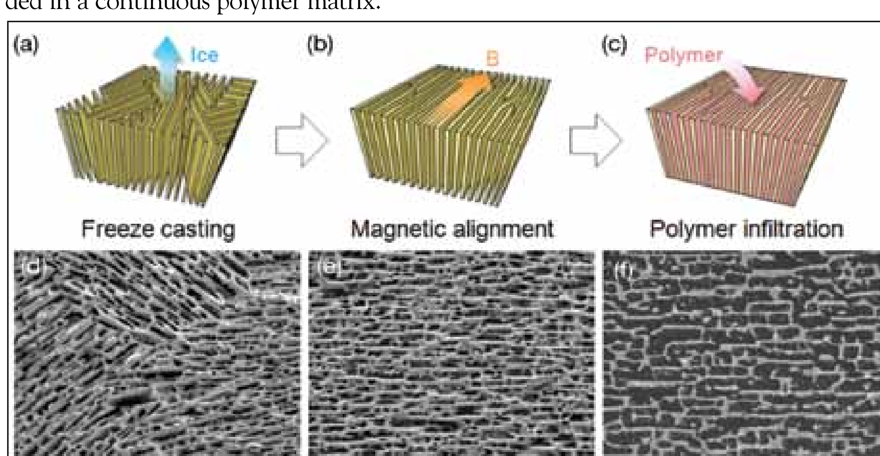
Table 1 compares flexural strength and fracture toughness for crack initiation of several high-toughness Al_2O_3-based composites. Pressure sintering and infiltrating with PMMA were used to form freeze-cast Al_2O_3 scaffold composites that resemble the brick-and-mortar structure of nacre with features such as mineral bridges extending from one lamella to another and surface roughness (asperities) on the ceramic phase.[33] Infiltrating molten Al-Si alloys into freeze-cast Al_2O_3 scaffolds increased flexural strength (up to 328 MPa) and toughness (up to 8.3 MPa·m$^{1/2}$).[34] However, polymeric or metallic phases in the Al_2O_3-based composites may be undesirable for certain applications, such as high-temperature enivronments. Therefore, freeze casting and densification with pressurized spark plasma sintering was used to develop $Al_2O_3/SiO_2/CaO$ composites. These composites exhibited the highest combination of strength (470 MPa) and toughness (6.2 MPa·m$^{1/2}$) yet to be reported for a fully ceramic material.[35] Capitalizing on freeze casting to control growth of ice crystals provides these materials microstructural alignment and outstanding combinations of strength and toughness. Similar to bone and nacre, these composites employ several fracture resistance mechanisms.

Yet another technique used low magnetic fields to align Al_2O_3 platelets in polymer matrices.[36,37] The aligned microstructures increased flexural modulus, strength, and fracture toughness significantly compared with identical composites without magnetic alignment.[37] However, these composites are limited by the low achievable volume fraction and discontinuity of ceramics platelets embedded in a continuous polymer matrix.

Inspirations from biological structures

Figure 3 shows two artificial materials inspired by bone that mimic the microstructures of osteons (Figures 3(a) and (c)) and trabeculae (Figures 3(b) and (d)). Figure 3(e) shows an artificial osteon-like architecture produced by freeze casting in a mold with a patterned bottom surface to promote alignment of the ceramic particles.[38] The artificial trabecular scaffold shown in Figure 3f was also fabricated by freeze casting using a high viscosity water-based freezing vehicle.

Figure 4 juxtaposes schematics and micrographs of natural abalone nacre (Figures 4(a)–(h)) with several bioinspired materials that mimic the microstructural features of nacre (Figures 4(i)–(l)). In the first column of Figure 4 (parts (a), (e), and (i)), the strong and tough ceramics developed by Bouville et al.[35] are compared with natural nacre. These ceramics had extremely high mechanical properties (Table 1) and mimicked almost all microstructural features of nacre on equivalent length scales, including the brick-and-mortar architecture, platelets, mineral bridges, and surface asperities. The next three columns of Figure 4 compare natural and artificial mineral bridges (Figure 4(b), (f), (j)), surface asperities (Figure 4(c),



Credit: Porter; UCSD

Figure 5. Microstructure alignment with applied magnetic field during freeze casting. (a) Freeze cast, (b) magnetic alignment, and (c) polymer infiltration to produce ceramic-based porous scaffolds and hybrid composites. (d, e) ZrO_2 scaffolds and (f) ZrO_2-epoxy composites fabricated by the respective techniques. All scale bars are 100 μm.

Table I. Structural and mechanical properties of bone and nacre compared to selected bioinspired thin films, porous scaffolds, and bulk composites.

		Material composition	Total porosity (%)	Young's modulus (GPa)	Ultimate strength* (MPa)	Ultimate strain (%)	Fracture toughness ($MPa\cdot m^{1/2}$)
Natural Materials	Bone (cancellous) [45–47]	HA/collagen	> 30	0.001-0.5	0.2-116^{C}	0.3-3	---
	Bone (cortical) [45,48,49]	HA/collagen	< 30	6-28	10-172^{T}	0.9-2	2-11
					106-283^{C}		
					157-238^{B}		
	Abalone nacre [17,50,51]	$CaCO_3$/chitin	---	10-147	3-170^{T}	0.2-2	3-9
					235-540^{C}		
					177-197^{B}		
Thin films^{a}	Podsiadla et al.[26]	MTM/PVA	---	106	400^{T}	0.33	---
	Bonderer et al.[21]	Al_2O_3/chitosan	---	9.6	315^{T}	21	---
	Walther et al.[27]	MTM/PVA	---	45.6	248^{T}	0.9	---
Porous Scaffolds^{b}	Almirall et al.[28]	HA	51-66	---	1.2-4.3^{C}	---	---
	Kim et al.[29]	ZrO_2	74-92	---	1.6-35^{C}	---	---
	Tampieri et al.[32]	HA	70-85	---	2.5-4^{C}	---	---
	Fu et al.[31]	Glass	60-80	---	40-136^{C}	---	---
	Deville et al.[30]	HA	47-64	---	16-145^{C}	---	---
Bulk Composites^{c}	Estili et al.[44]	Al_2O_3/CNT	---	---	404^{B}	---	4.62
	Munch et al.[33]	Al_2O_3/PMMA	---	---	210^{B}	---	5.1
	Launey et al.[34]	Al_2O_3/Al/Si	---	---	328^{B}	---	8.3
	Bouville et al.[35]	$Al_2O_3/SiO_2/CaO$	---	290	470^{B}	---	6.2
	Libanori et al.[37]	Al_2O_3/Epoxy	---	16.6	180^{B}	---	2.56

^{a}Highest reported values for Young's modulus, ultimate tensile strength, and ultimate strain to failure; ^{b}Range of values for the total porosity and ultimate compressive strength; ^{c}Highest reported values for Young's modulus (flexure), ultimate bend strength, and fracture toughness for crack initiation; *Legend: C: compressive; T: tensile; B: bend.

(g), (k)), and organic matrices (Figure 4(d), (h), (l)).[33,39,40] The artificial mineral bridges and surface asperities were fabricated by freeze casting,[33] and the artificial nacre was produced by sequential deposition of ZrN and PMMA.[41] Although all features occur on different length scales in the natural and artificial materials (on the order of ~50 nm for the natural and 500–5000 nm for the artificial), their mechanical functions are the same. The mineral bridges and surface asperities add strength and stiffness, resistance to tensile fracture, and intertile shearing. The organic matrix adds toughness and dissipates energy that accumulates between adjacent lamellae under stress.

The micrographs in Figures 3 and 4 show different processing techniques used to synthesize bioinspired materials that mimic structural features of bone and abalone nacre, leading to outstanding mechanical properties that either match or surpass those of their natural counterparts. Ceramic microstructures resulting from freeze casting can be further manipulated by applying an external magnetic or electric field. Figure 5 provides an overview of magnetic-field-assisted freeze casting, and Figure 6 shows an example of a rotating magnetic field used to make helix-reinforced structures inspired by narwhal tusks. Freeze casting efficiently fabricates porous ceramic scaffolds with unidirectionally aligned pores, perpendicular to the direction of ice growth (Figure 5(a)). Applying magnetic fields during freeze casting imposes a second order of microstructural alignment, parallel to the magnetic field direction and perpendicular to the ice growth direction (Figure 5(b)). Finally, infiltrating the bialigned porous scaffolds with a second phase, such as a polymer, yields bulk hybrid composite materials with designer architectures and enhanced mechanical properties (Figure 5(c)). With a static magnetic field, the resulting scaffolds have more than two times the strength in the transverse (magnetic field) direction, without significantly affecting the strength in the longitudinal (ice growth) direction.[42] With a rotating magnetic field, the polymer-infiltrated composites have enhanced torsional properties over those produced without the field.[43]

Summary

Structural bioinspired materials development is an active area of investigation and has led to ceramic thin films, porous scaffolds, and composites with unique and superior mechanical properties. Thin films are applied as hard coatings, and the most successful films are synthesized with self assembled monolayers of organic molecules that act as catalysts and templates for the nucleation and growth of the inorganic phase. Porous scaffolds have application as biomedical implants, especially in bone repair and replacement. Because living bone tissue adapts its structure to maximize strength and stiffness in the load bearing direction, synthetic scaffolds must have some degree of anisotropy. The most successful scaffolds are formed from particle infused sacrificial templates, 3D printing, and freeze casting. Fabrication of composites that mimic the structure of nacre is achieved mainly by freeze casting and subsequent polymer or metal infiltration of the aligned porous scaffolds, which leads to extremely strong and tough laminates, with fracture toughness values that exceed any monolithic ceramic. New developments involve field-assisted freeze casting, which can strengthen the scaffold in multiple directions.

It is not enough to simply examine a biological material and attempt to duplicate its structure. Rather, functional aspects of the constituents and the microstructural details that result in strength and toughness must be understood. Successful duplication of the important features results in new materials with exceptional properties.

Acknowledgements

We thank Marc Meyers at University of California, San Diego, and Antoni Tomsia at the Lawrence Berkeley

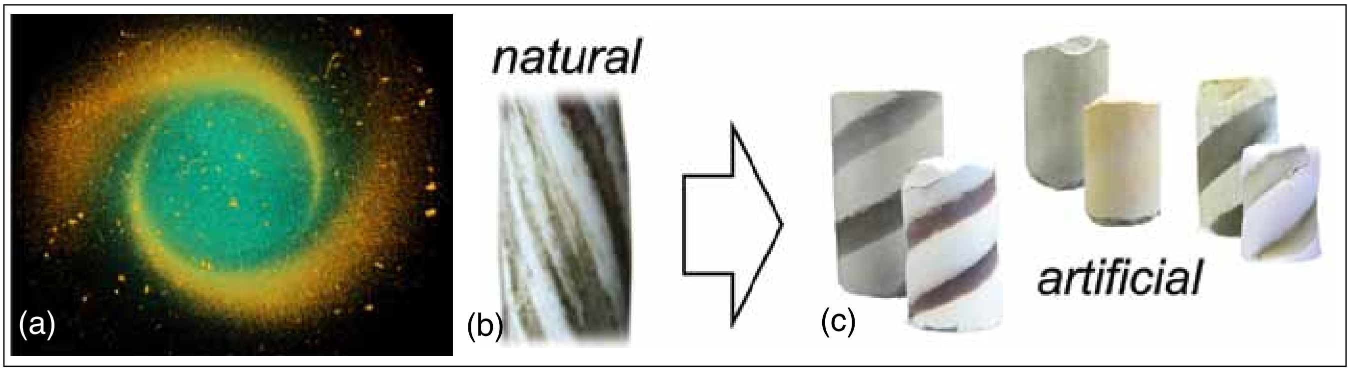


Figure 6. The helical structure of a narwhal tusk was replicated by applying a rotating magnetic field during freeze casting. (a) Micro-computed tomographic image of the top view of a sintered TiO_2 scaffold; (b) section of a narwhal tusk; (c) artificial scaffolds formed by magnetic field-assisted freeze casting.

National Laboratory for helpful discussions. The National Science Foundation Ceramics Program Grant No. 1006931, and a UCS, Academic Senate Bridge Grant (2013–2014) funded this work.

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PCSA delegation at their 2013 annual meeting in Montreal, Canada, with then-president Richard Brow.

Chair's update on PCSA activities and welcome to the student *ACerS Bulletin* issue

By Bradley Schultz
PCSA chair

The June/July issue of the *ACerS Bulletin* gives the President's Council of Student Advisors (PCSA) an opportunity to showcase students in the materials science and engineering community. You will read articles about what students learn inside and outside of the classroom, experiences on study abroad and internships, as well as personal research. As chair, it gives me great privilege to directly connect PCSA with the ACerS Education Integration Committee (EIC).

The EIC is made up of subcommittees composed of university faculty, industry representatives, and students. The subcommittees are Student Activities Committee (SAC), National Institute of Ceramic Engineers (NICE), Young Professionals Network (YPN), Ceramic Education Council (CEC), Keramos, and PCSA.

To support the founding idea and goal of EIC, PCSA works to spread interest in and excitement for ceramics and glass education. PCSA has hosted friendly competitions, including the "Ceramics-in-Writing" competition in this issue, and has more educational events on deck. PCSA is developing the idea of a 3D Stein Design competition, which would allow winners to get a ceramic replica of their designs. In addition, ACerS and PCSA continue to market materials science demo and lab kits to 7^{th}–12^{th} grade science teachers. Kits can be ordered for outreach purposes, or sponsors can donate kits to local schools of their choosing. PCSA is working on future ceramic- and glass-focused demo kits. Visit www.ceramics.org/pcsasciencekits for ordering details.

PCSA is collaborating with EIC subcommittees on interesting events for students, especially at MS&T14 in Pittsburgh, Pa., which also is the location for the PCSA's annual business meeting. In addition, PCSA is working with CEC and YPN on networking events where students can rub elbows with young professionals and industry professionals.

If any of the above events sound intriguing, or if you have an idea of how to better address the future of ceramics education and student participation, I encourage you to get involved or to contact me at bmschul@clemson.edu. Help us further the education of the next generation of scientists and engineers!

Bradley Schultz is a Ph.D. candidate in materials science and engineering at Clemson University and a tech analyst at the Clemson University Research Foundation Tech Transfer Office. He is current chair of PCSA. ■

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Alfred University was recommended by most of the faculty at my previous Institute in India. I am glad I selected this university as it gives me the unique opportunity of one-on-one interaction with faculty members who are at the forefront of their fields and also serve as platforms for interdisciplinary learning and collaborations across many fields of science and engineering. Additionally, the friendly atmosphere and close knit community values of Alfred helped me adapt and feel at home.

Dimple Pradhan, PhD Materials Science and Engineering candidate

Alfred University offers an exceptional hands-on experience, where students have the opportunity to work closely with the faculty in a variety of cutting-edge facilities. The relatively small size of the Alfred community promotes a very conversational atmosphere between the graduate student body and our faculty and staff- an ideal environment for personal scientific growth. As a self-motivated individual, this has permitted me to pursue a variety of scientific questions effectively.

Peter Metz, PhD Ceramic Engineering candidate

Alfred University

individuals inspired

KAZUO INAMORI SCHOOL OF ENGINEERING

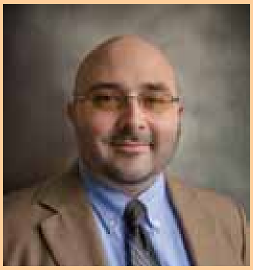
Ceramics, Glass & Biomaterials For Energy, Environment & Health Care

"My research is developing the optimization techniques on multi-objective engineering problems. Theoretically, I am developing game theory models and numerical algorithms to solve multi-objective optimization problems. In particular, the engineering problems and energy issues including energy policy, renewable energy and energy management are considered as problems with multi-objective functions and the optimum solution will be developed. The renewable energy is another topic that I am working on."

Dr. Ehsan Ghotbi, Assistant Professor of Mechanical Engineering

"My group is developing techniques for quantitatively characterizing microstructure evolution during materials processing. Our goal is to quantitatively link microstructure to properties, enabling improvements in materials performance. We are using electron backscatter diffraction to investigate the crystallographic relationships between parent and product phases in solid state phase transformations, as well as studying how 3D relationships in microstructures can be estimated from observations on 2D sections."

Dr. Eric J. Payton, Assistant Professor of Materials Science and Engineering



"My group is especially interested in applications of high-temperature solid-state thermochemistry toward synthesis of metals, ceramics, and their composites (e.g., via gas-solid interactions or via reaction-induced phase transformations). We prioritize the advancement of processing science with the purpose of achieving methodological control over morphological features of interest in order to establish the limits of our understanding of composition-structure-property relationships."

Dr. David W. Lipke, Assistant Professor of Materials Science and Engineering

CACT
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Center for Advanced Ceramic Technology (CACT)
At Alfred University's Center for Advanced Ceramic Technology (CACT), the primary mission is to help NYS companies retain and create jobs, increase their productivity, and boost their profitability through research in advanced ceramic materials and processing. The CACT offers a wide range of research options to help businesses grow and thrive.

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What is not to love about Congressional Visits Day?

By Tricia L. Freshour

Congressional Visits Day 2014 students and faculty in Washington, D.C.

Congressional Visits Day (CVD), organized each year by the Material Advantage Student Program, took place April 7–8, 2014, in Washington, D.C. CVD is a unique opportunity for materials science and engineering students to advocate for long-term funding for science, engineering, and technology through meetings with Congressional decision makers. Thirty-five students and faculty from 11 universities attended this year's event.

The CVD experience began with an opening reception on Monday, April 7, that included talks to help prepare students for their visits:

- "The 2015 Budget: Science, Technology, and Innovation for Opportunity and Growth," by Kei Koizumi, assistant director for R&D, White House Office of Science and Technology Policy;
- "Effective Communication with Hill Staff," by Deborah Koolbeck; and
- "Energy Policy and Life on the Hill," by Megan Brewster, 2013–2014 MRS/TMS/AAAS Congressional fellow, Senate Committee on Energy and Natural Resources.

David Bahr from Purdue University and Iver Anderson from Ames National Laboratory and Iowa State University led an active session during which students collaborated to arrange visits with their Representatives and Senators on Tuesday, April 8.

Students shared their experiences at a concluding event at a local club. Students remarked:

- "With this being my first CVD, I didn't really know what to expect, but with the support and advice, it went great! I thought the three speakers we had on Monday provided us with great information and great tips for talking with the Congress people and their staff. I felt like the people we talked to already seemed to have support for our cause so this made talking easier, and we could thank them and show our appreciation. I thought the trip was a great experience and will mostly likely be participating in the future."—David Beam, Washington State University
- "This Material Advantage CVD provided a wonderful opportunity to visit our nation's Capitol and speak with the offices of our Senators and Representatives. It was so exciting to share my experiences with them and hopefully remind them why science education and funding is so important. This was also a great way to meet students from other universities who are interested in science policy. I will definitely be back for next year's event!"—Kelly Kranjc, Washington University in St. Louis
- "I had a great experience during CVD. I look forward to participating in it again and bringing a bigger contingent from Georgia Tech! I think the visits went well, and I definitely have a better appreciation for how busy it is in the Congressional offices. I think it was a good idea to preface our visits with realistic expectations about the possibility of quick visits, visits in the hallway, and people checking their phones. I was able to meet with the legislative staff of both Georgia Senators and two Georgia Representatives. All of the people I met with were receptive to my thoughts and proactively asked me to keep in touch if I wanted to reach out to the office again."—Brian Doyle, Georgia Institute of Technology
- "I talked to officials for both Indiana Senators and both were very responsive to our stories about how governmental support of research has affected us. I love the way you set up the program: A little bit of learning about the way the system works on Monday night, then having some time to sight-see in between talking to Senator and Representative offices. I can't wait to hopefully be involved next year!"—Jasmine Duvall, Purdue University
- "I truly enjoyed this experience and will treasure it forever. It was a privilege to participate in CVD and I have already encouraged several of my colleagues here at UCSB to consider attending next year."—Kaylan Wessels, University of California, Santa Barbara

The partner societies in the Material Advantage Student Program are The American Ceramic Society, Association for Iron & Steel Technology, ASM International, and The Minerals, Metals, and Materials Society. Material Advantage would like to extend a special thank you to David Bahr of Purdue University and Iver Anderson of Ames National Laboratory and Iowa State University for their continued support and dedication to CVD.

Tricia Freshour is the ACerS liaison to the Material Advantage Student Program. ■

Internship—A pathway to employment

By Valerie Wiesner

I was fortunate to be selected to participate in the Pathways Intern Employment Program at NASA Glenn Research Center in Cleveland, Ohio, during my last year of graduate school at Purdue University. The Pathways Program gave me the opportunity to work at a NASA research center as a co-op student and explore a career in the federal government prior to graduation.

Throughout my four-month co-op at NASA Glenn, I worked directly with researchers and technologists on a variety of projects focusing on the development of ceramic materials for aerospace applications. The experience gave me the chance to learn from leading experts in the field and the opportunity to work on new and challenging topics in a collaborative research environment. This allowed me to grow and develop as an independent researcher and apply what I had learned throughout my Ph.D. to tackle current engineering problems. Additionally, I was able to access an extensive collection of knowledge and expertise within NASA by consulting with experienced scientists about my doctoral research.

Outside of research, I was able to pursue another interest of mine while at NASA Glenn—sharing science and engineering with youth. I participated in outreach events in the greater Cleveland community with the NASA Glenn Education Office. By working with STEM education specialists, I learned about large-scale educational programming and discovered new STEM activities, which I shared with others upon returning to Purdue.

I also had the opportunity to tour NASA Glenn and Plum Brook Station (Sandusky, Ohio) to see unique facilities ranging from the Zero Gravity Research Facility to the Reverberant Acoustic Test Facility. Furthermore, through panel discussions, presentations, and even a teleconference with the astronaut selection committee, I acquired greater insight into NASA, its missions, and career opportunities within the agency.

Overall, in addition to the valuable research and professional experience, the Pathways Program gave me a better understanding of what a career at NASA was like. The dedicated team, exciting research, and great working environment that I encountered during my co-op inspired me to pursue full-time employment within the agency, which ultimately led to my current position as a materials research engineer at NASA Glenn. I feel very lucky to have landed my dream job so early in my career. The Pathways Program provides students and young researchers like me the unique opportunity to start their careers in a government agency.

Credit: V. Wiesner

Valerie Wiesner having fun at a NASA outreach event in Cleveland, Ohio.

Valerie Wiesner is a materials research engineer in the Materials and Structures Division at NASA Glenn Research Center in Cleveland, Ohio. She is a recent graduate of Purdue University, where she earned her Ph.D. in materials engineering with a focus on structural ceramics. ■

Lessons from a study abroad

By Omar Cedillos Barraza

Barraza

Arriving in a completely different country with just a piece of luggage on each hand is not an easy task.

I travelled from Mexico to study at Imperial College London for my Ph.D. From the start, I realized that I was working in an international and multicultural environment—in 2014, students from 129 nationalities registered at Imperial College London. Being abroad is about getting out of your comfort zone, learning new experiences, learning to live in a different way, and getting the best from each culture.

Being at an international university has the advantage of great relations and networking links with other universities, research centers, and industries. I am researching ultra-high-temperature ceramics in a research group formed by various universities, national labs, and industries, a collaboration that encourages engagement and integration in research. Multidisciplinary research groups are valuable because they teach individuals how to solve problems in different ways. The high mobility of people at international universities also promotes the exchange of knowledge and ideas, enhancing quality and innovation in research.

Teaching opportunities, in undergraduate courses and outreach activities, also have enriched my experience abroad. Because the teaching system is different from what I knew, I have learned how to adapt to various working environments and teaching systems. In addition, outreach activities have shown me that I can make a difference to children by building early interest in science through exciting and interesting materials.

London is one of the most culturally diverse cities in the world, with more than 300 languages spoken and something different to learn, visit, and even eat daily. Studying abroad has been one of the great experiences in my life.

Omar Cedillos Barraza is a Ph.D. candidate in the Centre for Advanced Structural Ceramics at Imperial College London. He has served on the PCSA Recruiting and Communications Committees for the past two years. ■

GREEN in Iceland—Learning outside of a classroom

By Peter Robinson


Robinson

A common shortcoming in today's engineering programs is the inability to travel abroad or learn in a new environment. The rigid curriculum forces predetermined classes to be taken during particular semesters, and international studies require an additional year of commitment and tuition. Many universities are trying to tackle this problem by loosening the reins on class scheduling. However, this still does not allow everyone to sculpt a perfect schedule that allows studying abroad.

But the Global Renewable Energy Education Network (GREEN) program acknowledges universities' common constraint and works to make it possible for everyone to study and experience new destinations during a traditional education. As the name implies, the program aims to promote renewable energy studies to students in new environments by submersing them in the culture of another country.

The program understands the importance of internships and traditional studies, and it believes that studying abroad can be valuable to students through hands-on involvement in a program lasting less than two weeks. This curriculum aims to provide a unique experience by combining intensive education, adventure excursions, culture emersion, and a service learning project.

The program's organizers began as students and have since built this innovative idea to a fully fledged program with more than 1,000 alumni. Program selection began with Costa Rica, which boasts 93 percent electricity generation from renewable energy, and then migrated to Iceland, where that number reaches 100 percent. By teaming up with the Iceland School of Energy at Reykjavik University and South Iceland Adventure, the program provides credit-worthy classes inside and outside a classroom.


Credit: W. Gregory

Spring 2014 GREEN program participants hike Iceland's Sólheimajökull glacier.

I recently had the opportunity to travel to Iceland over spring break to attend the GREEN program. Touring geothermal energy plants, large-scale hydropower plants, and micro hydropower plants really showed me how I, as a materials science engineer, could improve the processes and materials used in these industries. The GREEN program gave me the opportunity to discover what I am truly interested in—the materials used for improving efficiency and minimizing environmental impacts of the energy industry.

For instance, turbine blades in a geothermal plant have a short lifespan. But, that life can be increased by depositing a coating for erosion or corrosion resistance onto the blades or producing the blades out of a ceramic composite material altogether. During my trip, I also learned that Iceland is testing onshore wind turbines, but wind power is difficult to capture on the island because of the high wind speeds. Several material fixes could be implemented into wind turbine technology to optimize for higher wind speeds and increase overall energy output.

This experience was incredible—it allowed me to interact with people from various cultures and form lasting relationships with like-minded individuals from across the world. The GREEN Program captures more than a traditional study abroad program in less than two weeks, making it a once-in-a-lifetime experience for an engineering student like myself.

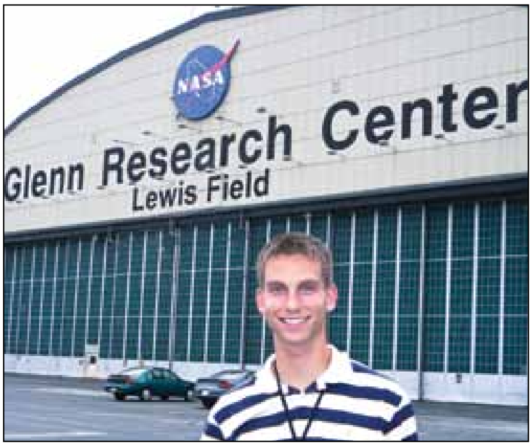
Peter Robinson is an undergraduate student in materials science and engineering at Pennsylvania State University. He currently serves as the PCSA Outreach chair, vice president of the Penn State chapter of Material Advantage, and herald of the Penn State chapter of Keramos. Robinson would like to thank his father for introducing him to ceramics at a young age. ■

Flexible ceramics and fracture-resistant friendships

By Derek Miller

My three summer internships at NASA Glenn Research Center in Cleveland, Ohio, were absolutely irreplaceable. What had the biggest effect on me was the pervasive "we can do that" attitude at NASA, no matter how impossible something may seem. That calm and calculated approach relies on principles of science and engineering to break an overwhelming mission into small, solvable problems.

My last two summers at NASA Glenn were spent working on a new type of flexible thermal insulation for space vehicles. Aluminosilicate aerogels are one of the best thermal insulators. They are stable above 1,000°C, but incredibly fragile. By making a composite of these aerogels and



Credit: D. Miller

Derek Miller outside of NASA Glenn Research Center.

ceramic fiber felts, I was able to fabricate a very low density, low thermal conductivity, and high-temperature flexible insulation. This insulation was intended as a primary heat-resistant layer in a multilayer stack containing several other specialized flexible materials. The stack forms an "inflatable decelerator" that deploys from a canister before atmospheric reentry to protect the vehicle from intense heat.

Because I was the first student to work on this project, my mentor relied on me to guide the project forward, a process opposite to every other job I had ever held. My confidence and abilities grew quickly as a result of these responsibilities. I even presented our new research ideas to the project leader of the Venus Lander Flagship Mission. I never imagined that I could be a part of such a grand challenge, and it kept me coming back for more.

On a personal level, I met great friends at NASA Glenn. We toured NASA labs together, explored the city together, and often got into heated academic arguments that were entirely too scientific for the local bar. But we all had the same appreciation for really big problems and the same desire to be a part of solving small pieces of those problems. I came away from these experiences with new lifelong friends, possible future colleagues, and an optimistic look at some of the people that will be driving the future of technological advancements.

I believe in space technology research because it is the heart and soul of inspiration in every classroom vying for the attention of young, wandering minds, as it did mine. Information is now gained so easily and freely that many young people are reluctant to tackle hard problems or unanswerable questions. I see the bright lights of our new phones drowning out the stars, because we tend to look down rather than up. But phones do not inspire young minds—rockets do. My time at NASA Glenn changed the way I perceive the world around me. The hardest problems are those most worth doing, which is an attitude I will carry with me for the rest of my life.

Derek Miller is a third-year Ph.D. candidate in materials science and engineering at Ohio State University. He holds a NASA Space Technology research fellowship and was the 2013 chair of PCSA. ■

Japan research experience—A study in science and attitude

By Jesse Angle

I had always wanted to visit Japan—ride the famed bullet trains, eat real Japanese sushi, see the centuries-old architecture, experience the hustle and bustle of Tokyo, and, above all, get a glimpse of the legendary Japanese work ethic. So when the opportunity presented itself, I spent nine of the most amazing weeks of my life in Japan.

So how did I get there? During graduate school at the University of California, Irvine, my advisor Martha Mecartney encouraged me to look into the National Science Foundation East Asian Summer Pacific Institute (NSF EASPI) program. The program has numerous requirements, but the most important one is to find a host researcher who is willing to supervise your work. Keeping this in mind, I approached Yuichi Ikuhara after hearing his talk at a Gordon Research Conference and asked him to host me through NSF EASPI. He agreed, I applied, and, to my delight, I was selected.

Ikuhara's research lab is part of the Institute for Engineering Innovation at the University of Tokyo. The institute is a world leader in crystal interface analysis via high-resolution and scanning transmission electron microscopy. My summer research project focused on determining the slip-system in mullite through in-situ transmission electron microscopy indentation, a technique pioneered by Ikuhara's group. Eita Tochigi and Shin Kondo supervised me and defined my experience with their time, patience, and kindness.

Adapting to the demanding lab work schedule was my biggest challenge. Until that summer, I had always thought of myself as a hard worker. Students, postdocs, and professors alike worked long and demanding hours, seven days a week, even occasionally sleeping in their office or at their desk. But never did I interpret this ethic in a negative light. These researchers did not work hard solely to meet a deadline or because of pressure from a superior—a clear sense of dedication and self-achievement overwhelming drove their actions. This attitude toward research had a bigger impact on my views about how science should be approached than the outcome of my project.

In addition to the time spent working in Ikuhara's lab, I was invited to spend the day with Teruyasu Mizoguchi, a professor at the Institute of Industrial Science at the University of Tokyo. During my visit, Mizoguchi's

Credit: J. Angle

Jesse Angle at the entrance to the Narita Temple Complex on his first day in Japan.

students presented their research projects to me to practice speaking English in a relaxed setting. The eagerness of students to practice their English with a native speaker was a theme I encountered often during my time in Japan. It gave me a new perspective on the difficulties and challenges researchers face in a world where the language of science is English.

Opportunities like spending the summer in Japan, living and working in Tokyo, and being exposed to world-class research do not happen very often in life. The experience I gained by working with Japanese professors and graduate students will forever shape how I approach research. I look forward to my second visit.

Jesse Angle recently graduated from the University of California at Irvine, with a Ph.D. in materials science and engineering. He has been active in ACerS for five years and is currently a PCSA delegate.

Genchi genbutsu—Go and see for yourself

By Dalton Devine

Devine

No one really knows what they want to do with their life, at least initially. Students are told to follow their passion, but that is generic advice.

Instead, students must answer one question: How can you discover what you enjoy doing enough to make a career out of it? My advice is simple yet effective—go and see for yourself.

If not planning on going to graduate school, materials science and engineering undergraduates have two large decisions upon graduation:

- Do I want to work at a small company or a large company?
- Do I want to be focused on R&D or processing?

These answers lead to four potential work options:

- Research within a large company;
- Research within a small company;
- Processing within a large company; and
- Processing within a small company.

Although this is a vast oversimplification, this list does represent the basic options. In the field of ceramic engineering, students are uniquely lucky to be a hot commodity. From my experience, it is common to go into a career fair and get more than 10 interviews that result in more than five offers for internships and co-ops. These offers are opportunities for students to explore industry jobs.

My first experience working with ceramics was during a co-op at Ceralink (Troy, N.Y.) during my sophomore year. Ceralink is a small—fewer than 15 employees—R&D company specializing in advanced ceramics. This experience provided a decent understanding of the research side of ceramics, although it left me wondering what the processing side of ceramics entailed.

During my junior year, I realized that I was in a unique position to work for a large processing company to try out the other side of the coin. This idea manifested itself in a summer internship at Alcoa Technical Center (Pittsburgh, Pa.), which houses 800–1,000 employees.

Because there are pros and cons to every scenario, my views are entirely subjective. I loved working at both companies because they provided me opportunities to learn and think in different ways. I was able to work with and learn from some of the smartest people I have ever known.

Small company vs. large company

At Ceralink, the close proximity of labs and offices provided ample access to bosses. At Alcoa, however, I shared an office with just a couple of colleagues and had what I consider normal access to my boss. She was available for meetings, but overall there was far less direct oversight.

Another aspect of working in a small company is that you coordinate with a few other people on a project. For me, trying a new idea or testing a new setup at Ceralink was as simple as offering a proposal with a specific rationale. However, even the best run companies introduce confusion as size increases. As an intern coordinating with several people at Alcoa, I noticed that everyone has similar but incongruent expectations as to how work should be done. These differences can lead to frustration between people because of how passionate they are about their work.

Large companies also often have more resources than smaller companies. At Alcoa, I had access to a variety of characterization techniques on site. However, at Ceralink, most characterization was outsourced.

R&D vs. processing

At a research company, the scope of work is very different from a processing company. The questions asked address fundamental baseline problems: "Can we do it?" and "How do we do it?" Research also typically involves several smaller projects and, therefore, several different types of materials, which can be very exciting.

Processing companies know they can create the product, so the question shifts from "How do we do it?" to "How do we go from making 50 of these to 10,000?" Processing inherently seeks optimization, so developing process controls are key. As my former boss would say, "We want to be able to pull a lever (i.e., change a process parameter) and know that '*x*' is going to change in our final products." Another difference is that processing companies generally make just one or two materials, so employees get to know those materials very closely.

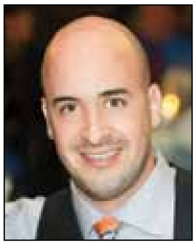
The decision about what direction to go should ultimately come down to how a person operates. Do you want direct contact with your boss or would you rather check-in daily? Do you like coordinating with several people or a few? Do you want to work with a variety of materials or get to understand one material very well? Finally, I urge you to test your assumptions—do you truly know what you like or do not like unless you have tried it?

Dalton Devine is an undergraduate in ceramic engineering at the Kazuo Inamori School of Engineering at Alfred University. He was chair of the 2013 PCSA Finance Committee. ■

Students weigh in on education

By Liangfa Hu and Bradley Richards

Hu



Richards

Improving and evolving the curricula of ceramics and materials science and engineering programs is challenging. Such improvement is invaluable in developing students' academic careers and in preparing students for the workforce. One way to improve is to know the students' perspectives. However, there are few metrics available for what students themselves believe is needed. To meet the needs for student metrics, The American Ceramic Society's President's Council of Student Advisors conducted a survey of graduate and undergraduate students from numerous schools to identify how current students view their education. The analysis gives us a fresh and modern perspective of the facets of United States education in ceramics and materials fields that have been successful and of areas where curricula are lacking.

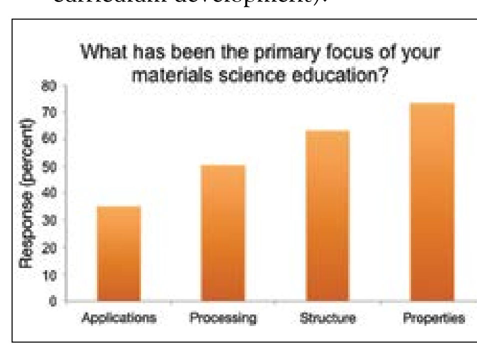
The PCSA developed a 34 multiple-choice question survey to determine the students' backgrounds and survey their opinions on academic curricula and workforce preparation. We distributed the survey online, sending an invitation email to current and former PCSA delegates, ACerS Young Professionals Network, ACerS student newsletter subscribers, and Materials Advantage chapter presidents and advisors with the request to forward the invitation along to other students. The survey was, therefore, neither entirely scientific nor explicitly representative, but we feel that the 193 responses representing 42 universities are informative and provide, at the very least, food for thought. Based on the size of the distribution list and estimates of further forwarding, we estimate that the response rate was roughly 15–30 percent of total recipients. All responses received were used in this survey report.

Whereas most responses were from students currently enrolled in a materials-related program, a few responses were from recent graduates (within seven years of their last-earned degree) currently working full-time. Specifically, 60 percent of responses were from undergraduate students, 36 percent from graduate students, and 4 percent from full-time employees. Students and employees were associated with 42 universities or colleges at the time they responded to the survey—36 in the U.S. and the rest in the United Kingdom, Finland, Brazil, Canada, Japan, and Germany.

The responses have led us to make several assertions about current education policies. First, students believe their education in terms of the uses of materials science has been broad (Figure 1). Breadth is desirable because it prepares students for a variety of careers and improves their ability to work with others of various backgrounds.

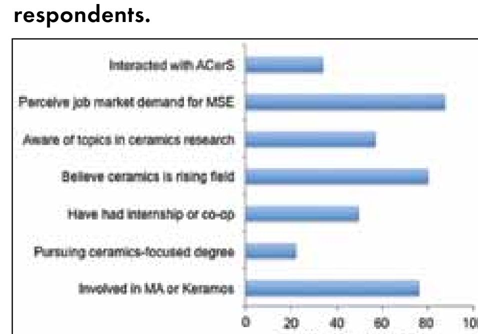
Second, their education and experiences have led students to believe that there is considerable demand in the job market and that ceramics is a rising field, even though most are not pursuing a strictly ceramics-focused degree. Many have interaction with materials- and ceramics-related programs, and about half have had an internship or co-op (Figure 2). This implies an awareness of ceramics and considerable perceived value in the field, although focused education in ceramics may be lacking, particularly for undergraduates.

Third, education has placed a focus on public interaction and technical skills: More than half of respondents had given four or more presentations in class or at conferences (less than 11 percent had given none), and almost all respondents felt comfortable making complex analytical calculations. (We believe that, regardless of intended career path, all students should be comfortable presenting by the time they have completed their education, so further emphasis should be put on presentations for future curriculum development).



Credit: L. Hu

Figure 1. Educational focus of student respondents.



Credit: L. Hu

Figure 2. Students' involvement with and opinions of the ceramics field.

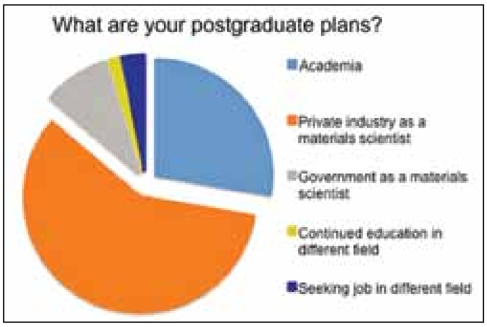


Figure 3. Students' postgraduate plans.

Fourth, about 40 percent of undergraduates surveyed intend to continue their education in graduate school. Undergraduate education and career anticipations appear to be considerable drivers for graduate education. Fifty-five percent of graduate students considered their alma mater for graduate school, and a large majority (86 percent) went to graduate school to prepare for intended careers. In addition, less than 40 percent of graduate respondents were involved in Material Advantage or Keramos as an undergraduate. Colleges can clearly do more to foster extracurricular activity in the materials fields.

Fifth, roughly a quarter of respondents plan to remain involved in academia after graduation (Figure 3). Presuming many of these are graduate students, a very large percentage of undergraduate students intend to work in private industry after graduation. Less than five percent of total respondents intend to either continue education or seek a job in a different field. These numbers are reassuring, indicating that the materials programs have a very high career retention rate.

Although 200 responses is a usable number, there are many more students in these fields. Our numbers are likely biased toward the most active and involved students, because this was not a random survey. However, our analyses bear weight. Students have a positive outlook on their field and the job market, and many hold internships or co-ops before graduation. There is strong interest in pursuing careers in private industry, but more than a quarter of respondents were interested in remaining in academia. Many students were comfortable using numerous scientific instruments and a strong majority had written research papers. These are all encouraging responses.

On the other hand, less than a quarter of respondents felt they had a strong knowledge of ceramics. Coming from a body of students with interest in the ceramic field, this number is alarming. Education in a field that most of our respondents believe is rising in importance is clearly underprioritized. Although current curricula appear to be doing many things well, there remain areas that require development.

Recommended actions

- Expand focused education in ceramics, especially for undergraduates.
- Develop more extracurricular activities in the materials fields.

Acknowledgements

The authors thank Geoff Brennecka and Tricia Freshour for valuable discussions.

About the authors

Liangfa Hu is a fourth-year Ph.D. student in materials science and engineering at Texas A&M University (College Station, Texas), president of the Material Advantage chapter at Texas A&M, and chair of the 2013 PCSA Communications Committee.

Bradley Richards is a fourth-year Ph.D. student in materials science and engineering at the University of Virginia (Charlottesville, Va.), a NASA Pathways intern at the Glenn Research Center, president of the Materials Science Graduate Student Board at Virginia, and chair of the 2014 PCSA Communications Committee. ■

REGISTER NOW!

5th Advances in Cement-based Materials:

Characterization, Processing, Modeling and Sensing

July 9-11, 2014 | Tennessee Technological University | Cookeville, Tenn.

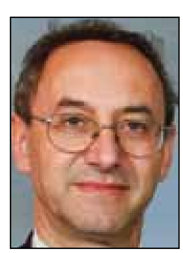
The 5th Advances in Cement-based Materials, hosted July 9–11, takes place at Tennessee Technological University in Cookeville, Tenn. Cements 2014 is organized by the Cements Division of ACerS and the Center for Advanced Cement-based Materials.

Technical Program

Authors will present oral and poster presentations on:

– **Cement chemistry and nanomaterials/microstructure**
– **Advances in material characterization techniques**
– **Alternative cementitious materials**
– **Durability and lifecycle modeling**
– **Advances in computational material science and chemo-mechanical modeling of cement-based materials**
– **Smart materials and sensors**
– **Rheology and advances in SCC**

Cements 2014 Della Roy Lecture



Gartner

Ellis Gartner, scientific director (chemistry), Lafarge Central Research Laboratory, France

Title: *40 years a cement scientist – Can this be sustainable?*

www.ceramics.org/cements2014

Registration

	On or before June 10, 2014	After June 10, 2014
ACerS or ACBM member	$230	$380
ACerS Member with membership renewal	$350	$500
Nonmember	$350	$500
ACerS Emeritus/Senior/Associate Member	$185	$335
Student member	$55	$130
Student nonmember	$95	$170

REGISTER NOW!

Innovations in Biomedical Materials: Focus on Ceramics

July 30 – August 1, 2014 | Hilton Columbus Downtown, Columbus, Ohio, USA

The meeting emphasizes collaboration between R&D, medical practitioners, and biomedical materials manufacturers/marketers to better develop emerging technologies into marketable products. Bioceramics 2014 will maximize networking activity by offering a common technical track for all attendees. The meeting consists of four plenary talks, eight panel discussions, and a poster session along with a commercial sponsor display.

FOR RAPID-FIRE PRESENTATIONS

Participate in the inaugural rapid-fire presentation session on Wednesday, July 30, from 4:30 to 6 p.m. Presenters will give a two-minute preview of their poster prior to the welcome reception and poster session. In addition to the talk, presenters may use two PowerPoint slides to highlight their research.

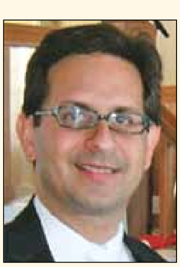
Plenary Speakers

Larry L. Hench, professor, Florida Institute of Technology, USA

Title: *Affordable Healthcare? Role of Bioceramic Technology, Socioeconomic, and Ethical Issues*

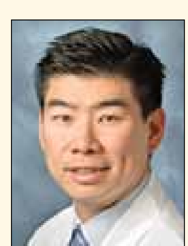
Glenn Stiegman, vice president, clinical and regulatory affairs, Musculoskeletal Clinical Regulatory Advisers LLC (MCRA), USA

Title: *The Current Regulatory Environment*



Safdar Khan, M.D., chief, division of spine, The Ohio State University, USA

Title: *Clinical Testing*



Hyun Bae, M.D., surgeon, The Spine Institute, USA

Title: *Surgical Trends*

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Safdar Khan, M.D., The Ohio State University

James H. Adair, Pennsylvania State University

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Steven Jung, chief technology officer
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573-364-2338

Registration

	On or before June 30, 2014	After June 30, 2014
ACerS member	$595	$745
ACerS member plus membership renewal	$715	$865
Nonmember	$715	$865
Speaker	$450	$600
ACerS Emeritus/Senior Member	$450	$600
Student member	$155	$230
Student nonmember	$195	$270
Spouse/companion	$65	$65

Note: Registration includes welcome reception, conference dinner, two lunches, and breaks. Spouse/companion registration includes welcome reception and conference dinner.

Hotel

Hilton Columbus Downtown
401 North High Street
Columbus, OH, 43215 USA
Tel: 614-384-8600

Rates:
Single/Double: $159

Cutoff Date:
July 8, 2014

Program

Wednesday, July 30, 2014

4 to 5:30 p.m.
Opening Session – Rapid-Fire Presentations

5:30 to 7 p.m.
Welcome Reception & Poster Session

Thursday, July 31, 2014

8:30 to 9:30 a.m.
Plenary Session I

Affordable Healthcare? Role of Bioceramic Technology, Socioeconomic, and Ethical Issues
Larry Hench, university professor of engineering, Florida Institute of Technology, and inventor of Bioglass®

10 to 11 a.m.
Orthopedics I Panel Discussion

This session discusses new and emerging bioceramic technologies and technologies that are in the commercial pipeline. It will focus on bioceramics with orthopedic applications, including cranial, facial, orthopedic, bone void fillers, and spinal applications. Individual panelists will discuss the many uses of bioactive glass for the treatment of bone injuries and bone defects in the body. It will explore material properties and forms along with dynamic bioactive bone graft material that can be molded into desired shapes for implantation.

Confirmed Panelists:
- Zehra Tosun, senior R&D biomedical engineer, NovaBone Products LLC
- Charanpreet S. Bagga, president and CEO, Prosidyan Inc.
- Markus Reiterer, senior principal scientist, Corp. Core Technologies, Medtronic Inc.
- Larry Hench, university professor of engineering, Florida Institute of Technology

11 a.m. to 12 p.m.
New Technologies Panel Discussion

This panel discussion focuses on emerging bioceramic technologies for wound care, bone grafting, drug delivery, and coatings, including research to increase the lifetime of biomedical implants and dental materials. Specific topics include emerging topics of bioactive glasses, including new frontiers in wound care and bone grafting. In addition, drug delivery will be discussed, including nanoparticulate alternatives for drug delivery, porous silica microspheres for medical applications, and coating technologies for medical implants.

Confirmed Panelists:
- James H. Adair, CSO, Keystone Nanos and professor, Pennsylvania State University
- George Wicks, president, Wicks Consulting Services
- Orville Bailey, president, Covalent Coatings Technologies LLC
- Jacob J. Stiglich, Ultramet Inc.

1:30 to 2:30 p.m.
Plenary Session II

The Current Regulatory Environment
Glenn Stiegman, vice president, regulatory affairs, Musculoskeletal Clinical Regulatory Advisers LLC (MCRA)

3 to 4 p.m.
Regulatory Panel Discussion

This panel discussion focuses on the current regulatory environment, Food and Drug Administration trends, obtaining and maintaining compliance, patent trends, and protecting intellectual property.

Confirmed Panelists:
- Aditya Sukthankar, regulatory consultant, MDI Consultants Inc.
- Tram Nguyen, partner, Monument IP Law Group
- Glenn Stiegman, vice president, regulatory affairs, Musculoskeletal Clinical Regulatory Advisers LLC (MCRA)

4 to 5 p.m.
Radiotherapeutics Panel Discussion

The panel will discuss clinical efficacy of tenured products along with new treatment options from emerging technologies and applications. Panelists will discuss product development, materials requirements, properties of good radiotherapeutic materials, chemical durability, maximizing specific activity, method of activation, and the right type of radioisotope.

Confirmed Panelists:
- Mark Tann, associate professor of clinical radiology, Indiana University School of Medicine
- Wayne Mullet, director of development, BTG International Canada Inc.
- Delbert Day, Curators' Professor Emeritus of materials science & engineering, Missouri University of Science and Technology

Friday, August 1, 2014

8:30 to 9:30 a.m.
Plenary Session III

Clinical Testing
Safdar Khan, M.D., chief, Division of Spine, The Ohio State University

10 to 11 a.m.
Clinical Testing Panel Discussion

This panel discussion focuses on the efficacy of a multitude of products from a variety of medical fields and how these products may be improved to get an improved outcome. Panelists will cover preliminary and primary research, testing required for commercialization, and clinical trials.

Confirmed Panelists:
- Paul M. Weinberger, assistant professor, Georgia Regents University
- Ben Tempel, CEO, NanOphthalmics
- Safdar Khan, M.D., chief, Division of Spine, The Ohio State University

August 4–7, 2014 | Westin San Francisco | San Francisco, Calif.

3RD INTERNATIONAL CONFERENCE ON ELECTROSPINNING

INTRODUCTION

Electrospin 2014 will provide a platform for researchers, engineers, and students to exchange knowledge and advance the field of electrospinning, nanomaterials, and their applications. The conference topics will address theory; all materials, including polymers, metals, and ceramics; applications in energy storage and harvesting; filtration; materials for sustainability; biomedical applications; and more. Special focus will be given to the fast-growing field of ceramic nanomaterials. **Register now to participate in this biennial event.**

WHO SHOULD ATTEND

Professionals in the academic field and industry should make their plans to attend. Newcomers to the field are highly welcome and will profit from high-quality presentations from top scientists and engineers from around the world. Students will meet and learn from the best and have a chance to interact with companies that electrospin or fabricate nanomaterials.

PROGRAM COMMITTEE

- Il-Doo Kim, KAIST, Korea
- Unyong Jeong, Yonsei University, Korea
- Wolfgang Sigmund, University of Florida, USA
- Younan Xia, Georgia Tech, USA
- Andreas Greiner, University of Bayreuth, Germany

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3RD INTERNATIONAL CONFERENCE ON ELECTROSPINNING

PLENARY SPEAKERS

Il-Doo Kim, KAIST, Department of Materials Science and Engineering, Korea

Kim received his Ph.D. (2002) from the Korea Institute of Science and Technology (KAIST). From 2003 to 2005, he was a postdoctoral fellow with Harry L. Tuller at MIT. He returned to KAIST as a senior research scientist, and in Feb. 2011, became a faculty member in the Department of Materials Science and Engineering. Kim's current research emphasizes controlled processing and characterization of functional nanofibers via electrospinning for practical applications in exhaled breath sensors and energy storage devices, such as Li–ion, Li–S, and Li–air batteries. Kim served as a conference chair at the 2012 International Conference on Electrospinning in Jeju, South Korea. He has published more than113 articles and holds 122 patents. Kim is a deputy editor of the *Journal of Electroceramics*.

Luana Persano, Nanoscience Institute, National Research Council-CNR, Italy

Persano, who holds a Ph.D. in innovative materials and technologies (2006), is staff researcher at the National Research Council–Nanoscience Institute. She has been a Marie-Curie fellow at the Foundation for Research & Technology–Hellas, Greece, and visiting scientist at Harvard University and University of Illinois. Her research interests include nanomanufacturing, conventional and soft lithography on organics and nanocomposites semiconductors, photonic and piezoelectric devices, and electrospinning technology transfer. Since 2003, she has authored or coauthored 70 papers in refereed journals, book chapters, and one international patent. She has several oral and invited contributions to international conferences. Among other prizes, she received the CNR-Start-Cup award in 2010 and the Bellisario award as Young Talent in Industrial Engineering in 2011.

Alexander Yarin, University of Illinois at Chicago, Department of Mechanical and Industrial Engineering, USA

Yarin received his Ph.D. (1980) and his D.S.C. (1989) from the Institute for Problems in Mechanics, USSR Academy of Sciences. He has been senior research associate at The Academy of Sciences of the USSR, Moscow (1977–1990); professor at the Technion-Israel Institute of Technology (1990–2006), and at the University of Illinois at Chicago, USA (2006–present). Concurrently, he has been professor at Korea University, Seoul, South Korea (2013–present). Yarin was a Fellow of the Center for Smart Interfaces at the Technical University of Darmstadt, Germany (2008–2012). Yarin is the author of three books, 10 book chapters, about 250 research papers, and six patents. He is an associate editor of the journal *Experiments in Fluids* and one of the three coeditors of *Springer Handbook of Experimental Fluid Mechanics*, (2007). The recent book by A.L. Yarin, B. Pourdeyhimi, and S. Ramakrishna is *Fundamentals and Applications of Micro- and Nanofibers*, (Cambridge University Press 2014).

REGISTRATION

	On or before July 1, 2014	After July 1, 2014
Attendee	$575	$725
One day	$425	$575
ACerS Emeritus/Senior/Associate Member	$425	$575
Student	$295	$370
Spouse/companion*	$75	$75

Note: Registration includes two receptions, conference dinner, and breaks.

* Includes only evening reception and dinner.

SESSION TOPICS

- Advances in electrospinning theory and modeling
- Energy storage and harvesting with electrospun or sprayed materials
- Novel developments in electrospinning and other nanofiber fabrication technologies
- Ceramic and composite nanofibers
- Polymer nanofibers
- Biomedical applications of electrospun materials
- Filtration and textiles
- Electrospinning for green materials and sustainability

HOTEL

The Westin San Francisco Market Street
50 Third Street
San Francisco, CA 94105

SCHEDULE

Monday, August 4, 2014

5 – 7:30 p.m.	Welcome reception

Tuesday, August 5, 2014

8:40 a.m. – 9:45 a.m.	Opening remarks and Plenary Speaker 1
9:45 – 10 a.m.	Break
10 a.m. – 12 p.m.	Two to three concurrent sessions
12 – 2 p.m.	Lunch on own
2 – 2:45 p.m.	Plenary Speaker 2
2:45 – 3 p.m.	Break
3 – 5 p.m.	Two to three concurrent sessions
7 – 9 p.m.	Poster session

Wednesday, August 6, 2014

9 – 9:45 a.m.	Plenary Speaker 3
9:45 – 10 a.m.	Break
10 a.m. – 12 p.m.	Two to three concurrent sessions
12 – 2 p.m.	Lunch on own
2 – 2:45 p.m.	Plenary Speaker 4
2:45 – 3 p.m.	Break
3 – 5 p.m.	Two to three concurrent sessions
7 – 9:30 p.m.	Conference dinner

Thursday, August 7, 2014

9 – 9:45 a.m.	Plenary Speaker 5
9:45 – 10 a.m.	Break
10 a.m. – 12 p.m.	Two to three concurrent sessions
1 – 5 p.m.	Optional tour

join us for the ACerS 116th annual meeting!

MS&T14®

Materials Science & Technology 2014

David L. Lawrence Convention Center
Pittsburgh, Pa., USA
October 12–16, 2014

Special Events

MS&T14 includes a variety of special lectures and activities. Activities are added as additional information is available.

Sunday, October 12

Welcome Reception
Network with your colleagues, and make new connections.

Monday, October 13

ACerS 116th Annual Meeting
Be there as newly elected officers take their positions. All ACerS members and guests are welcome.

Women in Materials Science and Engineering Reception
Enjoy the chance to network with professionals and peers in a relaxed environment.

ACerS 116th Annual Honors and Awards Banquet
Enjoy dinner, conversation, and the presentation of Society awards. Purchase tickets for $90 via the conference registration form.

Tuesday, October 14

MS&T Young Professionals Reception
Attend this reception to meet and network with fellow young professionals.

MS&T14 Exhibit Happy Hour Reception
Network with colleagues and build relationships with qualified attendees, buyers, and prospects!

Lectures

Sunday, October 12

5 – 6 p.m.
ACerS Frontiers of Science and Society – Rustum Roy Lecture
– Wolfgang Rossner, Siemens AG, Germany

Monday, October 13

8 – 10 a.m.
MS&T 2014 Plenary Session

2 – 4:40 p.m.
ACerS Richard M. Fulrath Award Session
– Ken-ichi Kakimoto, Nagoya Institute of Technology, Japan
– Takanori Nakamura, Murata Manufacturing Co., Ltd., Japan
– Edward Herderick, rapid prototype + manufacturing (rp+m)
– Yasushi Enokido, TDK Corp., Japan
– Susmita Bose, Washington State University

2 – 5 p.m.
ACerS Cooper Award Session
– C. Austen Angell, Arizona State University (Distinguished speaker)
– John Mauro, Corning, Inc.
– Cornelius T. Moynihan, Rensselaer Polytechnic Institute (Distinguished speaker)
– Jared Seaman, Rensselaer Polytechnic Institute
– Cooper Scholar winner: To be determined

Tuesday, October 14

9 – 10 a.m.
ACerS Arthur L. Friedberg Ceramic Engineering Tutorial Lecture
– John Ballato, Clemson University

1 – 2 p.m.
ACerS Edward Orton Jr. Memorial Lecture
– Adrian C. Wright, professor emeritus, University of Reading, UK

Wednesday, October 15

1 – 2 p.m.
ACerS Robert B. Sosman Lecture
– Robert F. Cook, NIST

Hotel Options

Reserve your room at www.matscitech.org!

Westin Convention Center Hotel (ACerS HQ) – $205
Hampton Inn & Suites Pittsburgh Downtown – $169

Student activities (Information subject to change)

Material Advantage Student Chapter Travel Grants

The Material Advantage Student Program offers $500 travel grants to student chapters to support attending the ACerS and ASM annual meetings at MS&T. The student chapter may determine how the grant is spent. The grants are restricted to one grant per chapter per academic year. All grants are issued as checks to the chapter advisor and will be sent after the event upon verification that the chapter was in attendance. Travel grants will be awarded on a first come, first served. basis, so act early! Chapters must be active and in good standing to be eligible for a travel grant. For more information, contact Student Relations at **students@asminternational.org**.

Student Monitors

Students may partially defray expenses by serving as session monitors. Monitors assist session chairs, record session attendance statistics, assist with audio/visual equipment, etc. Monitor positions are limited and are assigned on a first-come, first-served basis. Interested students should contact Patricia Warren at **pwarren@tms.org**.

Professional Recruitment & Career Pavilion

Stop by the Professional Recruitment & Career Pavilion in the expo hall on Tuesday during regular expo hall hours. This is your chance to make valuable contacts with potential employers.

Undergraduate Student Poster Contest Display

Stop by the convention center to view all the submissions to the 2014 undergraduate poster contest. The posters will be displayed from Sunday, October 12, to Wednesday, October 15. For more information about this poster contest for undergraduates, contact Tricia Freshour at **tfreshour@ceramics.org**. Deadline for poster abstracts is **September 26, 2014**.

Sunday, October 12, 2014

Chapter Leadership Workshop – FOR CHAPTER OFFICERS ONLY

Network and share best practices. This workshop provides a detailed introduction to the Material Advantage Student Program for chapter officers. Registration is required for this workshop as well as MS&T conference registration. This workshop is for Material Advantage Chapter Officers only. Contact Student Relations at **students@asminternational.org** for more information.

Undergraduate Student Speaking Contest

The purpose of the contest is to encourage undergraduate students to present technical papers and to improve their presentation skills. The presentation subject must be technical but can relate to any aspect of materials science and engineering. One contestant per university is able to compete in this contest, and each entrant must be the winner of a local speaking contest. Participants receive a travel grant awarded at the end of the semi-final/final rounds. Winners of the finals receive cash prizes. For contest rules, contact Tricia Freshour at **tfreshour@ceramics.org**. MS&T speaking contestants must be reported to Tricia by **September 26, 2014**.

Student Networking Mixer

Join in this relaxed, casual, and fun atmosphere designed for students, Material Advantage Faculty Advisors, and society volunteer leaders. Students are encouraged to wear their school colors. Music will be provided.

Monday, October 13, 2014

ACerS Student Tour

Students have the opportunity to attend a tour, organized by ACerS's President's Council of Student Advisors, during MS&T14. The tour is subject to change. Stay tuned for more details in the near future. Contact Tricia Freshour at **tfreshour@ceramics.org** with any questions.

Tuesday, October 14, 2014

Ceramic Mug Drop Contest

Mugs fabricated by students from ceramic raw materials are judged on aesthetics and breaking thresholds. Mugs are dropped from varying levels until the breaking threshold is reached. The mug with the highest successful drop distance wins!

Ceramic Disc Golf Contest

This student-initiated contest is sure to draw a crowd! Students create discs from ceramic or glass materials to meet certain specifications, and the discs are thrown into a regulation disc golf basket. Each disc will be judged in the categories of farthest distance achieved and artistic merit (aesthetics). The disc that is successfully thrown into the disc golf basket from the farthest distance in the fewest number of shots will be named winner of the Ceramic Disc Golf Contest, and the most aesthetically pleasing/creative disc will be recorded as "Best Looking" disc.

Student Awards Ceremony

Congratulate the winners of this year's contests: Material Advantage Chapters of Excellence, Student Speaking Contest, Graduate and Undergraduate Poster Contests, Ceramic Mug Drop Contest, Ceramic Disc Golf Contest, TMS Superalloys Awards, ASM Materials Design Competition, AIST/AISI Scholarships, and Keramos National Awards.

Short Courses

Saturday – Sunday, October 11-12, 2014

Fundamentals of Glass Science and Technology

9 a.m. to 4:30 p.m.; 9 a.m. to 2:30 p.m.

Sunday, October 12, 2014

Recent Innovations in Electroceramics and Their Applications

8 a.m. to 4:30 p.m.

Understanding Why Ceramics Fail and Designing for Safety

8 a.m. to 4:30 p.m.

Organizers:

The American Ceramic Society www.ceramics.org | AIST Association for Iron & Steel Technology | ASM International | TMS The Minerals, Metals & Materials Society

Co-sponsor:

NACE International The Corrosion Society

Calendar of events

June 2014

1–5 American Conference on Neutron Scattering – Crown Plaza, Knoxville, Tenn.; www.mrs.org/acns-2014

4–6 ➡ Workshop on Testing and Modeling Ceramic and Carbon Matrix Composites – Paris, France; www.lmt.ens-cachan.fr

8–13 CIMTEC 2014: 13th Int'l Ceramics Conference – Montecatini Terme, Italy; www.cimtec-congress.org/2014

15–20 6th Forum on New Materials – Montecatini Terme, Italy; www.cimtec-congress.org/2014

17–18 ACerS/NSF Principal Investigator Workshop – Hyatt House Falls Church, Fairfax, Va.; www.ceramics.org

22–25 Hydrometallurgy 2014: 7th Int'l Symposium – Victoria, British Columbia, Canada; http://web.cim.org/hydro2014

July 2014

9–11 5th Advances in Cement-based Materials – Tennessee Technological University, Cookeville, Tenn.; www.ceramics.org

20–25 Gordon Research Conference: Solid State Studies in Ceramics – Mount Holyoke College, South Hadley, Mass.; www.grc.org

29–30 ➡ DMM1: Diversity in the Minerals, Metals, and Materials Professions – National Academy of Sciences Building, Washington, D.C.; www.tms.org/diversitysummit

30–Aug. 1 Innovations in Biomedical Materials: Focus on Ceramics – Hilton Columbus Downtown, Columbus, Ohio; www.ceramics.org

August 2014

4–7 3rd Int'l Conference on Electrospinning – Westin San Francisco Market Street, San Francisco, Calif.; www.ceramics.org

17–21 ➡ ICC5: Int'l Congress on Ceramics – Beijing Int'l Conference Center, Beijing, China; www.icc-5.com

18–22 2014 Forum: Innovations & Breakthroughs in ResonantAcoustic Industrial Mixing – Butte, Mont.; www.resodynmixers.com

24–28 ➡ ISNOG 2014: Int'l Symposium on Non-oxide and New Optical Glasses – Ramada Plaza Hotel, Jeju, Republic of Korea; www.isnog.org

September 2014

22–25 Int'l Commission on Glass Annual Meeting – Parma, Italy; www.icglass.org

28–Oct. 1 COM 2014: 53rd Annual Conference of Metallurgists – Hyatt Regency Hotel, Vancouver, British Columbia, Canada; http://web.cim.org/COM2014

October 2014

5–10 ➡ EPD 2014: 5th Int'l Conference on Electrophoretic Deposition: Fundamentals and Applications – Schloss Hernstein Seminar Hotel, Hernstein, Austria; www.engconf.org

12–16 ➡ MS&T'14: Materials Science & Technology Conference and Exhibition —Materials 2014 – David L. Lawrence Convention Center, Pittsburgh, Pa.; www.matscitech.org

12–16 ACerS Annual Meeting and Awards Banquet – David L. Lawrence Convention Center, Pittsburgh, Pa.; www.ceramics.org

21–24 Glasstec 2014: Int'l Trade Fair for Glass Production – Düsseldorf, Germany; www.glasstec-online.com

26–29 ISHA2014: 4th Int'l Solvothermal and Hydrothermal Conference – Bordeaux, France; www.isha2014.univ-bordeaux.fr

November 2014

3–6 75th Conference on Glass Problems – Greater Columbus Convention Center, Columbus, Ohio; www.glassproblemsconference.org

December 2014

4–6 ➡ MET-14 (Materials Engineering Technology) with 11th Heat Treat Show – The Exhibition Centre, Mahatma Mandir, Gandhinagar, Gujarat, India; www.meth-texpo.com

January 2015

21–23 EMA 2015 – DoubleTree by Hilton Orlando, Orlando, Fla.; www.ceramics.org

25–30 ICACC'15 – Daytona Beach, Fla.; www.ceramics.org

April 2015

28–30 Ceramics Expo 2015 – I-X Center, Cleveland, Ohio; www.ceramicsexpousa.com

May 2015

17–21 ACerS GOMD–DGG Joint Annual Meeting – Miami, Fla.; www.ceramics.org

June 2015

14–19 CMCEE: 11th Int'l Symposium on Ceramic Materials and Components for Energy and Environmental Applications – Hyatt Regency, Vancouver, British Columbia, Canada; www.ceramics.org

September 2015

15–18 UNITECR 2015 – Hofburg Congress Center, Vienna, Austria; www.unitecr2015.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.

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AMERICAN CERAMIC SOCIETY
bulletin

JUNE-JULY 2014

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600 N. Cleveland Ave, Suite 210
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Gordon Alanko
Guest columnist

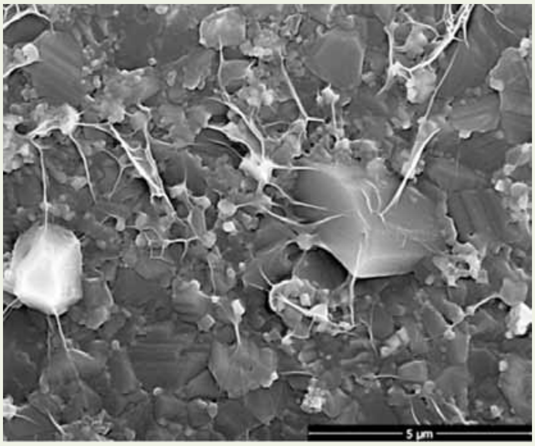
Second writing contest inspires student scientists

The PCSA Ceramics-in-Writing contest, now in its second year, offers students the opportunity to display their creative side by submitting original works of creative writing inspired by a ceramic micrograph. The PCSA Programming Committee evaluated entries based on their originality, style, creativity, and execution.

The goal of the contest is to engage students from around the world in the ceramics community, increase awareness of PCSA, and recognize students for their creativity.

This year's winner is Gordon Alanko from Boise State University. Alanko's poem, titled "The Autoclave," was inspired by a scanning electron micrograph of corroded nickel and alumina (below). The poem is a reflection on the journey to the present while waiting for a verdict after doctoral examinations.

The first and second runner-up entries were submitted by Amy Zhao from the University of Toronto and Ryan McCarthy from Stanford University, respectively. Congratulations to our winners!



Credit: J. Angle; U. of California, Irvine

Scanning electron micrograph of the surface of polycrystalline α-Al_2O_3-containing Ni particles exposed to a water-vapor-rich environment at high temperatures. The weblike structures are believed to be $NiAl_2O_4$ that formed during oxidation.

The Autoclave

by Gordon Alanko

Sometime in springtime you stand
Saluted not by flowers
But by your friends and fellows
Addressing your would-be peers

Oh for the days of youth
Or what passed for it, with you
Carefree under the springtime sky
Free to wander, and wonder too

These years reduced to micrograph
How many times muttered, brave
This, this is the one, this time
Only to return to the autoclave

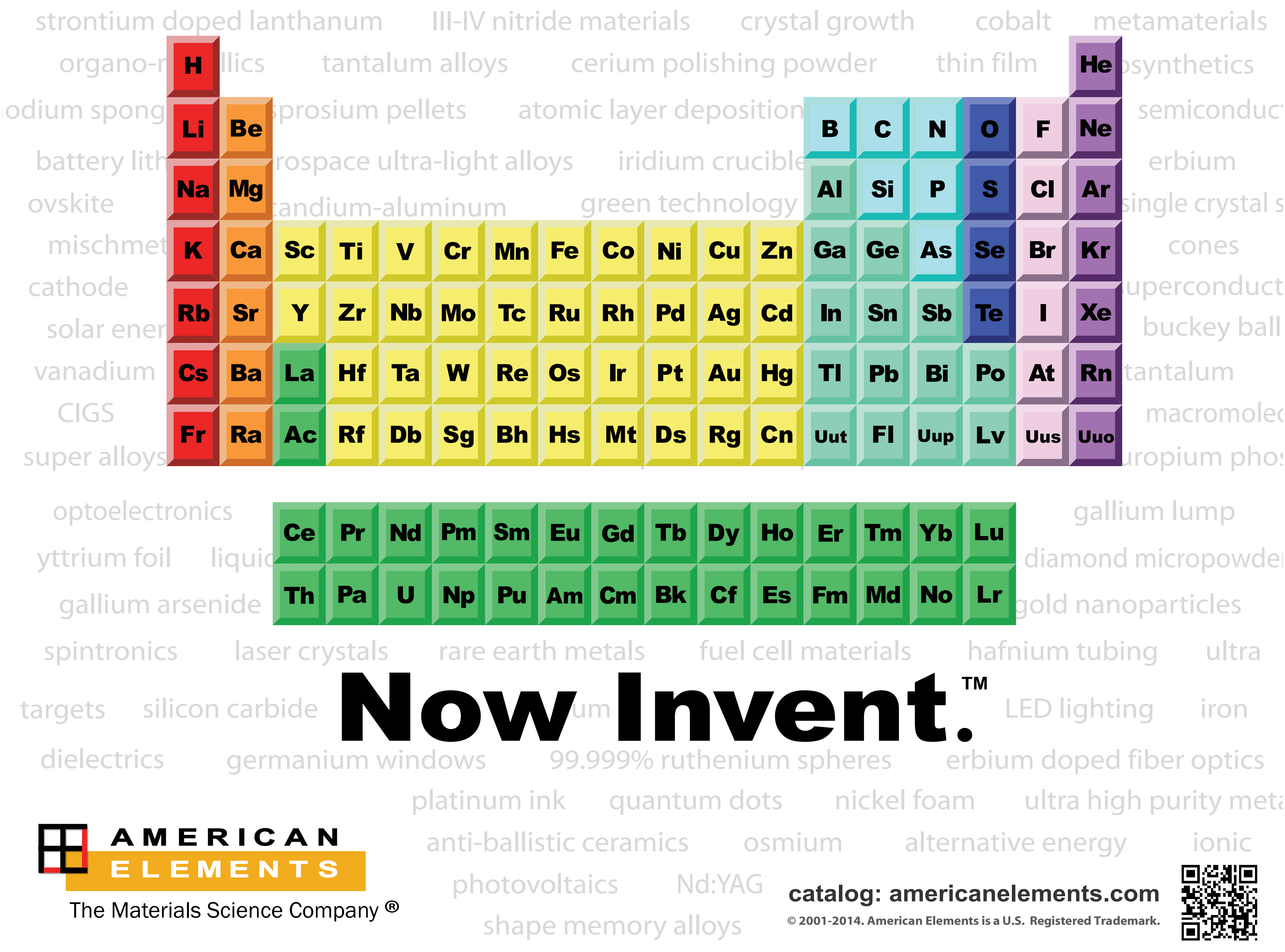
Screw down, monitor, and build steam
Cool off, anticipating
Investigation in microscale
While outside your friends are waiting

This environment designed
For testing, to try, to weigh
What you're made of inside
To endure or corrode away

Tenuous as wind and half
Half so strong, grown slowly
These webs wind through, connect us
Pieces linked in time and space

Wander on through the web
With wonder never ending
Their words bring you back to earth
Congratulations, doctor.
But inside you'll still wonder

Gordon Alanko is a Ph.D. candidate in materials science at Boise State University. His advisor, Darryl P. Butt, has described him as "a scientist, an engineer, a soldier, a husband, a father, and a poet." Gordon's research applies in-situ measurements to study phenomena during mechanochemical processing of refractory and nuclear materials. ■


H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Rf Db Sg Bh Hs Mt Ds Rg Cn Uut Fl Uup Lv Uus Uuo
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr
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