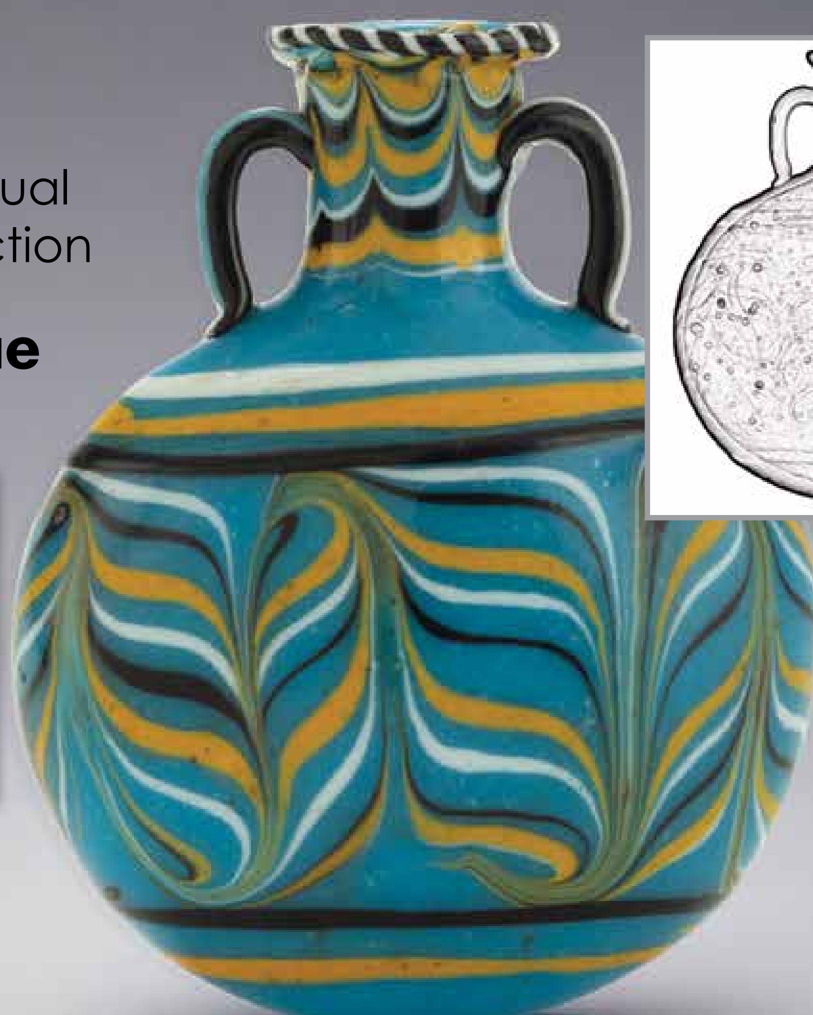
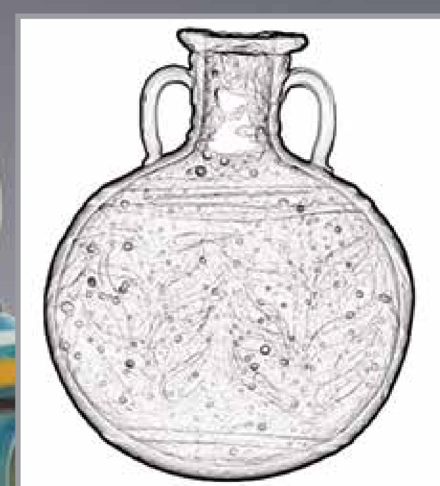
AMERICAN CERAMIC SOCIETY
bulletin
emerging ceramics & glass technology
JUNE/JULY 2020

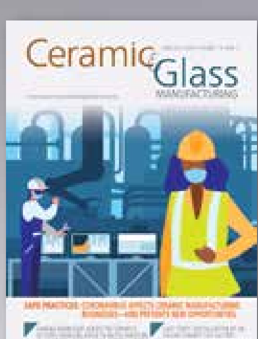
Examination of processing techniques in cultural heritage objects with radiography





Plus: Annual student section

New issue inside:



The future of 5G fiber optics | Student research in the face of COVID-19

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feature articles

Correction

In the May 2020 *Bulletin*, Reference 15 in the article "Reconfigurable optics—a phase change for the better" was incorrect. The correct citation is Zhang, Q. et al. *Optics Letters* **43**, 94 (2018).

department

columns

meetings

resources

AMERICAN CERAMIC SOCIETY

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As seen on *Ceramic Tech Today*...

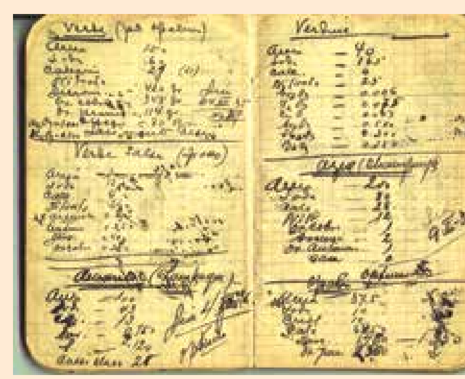
Credit: University of the Witwatersrand

Achieve arbitrary control of light chirality by breaking orbital symmetry

Controlling the chirality of light is important in many fundamental and applied studies. An international research collaboration designed and fabricated a metasurface that can control chirality by breaking the symmetry of light's orbital angular momentum.

Read more at www.ceramics.org/lightchirality

Also see our ACerS journals...



Reproducing crystal glass from three 18th–20th centuries Portuguese glass arcana
By C. R. Santos, M. Vilarigues, P. Dabas, et al.
International Journal of Applied Glass Science

Enhanced vacuum glazing bonding strength by anodic bonding-assisted sealing method
By H. Li, P. Chen. P. Zhang, et al.
International Journal of Applied Glass Science

Simultaneous measurement of coefficient of thermal expansion and biaxial modulus of enamel thick films deposited on glass substrates by curvature technique
By E. B. T. Walch, A. Benedetto, J. Bacharouche, C. Roos
International Journal of Applied Glass Science

Read more at www.ceramics.org/journals

American Ceramic Society Bulletin covers news and activities of the Society and its members, includes items of interest to the ceramics community, and provides the most current information concerning all aspects of ceramic technology, including R&D, manufacturing, engineering, and marketing. The American Ceramic Society is not responsible for the accuracy of information in the editorial, articles, and advertising sections of this publication. Readers should independently evaluate the accuracy of any statement in the editorial, articles, and advertising sections of this publication. *American Ceramic Society Bulletin* (ISSN No. 0002-7812). ©2020. Printed in the United States of America. *ACerS Bulletin* is published monthly, except for February, July, and November, as a "dual-media" magazine in print and electronic formats (www.ceramics.org). Editorial and Subscription Offices: 550 Polaris Parkway, Suite 510, Westerville, OH 43082-7045. Subscription included with The American Ceramic Society membership. Nonmember print subscription rates, including online access: United States and Canada, 1 year $135; international, 1 year $150.* Rates include shipping charges. International Remail Service is standard outside of the United States and Canada. *International nonmembers also may elect to receive an electronic-only, email delivery subscription for $100. Single issues, January–October/November: member $6 per issue; nonmember $15 per issue. December issue (*ceramicSOURCE*): member $20, nonmember $40. Postage/handling for single issues: United States and Canada, $3 per item; United States and Canada Expedited (UPS 2nd day air), $8 per item; International Standard, $6 per item.

POSTMASTER: Please send address changes to American Ceramic Society Bulletin, 550 Polaris Parkway, Suite 510, Westerville, OH 43082-7045. Periodical postage paid at Westerville, Ohio, and additional mailing offices. Allow six weeks for address changes.

ACSBA7, Vol. 99, No. 5, pp 1– 64. All feature articles are covered in Current Contents.

letter to the editor

Dear editor,

Here is a poem I wrote while at home in seclusion/sequestration.

Straightening Nails in a Bent Economy

I know well that nail straightening
Is not what I might do with time so precious
Books on making most of one's time
Lectures by the efficiency experts
Would not but condemn this action.

And too, the modern ways demand
Replacement not recycling.
Yet part of me feels deeply that is wrong
To throw away much of our lives
So much of our day to day.

Oh let the poet out and hammer away
It feels right, here and now
In spite of the advice
About keeping focus all the time
On the big stuff.

And indeed, what is big stuff to a poet?
Straightening nails, saving them,
Putting them in the right bin
That, for this moment is big stuff.
What are poets if not for the moment?

And, as I sit on the basement step
Pounding judiciously, carefully
Straightening, turning each nail
Over and around
A wave of tranquility
Washes over. And once again
Peace with myself,
And those misdirects that build
Into a lifetime.

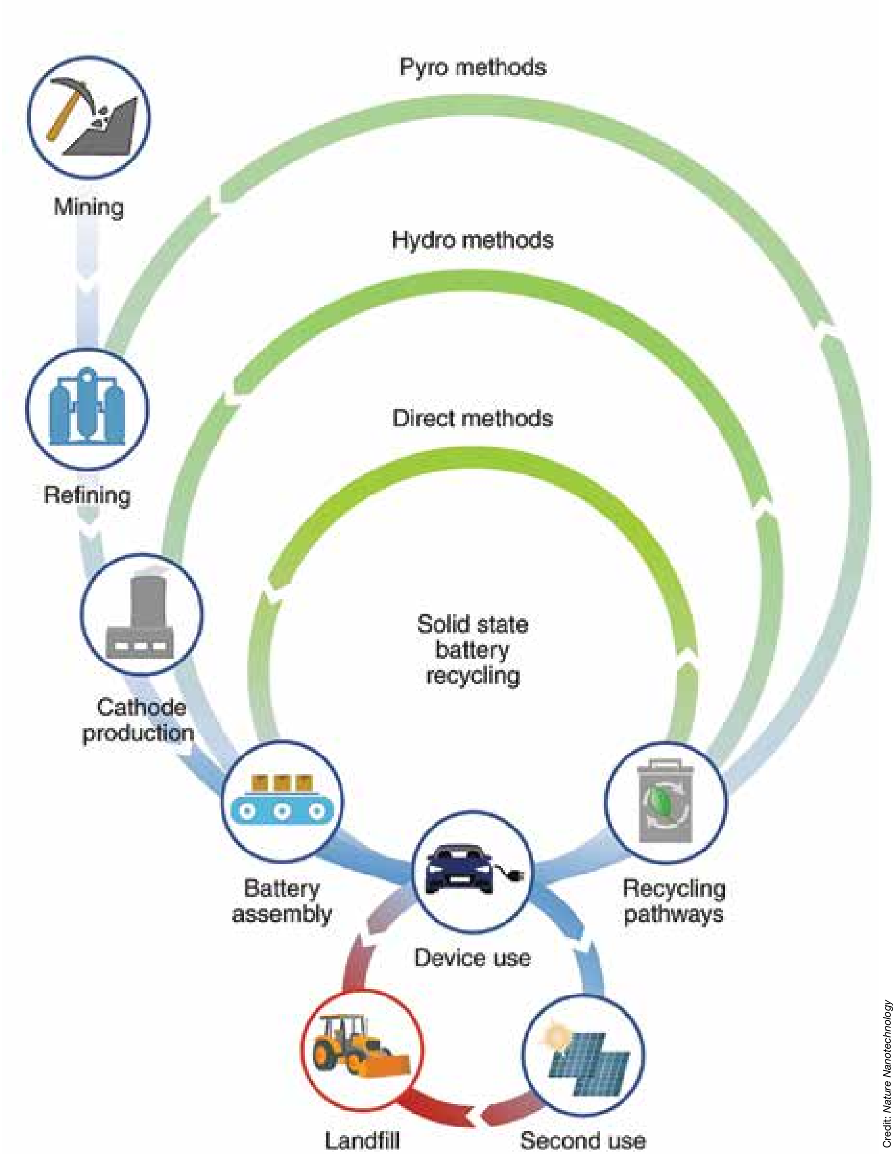
– Harrie Buswell, Buswell Energy LLC

news & trends

Roadmap to commercialize all-solid-state batteries

Renewable energy reached a new high last year, accounting for almost 75% of new electricity-generating capacity built in 2019. Solar power led the way, followed by wind—together accounting for almost 90% of the new total capacity.

In addition to the capacity to generate renewable energy, an often-overlooked component of the transition to an all renewable-powered future is grid storage. Natural energy sources, such as the sun and wind, are variable—they fluctuate up and down in their capacity, which limits their ability to meet energy demand at any given time. Energy storage solves that problem by affording the ability to collect renewable energy and save it for later use.



Lifecycle approach to recycling solid state batteries.

While there are various forms of energy storage, batteries are perhaps one of the most familiar solutions, and they also offer some of the highest efficiencies. Most commercially prevalent today are lithium-ion batteries, although they have their limits and drawbacks. So many researchers are now investigating all-solid-state batteries instead to power the future.

All-solid-state batteries, as their name implies, feature a solid electrolyte—often made of ceramic materials—instead of the liquid electrolyte found in lithium-ions (the part of lithium-ion batteries that makes them prone to catch fire). Thus, all-solid-state batteries are safer than lithium-ions, and they also boast higher performance, longer lifecycles, and wide operating ranges. Plus, on a systems level, their ability to be easily stacked together means all-solid-state batteries offer higher potential capabilities than lithium-ions, despite the batteries' materials having similar energy densities.

Much research and development on all-solid-state batteries happened in the past several years, steadily building momentum toward their commercialization. However, significant challenges remain, including developing more scalable manufacturing processes, before all-solid-state batteries can have their moment.

In a review article published in *Nature Nanotechnology*, nanoengineers at the University of California, San Diego (UCSD) outline a research roadmap detailing four remaining challenges to address before all-solid-state batteries reach their commercial potential.

Create stable interfaces with solid electrolytes

Although researchers have developed various battery materials with sufficiently high ionic conductivities, poor interfacial stability still limits their use in all-solid-state batteries.

"At this point, we should shift our focus away from chasing higher ionic conductivity. Instead, we should focus on stability between solid-state electrolytes and electrodes," Shirley Meng, nanoengineering professor at UCSD Jacobs School of Engineering, says in a UCSD press release.

Particularly, that stability is challenged by reactions between both cathode and anode electrodes and the solid-state electrolyte, which cause voltage loss and reduce power-generating ability, leading to poor battery performance.

One potential solution to mitigate these interfacial reactions is to incorporate a thin coating material in between the electrodes and electrolyte, and various such strategies have shown some success in previous research. Another potential solution is to go moderate—instead of opting for the electrolyte with the highest ionic conductivity, the researchers suggest electrolytes with more moderate ionic conductivities yet better interfacial stability can provide better battery performance overall.

Establish new tools to characterize solid-state batteries

The methods traditionally used to probe the transparent electrolytes of lithium-ion batteries do not adequately visualize the solid and buried components in all-solid-state batteries, making it difficult to analyze why all-solid-state batteries fail or understand what limits their performance.

Previous work showed some success in analysis with X-ray computed tomography, neutron-based techniques, nuclear magnetic resonance imaging, cryogenic focused ion beam techniques, and spectroscopy, but ability of these techniques to adequately characterize all-solid-state batteries highly depends on the individual battery materials, and all listed methods have certain drawback and limitations.

More sensitive, reliable strategies are still needed to adequately characterize all-solid-state batteries in operation—information that is essential to further improve this technology and bring it to commercial scale.

Develop scalable and cost-effective manufacturing

Despite numerous lab-scale battery developments over the past several decades, the vast majority of these discoveries never move beyond the lab because they are too expensive or cannot be manufactured at scale, two components critical for commercial success.

That is particularly true for inorganic solid electrolytes like ceramics, which often lack the necessary mechanical stability in scale-up.

"For example, many become highly brittle when made thin enough for roll-to-roll manufacturing, which demands thicknesses of under 30 micrometers," according to the UCSD press release.

"To overcome such limitations, researchers at UC San Diego are merging multiple fields of expertise," the release continues. "They are combining ceramics used in traditional material sciences with polymers used in organic chemistry to develop flexible and stable solid electrolytes that are compatible with scalable manufacturing processes."

Design batteries for recyclability

When it comes to lithium-ion batteries, recyclability is not one of their strong suits. That is a problem from a sustainability perspective as well as a materials perspective because it represents a loss of valuable battery materials such as lithium, cobalt, and nickel.

Because all-solid-state batteries are just approaching the commercialization phase of their development, the UCSD researchers argue that an entire sustainable lifecycle approach is needed to prevent the same problems lithium-ion batteries suffer.

For instance, better regulation is needed to encourage and enable recycling efforts, both at the level of governments and regulating bodies as well as at the manufacturer level. In addition, more complete recycling of the whole battery, rather than just the electrodes as is currently done, would prevent loss of material and waste. Improved processing techniques would also benefit both the product and cycle—instead of completely breaking down materials during recycling, techniques to reduce the required processing steps would also reduce energy and processing costs, better preserve material integrity, and prevent material loss.

At the end of the paper, the researchers conclude, "Nanotechnology itself may not be an all-encompassing silver bullet for every challenge faced by [all-solid-state batteries], however it is certainly becoming an enabler for deeper understanding of nanoscale phenomena, helping better design strategies that can translate into improvements in materials and cell level performance."

The review paper, published in *Nature Nanotechnology*, is "From nanoscale interface characterization to sustainable energy storage using all-solid-state batteries" (DOI: 10.1038/s41565-020-0657-x). ■

The future of 5G fiber optics: Interview with Sir David Payne

In a special BCC white paper, Sir David Payne, director of the Optoelectronics Research Centre at the University of Southampton in the United Kingdom, discusses the role he sees silica playing in the fiber optic market in the coming years. An excerpt of the interview is below.

BCC: In the 60s, Charles Kao predicted silica would be the material to lead the way in optical fibers. Was he right? Is he still right? What is the role silica plays currently in fiber optic cables, what are its strengths and what are its limitations?

David Payne: *Charles Kao (whom I knew well) was a passionate advocate of silica as the ultimate low-loss material for optical fiber transmission. So far he has been proved right. There are materials thought to have lower loss than silica, but they are impractical for technological reasons, such as ZnCl, which dissolves in water. A perfect (defect-free) crystal also in principle has lower loss because it does not exhibit Raleigh scattering –the limiting factor in today's fiber losses. Because a crystalline fiber cannot be made by the current exquisitely simple fiber drawing process that relies on the viscous flow of glass, crystals too can be ruled out. Lengths of a few meters have been made, though.*

As a result of these factors, silica is dominant in installed fiber cables. In fact, I am not aware of any operating telecoms fiber that is not made from silica. Silica is a 'wonder material' having high strength, a high optical damage threshold, low nonlinearity, a very high melting point, extraordinarily low loss, and a convenient operating window in which lasers and detectors are readily available. It is also a compound of the two most abundant elements in Earth's crust, silicon and oxygen, so is amazingly cheap. It is remarkable that the best telecom transmission medium ever known now sells for a few dollars a kilometer, far cheaper than copper.

BCC: What materials are potential replacements for silica's central role? Which are you personally most excited about?

David Payne: *I do not think that silica is likely to be replaced in conventional fibers by any other material. However, there is a way to make optical fibers that are insensitive to the characteristics of the materials from which they are made. That is to use air as the transmission medium within a so-called hollow-core fiber. These fibers overcome diffraction of the light by confining it in an airhole in the center by use of clever resonance effects in the cladding–rather like bars in the cage of a gorilla.*

These fibers can have only 0.01% or less of the optical power traveling in the glass, so the optical loss (and all other characteristics of the cladding material) are reduced proportionally.

As you might expect, these air core fibers have characteristics dominated by the gas (or vacuum) in the core, so potentially could have the zero loss of vacuum. The challenge is to improve the guidance mechanism so that light does not leak out of the hole, as well as to make these relatively complex structures in sufficient lengths and with the required precision. The latest result from the Southampton University labs is 0.28 dB/km, a startling result that is within a factor of two of conventional fiber losses. So we are within striking difference of beating standard fiber, with the added advantage of near zero scattering and nonlinearity, low latency, and with high power handling and radiation hardness thrown in. While this fiber still uses silica as the base material, it is interesting to speculate that other glasses that were abandoned in the race for low loss, such as lead glasses, could now be used as a cladding material because their loss is no longer as important. Whether there is an advantage to so doing is another question, but for infrared fiber transmission, in which material losses are dominant, there is a real opportunity. It could be that using chalcogenide glasses to make hollow core fibers could lead to low loss fibers transmitting at wavelengths beyond 10 microns. ■

Credit: BCC Research

Sir David Payne

acers spotlight

SOCIETY, DIVISION, SECTION, AND CHAPTER NEWS

Corporate Partner news

ACerS extends a warm welcome to all our new members. Please contact us with any questions you may have regarding your membership.

Our newest Corporate Partners are:

– Applied Ceramics, Inc.

– Howmet Aerospace

ACerS thanks its Corporate Partners for supporting the industry and encourages members to support them. Visit the ACerS Corporate Membership webpage for a complete listing of corporate partners. ■

ACerS Member Community offers new ways to connect with fellow members

Part of the excitement of attending ACerS meetings and conferences is making new friends and contacts. Some of these colleagues become your mentors. Some become partners and collaborators. And many end up becoming lifelong friends.

But how do you continue to stay in touch with these new contacts after the event is over, especially if they live hours—or even countries—away?

ACerS is excited to announce a new online community exclusively for ACerS members—ACerS Member Community.

ACerS Member Community, accessed through your membership account on www.ceramics.org, is your place to follow up and stay connected with other members, but it is also a lot more. In this new community you can:

- Communicate with other members between meetings
- Search the member database to find colleagues
- Follow up with new friends after a conference
- Send direct messages to your contacts—no more searching your inbox for lost emails!

- Create a poll, ask a question, or share an update
- Bookmark conversations for quick reference later
- Share documents with other members
- And much more!

This is YOUR community. We will continue to add new groups, topics, features, and more as we move forward. What would you like to see in your new community? Email Yolanda Natividad, member engagement manager, at ynatividad@ceramics.org with your feedback and questions. ■

Society, Division, Section, and Chapter news (cont)

Volunteer Spotlight


Backman

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

Lavina Backman recently completed her Ph.D. at the Department of Materials Science and Engineering at the University of Virginia (UVA). She specializes in ultrahigh-temperature materials for extreme environments, and her dissertation work focused on the oxidation behavior of high-entropy ultrahigh-temperature ceramics.

She has a B.Sc. in mechanical engineering with a concentration in mechatronics from De La Salle University in Manila, Philippines. Before graduate school, she worked as an associate manufacturing engineer and then a mechanical design engineer for surgical devices.

Backman's leadership is recognized through her election to important positions, such as the recruitment and professional development chairs for her department at UVA and co-chair for the 2021 Gordon Research Seminar on High Temperature Corrosion. She was inducted into UVA's Raven Society, an honor society recognizing academic and service excellence. Backman received the Virginia Space Grant Consortium Fellowship, which was renewed for a second year.

For most of her graduate career, Backman was actively involved with ACerS President's Council of Student Advisors, serving on the outreach subcommittee (which she led in her first year), the communication subcommittee, and as a liaison to the Basic Science Division. While in the PCSA, she contributed to an outreach program to design and make available educational posters for a K–12 audience and helped implement social media campaigns to highlight the achievements of past and present PCSA members.

In addition to her activities in the PCSA, Backman served as a peer reviewer for *Journal of the American Ceramic Society*. After graduation, she plans to remain active in ACerS through contributions to the Young Professional Network.

We extend our deep appreciation to Backman for her service to our Society! ■

ACerS welcomes new Korea Chapter

ACerS Board of Directors recently approved a petition to establish the Korea Chapter of The American Ceramic Society. Officers of the new chapter are

Chair: **Young-Wook Kim**, University of Seoul

Secretary: **Miso Kim**, Korea Research Institute of Standards and Science

Treasurer: **Weon-Ju Kim**, Korea Atomic Energy Research Institute ■

Meet the 2020–2021 Officers and Board Members

President-elect


Dickey

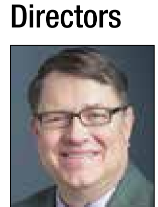
ELIZABETH DICKEY
Distinguished professor and associate department head
Department of Materials Science and Engineering
NC State University
Raleigh, NC, USA

ACerS plays an important role in the development and dissemination of ceramic science and engineering to address an increasingly diverse set of engineering challenges facing our world. Through technical programming, communications, outreach, and leadership development, the Society serves as the main interaction hub for current and future professionals in our discipline. Through these means, the Society must anticipate, influence, and drive advancements in scientific and technological discovery and impact.

As ACerS president, I would champion efforts to build a stronger identity and compelling vision for our Society that embraces the critical interrelationships between ceramic and glass science, engineering, innovation, manufacturing, education, and outreach. I would emphasize integration of students and early-career professionals into Society planning, providing a strategy that builds from our rich history while positioning ACerS for the global challenges and opportunities of 2020 and beyond.

Having been a member of ACerS for 25 years, as a student, national laboratory intern, faculty member, ACerS Division leader, and member of the Board of Directors, I have experienced ACerS from multiple perspectives and have seen it and the profession evolve over almost three decades. There is no doubt the Society has positively influenced my career development and driven my passion for ceramics research and education, and now is an opportune time for me to give back at a deeper level.

Directors


Butt

DARRYL P. BUTT
Dean of the College of Mines and Earth Sciences, professor of materials science and engineering, and director of the Energy Frontiers Research Center, MUSE
University of Utah
Salt Lake City, Utah, USA

As a member of ACerS for approximately 35 years, I've come to value its many contributions to materials industries and to our economic and national security. I'm very proud to be part of a society that brings together diverse perspectives from across the globe to communicate and contribute to the advancement of science and engineering in order to understand and find solutions to a variety of interdisciplinary problems and challenges that we face as a global society. While we are known as The "American" Ceramic Society, we are in reality a global society that has very successfully embraced and partnered with societies in Asia, Europe, and Central and South America.

My background and interests are quite diverse, having worked in industry, academia, and at national laboratories. These research, administrative, and society experiences give me considerable perspective to appreciate the entire Society and all of its parts. As a member of the Board, my priorities would be to continue to strengthen collaborative opportunities with other societies, to further enhance and leverage collaboration and our diversity, and to seek innovative and effective ways to increase membership toward a sustainable society.


Hemmer

EVA HEMMER

Assistant professor
Department of Chemistry and Biomolecular Sciences, Materials Chemistry
University of Ottawa
Ottawa, Ontario, Canada

As an active member of ACerS for several years, I was first engaged in symposia organization, for instance, the Global Young Investigator Forum at Daytona and elsewhere, while getting more and more involved through committee activities such as the Strategic Planning for Emerging Opportunities Committee, the ACerS Canada Chapter, or the newly founded Energy Materials and Systems Division. Becoming a member of the Board will allow me to contribute to ACerS at the next higher level, developing and impacting strategies toward ACerS as a modern society that is closely connected to their members and the community.

Having deeply profited myself from ACerS activities and networks, being on the Board will be a great chance to give back, to ACerS and to the community, by ensuring continuation and further development of stimulating activities and supporting networks to the young generation. Moreover, having experienced training and professional life at an international level and working in the highly interdisciplinary field of materials science, I truly respect ACerS' commitments to the young generation, internationalization, and diversity. Finding ways and means to support and motivate young researchers and students to become future entrepreneurs, scientists, and leaders is crucial, particularly to ensure the development of leadership skills, self-motivation, endurance, and an open mind. These qualities are highly needed in the general society to overcome societal challenges. As such, I believe in the strengthening of international relations as an important aspect to stay attractive for international members and participants but also with respect to make the local community more diverse.


Naito

MAKIO NAITO

Professor
Joining and Welding Research Institute (JWRI)
Osaka University
Osaka, Japan

I am honored to be nominated for the ACerS Board of Directors. I have been an active member of ACerS since 1998 and a Fellow since 2010. I have organized many international symposia and conferences sponsored by ACerS. Leveraging my experience from industry and academia, I have also been an organizer and leader in the ceramic powder processing and characterization technology communities in Japan and internationally for many years.

I will work to strengthen ACerS and its impact on ceramic scientists and engineers in the U.S. and Asia, as well as to broaden its impact in other parts of the world. Two of my goals as a Board member are to continue to grow international networks to build and strengthen international alliances and fruitful relationships between industry and academia, and to grow student and staff exchange programs, especially for graduate students and young scientists and engineers in

Society, Division, Section, and Chapter news (cont)

ACerS, to develop the next generation of ceramic scientists and engineers.

International networking and bridges between industry and academia will be crucial to advancing materials science and technology and its application to address world issues, including issues in energy and environment. And ACerS must continue to play its important role in the education of ceramic engineers and scientists.

Leveraging my experience in industry, as an educator and academician, and in my roles as an organizer and leader in the field, I am well positioned to serve as a catalyst to realize these goals as an ACerS Board member. ■

2020-2021 ACerS officers

The new slate of ACerS officers was determined. There were no contested offices and no write-in candidates, automatically making all nominees "elected." ACerS rules eliminate the need to prepare a ballot or hold an election when only one name is put forward for each office. The new term will begin Oct. 8, 2020, at the conclusion of ACerS Annual Meeting at MS&T.

ACerS President-elect

To serve a one-year term from Oct. 8, 2020, to Oct. 21, 2021

Elizabeth Dickey

ACerS Board of Directors

To serve three-year terms from Oct. 8, 2020, to May 21, 2023

Darryl Butt
Eva Hemmer
Makio Natio

Division and Class Officers

To serve a one-year term Oct. 8, 2020, to Oct. 21, 2021, unless otherwise noted

Art, Archaeology and Conservation Science Division

Chair: **Glenn Gates**
Vice chair: **Marie Jackson**
Secretary: **Jamie Weaver**
Treasurer: **Christina Bisulca**
Trustee: **Ed Fuller**

Basic Science Division

Chair: **Kristen Brosnan**
Chair-elect: **Yiquan Wu**
Vice chair: **Wolfgang Rheinheimer**
Secretary: **Edwin García**
Secretary-elect: **Amanda Krause**

Bioceramics Division

Chair: **Julian Jones**
Chair-elect: **Ashutosh Goel**
Vice chair: **Bikramjit Basu**
Secretary: **Kalpana Katti**

Cements Division

Chair: **Shiho Kawashima**
Chair-elect: **Dimitri Feys**
Secretary: **TBD**
Trustee: **Maria Juenger**

Education and Professional Development Council

Co-chair: **Ashley Hilmas**, 2019–2021
Co-chair: **TBD**, 2020–2022

Electronics Division

Chair: **Alp Sehirlioglu**
Chair-elect: **Claire Xiong**
Vice chair: **Jenny Andrew**
Secretary: **Ed Gorzkowski**
Secretary-elect: **Matjaz Spreitzer**
Trustee: **Steven Tidrow**

Energy Materials and Systems Division

Division chair: **Armin Feldhoff**
Vice chair: **Kyle Brinkman**
Secretary: **Krista Carlson**
Program committee chair: **Eva Hemmer**

Engineering Ceramics Division

Chair: **Valerie Wiesner**
Chair-elect: **Hisayuki Suematsu**
Vice chair/Treasurer: **Palani Balaya**
Secretary: **Thomas Fisher**
Trustee: **Michael Halbig**
Parliamentarian: **Dileep Singh**

Glass & Optical Materials Division

Chair: **John Mauro**
Chair-elect: **Sabyasachi Sen**
Vice chair: **Gang Chen**
Secretary: **Joseph Ryan**

Manufacturing Division

Chair: **Steven Jung**
Chair-elect: **William Headrick**
Vice chair: **Weston Wright**
Secretary: **Ashley Hampton**

Refractory Ceramics Division

(term begins September 2020)

Chair: **Steven Ashlock**
Vice chair: **Dawn Hill**
Secretary: **Kelley Wilkerson**
Program chair: **Robert Hunter**
Trustee: **Louis J. Trostel, Jr.**

Structural Clay Products Division

(term begins March 2020)

Chair: **Mike Walker**
Chair-elect: **Jed Lee**
Vice chair: **Holly Rohrer**
Secretary: **Jim Krueger**
Trustee: **John Dowdle** ■

Names in the news


Du

Jincheng Du, professor in the Department of Materials Science and Engineering at University of North Texas, was appointed the editor for *Journal of the American Ceramic Society.*

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

In memoriam

Tom Crafton
William (Bill) Crandall
Robert Insely
Robert Russell

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

AWARDS AND DEADLINES

ACerS 2020 Society awardees announced

Congratulations to this year's Society awardees. View a list of the 2020 awardees at https://bit.ly/2020societyawards. Biographies and photos of the 2020 awardees will be posted online over the next few months and will be featured in the September 2020 issue of the *ACerS Bulletin*. The awards will be presented October 5 during the ACerS Honors and Awards Banquet at ACerS Annual Meeting at MS&T in Pittsburgh, Pa. Be sure to purchase your banquet tickets before the meeting. ■

ECD award nominations deadline July 1

The Engineering Ceramics Division invites nominations for the 2021 Jubilee Global Diversity, James I. Mueller, Bridge Building, and Global Young Investigator awards.

The Jubilee Global Diversity Award recognizes exceptional early- to mid-career professionals who are women and/or underrepresented minorities (i.e., based on race, ethnicity, nationality, and/or geographic location) in ceramic science and engineering. Nominees must be 45 years old or younger on January 1 of the award year and a member of ACerS Engineering Ceramics Division. Three awards are given per year and consist of a certificate, complimentary registration, and a $500 honorarium presented during the plenary session of ICACC. Awardees will make invited presentations at ICACC. For more information, contact Michael Halbig at michael.c.halbig@nasa.gov.

The Mueller Award honors the enormous contributions of James I. Mueller to the Engineering Ceramics Division and the field of engineering ceramics. The award recognizes the accomplishments of individuals who have made similar contributions. The main criteria are long-term service to ECD and/or work in the area of engineering ceramics that has resulted in significant industrial, national, or academic impact. The award consists of a memorial plaque, certificate, and an honorarium of $1,000. For more information, contact Surojit Gupta at gsurojit1@gmail.com.

The Bridge Building Award recognizes individuals outside of the United States who have made outstanding contributions to engineering ceramics. The main criteria are contributions to the field of engineering ceramics, including expansion of the knowledge base and/or commercial use thereof, and contributions to the visibility of the field and international advocacy. The award consists of a glass piece, certificate, and an honorarium of $1,000. For more information, contact Valerie Wiesner at valerie.l.wiesner@nasa.gov.

The Global Young Investigator Award recognizes an outstanding scientist conducting research in academia, industry, or at a government-funded laboratory. Candidates must be ACerS members and 35 years of age or younger. Selection will be based on the nomination and accompanying evidence of scientific contributions and visibility of the field, and advocacy of the global young investigator and professional scientific forum. The award consists of $1,000, a glass piece, and certificate. For more information, contact Hisayuki Suematsu at suematsu@etigo.nagaokaut.ac.jp ■

Nominate 2021 Class of Fellows by Aug. 20, 2020

The Fellow award recognizes members who have made outstanding contributions to the ceramic arts or sciences through productive scholarship or conspicuous achievement in the industry or by outstanding service to the Society. Nominees shall be persons of good reputation who have reached their 35th birthday and who have been members of the Society at least five years continuously. Visit http://bit.ly/SocietyFellows to download the nomination form. ■

Awards and Deadlines (cont)

Nominations for Varshneya Frontiers of Glass Lectures

Nominations are sought for the Darshana and Arun Varshneya Frontiers of Glass lectures that will be presented at the PACRIM14 meeting, May 23–28, 2021, in Vancouver, BC, Canada.

The Frontiers of Glass Science and the Frontiers of Glass Technology lectures encourage scientific and technical dialogue in glass topics of significance that define new horizons, highlight new research concepts, or demonstrate the potential to develop products and processes for the benefit of humankind.

Please submit nominations by **Sept. 1, 2020**, for individuals who have helped to define new horizons in glass science and technology to Erica Zimmerman at ezimmerman@ceramics.org. Find additional information at www.bit.ly/VarshneyaLectures. ■

MS&T20 registration for ACerS Distinguished Life and Senior, Emeritus members

ACerS is again offering complimentary MS&T20 registration for Distinguished Life Members and reduced registration for Senior and Emeritus members. These special offers are only available through ACerS and are not offered on the MS&T registration site. Registration forms are available at this link https://bit.ly/MST-Forms and should be submitted by **Aug. 28, 2020**, to Erica Zimmerman at ezimmerman@ceramics.org. ■

Ceramographic Exhibit & Competition

Start working on your entry for the 2020 Ceramographic Exhibit & Competition, organized by the ACerS Basic Science Division. This unique competition, to be held at the ACerS Annual Meeting at MS&T20 in October in Pittsburgh, Pa., promotes use of microscopy and microanalysis in the scientific investigation of ceramic materials. The Roland B. Snow award is presented to the Best of Show winner of the competition. Winning entries are featured on the back covers of *Journal of the American Ceramic Society*. Learn more at https://ceramics.org/awards/ceramographic-competition-and-roland-b-snow-award. ■

STUDENTS AND OUTREACH

Are you eligible for the GEMS award?

The Basic Science Division organizes the annual Graduate Excellence in Materials Science (GEMS) awards to recognize the outstanding achievements of graduate students in materials science and engineering. The award is open to all graduate students who are making an oral presentation in any symposium or session at ACerS Annual Meeting at MS&T.

In addition to their abstract submission, students must also submit a nomination packet to John Blendell, chair of the GEMS award selection committee, by **July 20, 2020**. For further details go to www.ceramics.org/gemsaward. ■

Lewis C. Hoffman Scholarship for undergraduate students

This $2,000 tuition award encourages academic interest and excellence among undergraduate students in ceramics/materials science and engineering. The 2020 essay topic is “Reflecting on the last 100 years of ferroelectricity, predict where the field may be in 50 years.” For additional information and nomination instructions, visit https://ceramics.org/awards/lewis-c-hoffman-scholarship. The nomination deadline for this scholarship was extended to **June 15**. ■

Electronics Division Edward C. Henry Award for outstanding paper

This annual award recognizes an outstanding paper reporting original work in *Journal of the American Ceramic Society* or the *ACerS Bulletin* during the previous calendar year on a subject related to electronic ceramics. The author(s) will be presented with a plaque and $500 (split among authors). For additional information and nomination instructions, visit https://ceramics.org/awards/edward-c-henry-award. The nomination deadline for this award was extended to **June 15**. ■

Outstanding Student Researcher Award

The Outstanding Student Researcher Award recognizes exemplary student research related to the mission of the Energy Materials and Systems Division (EMSD). The award is open to U.S. and international graduate and undergraduate students actively engaged in research related to the EMSD. Applicants must have an accepted abstract for ACerS Annual Meeting at MS&T20. It is strongly encouraged that undergraduate submissions present extracurricular projects only, i.e., research conducted outside the normal scope of one’s coursework. Instructions, templates, and examples can be found at https://ceramics.org/awards/outstanding-student-researcher-award. Applications are accepted until **July 31**. ■

CERAMICANDGLASSINDUSTRY FOUNDATION

CGIF grant recipient offers leading-edge programming

The Science Research Institute (SRI) at Albright College in Reading, Pa., partnered with CrossTrainer Learning to develop brand new, state-of-the-art platforms for online learning. Because of the COVID-19 pandemic, SRI is prepared to offer all programming online, including augmented and virtual reality learning platforms, that will be used to teach ceramic and glass science.

The SRI Summer Program encompasses five weeks during the months of July and August. The program integrates a variety of STEM disciplines with a strong materials science foundation, and the curriculum is differentiated for varied experience levels and age of student participants.

The CGIF has provided grants to SRI over the past several years and is proud to support their award-winning programs, as SRI was recently named one of the top four career and technology STEM programs in the U.S. Middle and high school students learn to function in a high-level scientific research setting, developing projects and research that are meaningful to them. It is an authentic learning experience that brings a student's own creativity and innovation to learning while also preparing students for college-level, graduate-level, and "real world" research.

In addition to SRI's outstanding student programs, director of SRI Adelle Schade has masterminded the creation of the Berks County, Pa., PPE Resource Network in conjunction with several local organizations. Recognizing the desperate need for personal protection equipment, more than 18,500 face shields were 3D-printed and donated to essential workers in Berks County. The PPE Resource Network donated face shields to nearly 200 essential businesses in the county, from private medical practices to police departments, at no cost to those individuals and organizations who have a need for protective equipment during these challenging times.

Credit: Berks PPE Resource Network

A 30-hour print of 60 face shields

The CGIF's support of SRI is only possible because of donations from ACerS members. If you would like to join us in our mission of inspiring and training the next generation of ceramic and glass professionals, please visit our website at foundation.ceramics.org/give. ■

PCSA Humanitarian Pitch Competition at MS&T20

The President's Council of Student Advisors will host the Humanitarian Pitch Competition, in which students pitch ideas to a panel of judges about how to address a challenge that a community is experiencing through materials engineering and processes.

Students may put together a team of up to four participants to develop a solution to a real-world problem using materials science. Both undergraduate and graduate students are eligible to participate. Visit www.ceramics.org/pitchcomp to submit your abstracts by **Sept. 1, 2020.** ■

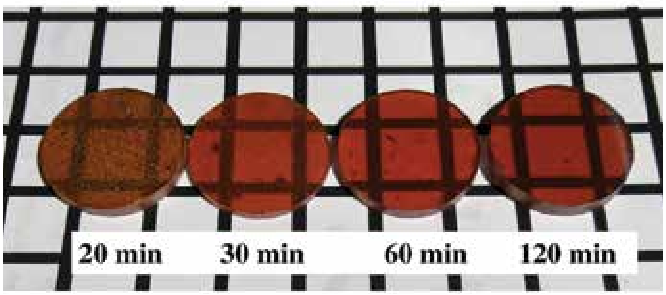
Graduation gift from ACerS

ACerS offers a one-year Associate membership at no charge for recent graduates who have completed their terminal degree. ACerS is a truly global community and an Associate membership can connect you to more than 11,000 professionals from more than 70 countries. More than 35% of our members live and work outside North America. They collaborate and inspire one another through participation in Divisions, Classes, Sections, Chapters, and Technical Interest Groups. Visit www.ceramics.org/associate to learn about this vibrant community and join as an Associate Member. For more information, contact Yolanda Natividad at ynatividad@ceramics.org. ■

Transparent ceramic materials may make self-driving vehicles faster and safer

Researchers from Alfred University improved on previous ceramic processing attempts to fabricate transition metal ion-doped II-VI chalcogenide materials.

Currently, TM:II-VI chalcogenide materials are the most favorable candidates for broadly tunable and room-temperature mid-infrared (2–5 µm) laser gain materials. Mid-infrared lasers are seen as essential for developing high-performance LiDAR systems, which are used for imaging in emerging applications such as self-driving vehicles.



Credit: Yu, Carloni, and Wu; Journal of the American Ceramic Society

Photograph of the polished Fe:ZnSe transparent ceramic sintered at 900°C under 90 MPa for different times. The ceramics could prove an ideal lasing material for mid-infrared lasers.

However, creating TM:II-VI laser materials remains a significant challenge. The four main methods for preparing TM:II-VI laser materials—physical vapor transport growth, melt growth, solid phase recrystallization, and thermal diffusion—deal mainly with these materials in their crystalline form, which places limitations on the materials' size, dopant concentrations, and homogeneity of lasing ion distribution. These limitations make it difficult to scale-up output power of the laser.

In contrast, preparing TM:II-VI laser materials in their ceramic form could offer some advantages.

"Compared to crystal materials, transparent ceramics have unique advantages which are important in the development of high performance lasers: such as easy fabrication of composite structures with different doping content, heavy and homogeneous doping of rare earth ions, and fabrication of large size components," SUNY Empire Innovation Professor Yiquan Wu, postdoctoral researcher Shengquan Yu, and graduate student David Carloni write in their paper. "Because of these advantages, material scientists have made great efforts to fabricate TM:II-VI laser materials using the ceramic method."

They prepared iron-doped zinc selenide (Fe:ZnSe) transparent ceramics by spark plasma sintering Fe:ZnSe nanopowders they created using co-precipitation. (Prior to their research, reports of Fe:ZnSe transparent ceramics prepared using co-precipitated powders were scarce.) Then, they used scanning electron micrographs to analyze the effects of sintering temperature, pressure, and time on the microstructure.

They determined that Fe:ZnSe transparent ceramics sintered at 900°C under 90 MPa for 120 minutes presented the best transmittance (about 60% at 1.4 μm grain size and 68% at 7.5 μm).

"In conclusion, the transparent ceramic fabrication method (including the coprecipitation of Fe:ZnSe powders) discussed in this paper provided an alternative for creating Fe:ZnSe mid-infrared materials," they write.

To test the potential of their Fe:ZnSe ceramics, Wu's group contacted professor of physics Sergey Mirov from the University of Alabama at Birmingham. Mirov and his group took the ceramics that Wu's group created and demonstrated the first room-temperature gain-switched lasing of the material.

"The maximum output energy was measured to be 0.7 mJ. The slope efficiency was measured to be 3.5% and was limited by scattering losses," they write in conference proceedings for the 2020 CLEO Technical Conference.

Although Wu says this output energy—and the efficiency—are low, they plan to increase the output by studying the technique further.

"Purification of synthesized powders and post-sintering processing is planned as an effort to increase the output efficiency," he says.

The paper, published in *Journal of the American Ceramic Society*, is "Microstructure development and optical properties of Fe:ZnSe transparent ceramics sintered by spark plasma sintering" (DOI: 10.1111/jace.17144). ■

Ceramic 3D printing aids production of vaccines

A European Union-funded research project called NESSIE aims to address the slow and expensive development and production process for essential vaccines.

The NESSIE research project was initiated by SINTEF, a Norwegian research organization; Lithoz, a world market leader in 3D printing of ceramics; and IBET, a Portuguese biopharmaceutical research center. genIbet and Cerpotech later joined the consortium, bringing their expertise on manufacturing of biopharmaceuticals and innovative materials, respectively.

Ceramic materials are used in NESSIE to help improve the end of the vaccine production process—vaccine purification.

"Vaccine candidates are typically produced in a multi-component environment consisting of numerous impurities and co-produced contaminant," an American Pharmaceutical Review article explains. As such, purification of vaccines is required to remove these impurities.

Purification is a multistep process that faces many technological and economic challenges and thus accounts for a substantial fraction of the total vaccine manufacturing cost. So finding low-cost purification methods is an important step toward making affordable vaccines.

One method of vaccine purification is chromatography, a technique that separates a mixture by passing it through a medium in which the mixture's components move at different rates. The medium through which the mixture flows is what NESSIE looks to improve.

Research News

Speeding up long-range coherent LiDAR

Researchers at Ecole Polytechnique Fédérale de Lausanne found a new way to implement a parallel frequency-modulated continuous wave (FMCW) LiDAR engine by using integrated nonlinear photonic circuitry. They coupled a single FMCW laser into a silicon-nitride planar microresonator, where the continuous wave laser light is converted into a stable optical pulse train. The silicon-nitride microresonators are already commercially available by EPFL spinoff LiGENTEC SA, which has specialized in fabrication of silicon nitride-based photonic integrated circuits. For more information, visit https://actu.epfl.ch. ■

A European Union-funded project is using ceramic 3D printing to create devices used in vaccine purification processes.

"The main goal of this project is to produce new structured adsorbents as selective chromatographic media to separate complex biopharmaceuticals," the project website explains. In other words, the goal of NESSIE is to manufacture novel chromatographic columns, devices used to separate chemical compounds.

To create the columns, NESSIE used Lithoz's ultra-high-resolution ceramic 3D printing technology to create columns with tailored shapes and controlled porosity. Ideally, these specially designed columns will improve separation and reduce the number of necessary purification steps, thus cutting production costs.

According to a recent press release on the project, NESSIE so far has successfully produced the first chromatographic supports and will soon test them by purifying adenoviruses, a group of common viruses that often cause fever, coughs, sore throats, diarrhea, and pink eye, among other illnesses.

For more information about NESSIE and the consortium, contact Martin Schwentenwein, head of material development at Lithoz GmbH, at mschwentenwein@lithoz.com or Carlos A. Grande, senior research scientist at SINTEF, at carlos.grande@sintef.no.

3D-printed rocks improve understanding of fracture formation

Researchers at Purdue University 3D-printed gypsum rocks to clearly investigate the effect of mineral fabric and layering on fracture formation.

Fracture geometry, i.e., the corrugated surfaces that emerge when a rock fractures, plays an important role in material flow. "Thus knowledge of the presence and orientation of corrugated surfaces enables design strategies for maximizing flow potential," the researchers write in their open-access paper.

However, predicting how a rock will fracture is difficult.

"...the inherent heterogeneity in mineral phases and composition among rock samples causes a difficulty in identifying the contributions to surface roughness from each of these rock properties and processes, even when extracted from the same rock mass," they write. Thus, "The spatial variability in compositional and structural features prevents reproducible measurements of fracture formation, deformation, and other physical and chemical properties."

To ensure reproducible measurements of these various properties, the researchers decided to 3D print their samples because "the orientation of the mineral fabric and layering can be controlled and used to determine the contributions to fracture surface roughness," they explain.

They additively manufactured gypsum rock by bonding layers of bassanite (calcium sulfate hemi-hydrate, $2CaSO_4 \cdot H_2O$) with a proprietary water-based binder. Then, they performed three-point bending tests to induce tensile fractures and used 3D X-ray computed microscopy to image the fracture propagation, followed by a laser profilometry scan to measure the fracture surface roughness.

The researchers discovered that when layers and minerals of the rock were oriented in the same direction, corrugated fractures tended to form. "The corrugations were enhanced in these samples because the layering and mineral fabric provided resistance to fracturing in the same direction," they explain. In contrast, when the layers and mineral fabric were oriented orthogonally to each other, "corrugations

Research News

Polymer composite could serve as lighter, nontoxic radiation shielding

North Carolina State University researchers suggest that a material consisting of a polymer compound embedded with bismuth trioxide particles holds tremendous potential for replacing conventional radiation shielding materials, such as lead. They demonstrated they could create the compound using a curing method that relies on ultraviolet light rather than relying on time-consuming high-temperature techniques. They so far have determined the compound is effective at shielding gamma rays and are working to further optimize the technique. For more information, visit https://news.ncsu.edu.

Graphene-reinforced carbon fiber may lead to affordable, stronger car materials

Using a mix of computer simulations and laboratory experiments, researchers at The Pennsylvania State University found adding small amounts of graphene to the carbon fiber production process both reduces the production cost and strengthens the fibers. Currently most carbon fibers are produced from a polymer known as polyacrylonitrile, or PAN. The researchers found adding only 0.075% concentration by weight amounts of graphene to the first stages of PAN production allowed them to create a carbon fiber with 225% greater strength and 184% greater stiffness than the conventionally made PAN-based carbon fibers. For more information, visit https://news.psu.edu.

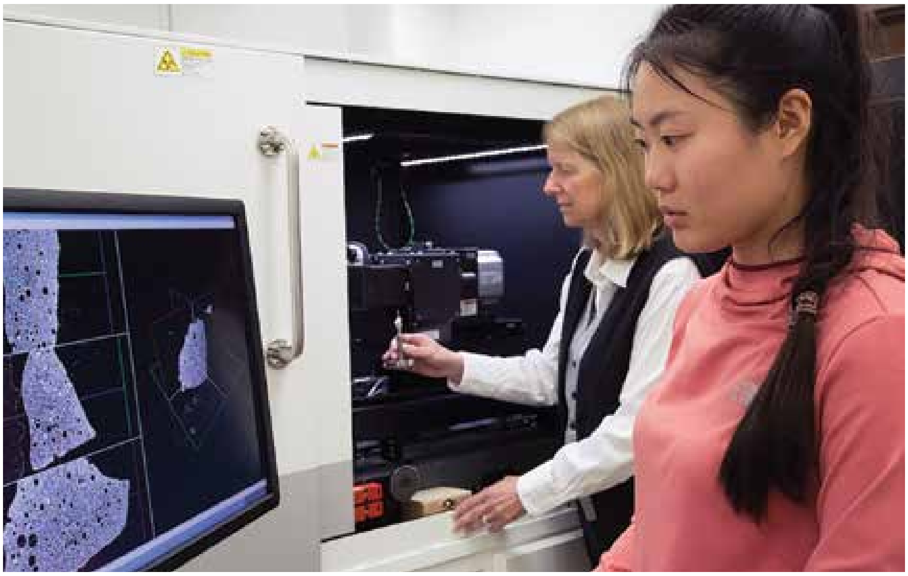
in fracture surfaces are suppressed."

After the researchers observed this phenomenon, they tested randomly generated rock samples made with a traditional casting method, according to a Purdue University press release.

"They discovered that in rock samples with no layers and no oriented grains, fractures formed smoothly, with no corrugations," the release states. "However, different roughnesses emerged in each sample because of the different mechanical qualities in the rock."

These observations provided the researchers with clues about how the rock's layers and grains affect the geometry of how it fractures, which is critical information for being able to predict fracture formation.

In the conclusion, the researchers note some limits of their study, such as the fact they only tested tensile failure. However, "The results presented here suggest that detailed mineralogical studies of cores should be performed to aid interpretation of preferred flow paths in existing fractures and to aid the design of induced fractures to maximize production potential," they conclude.



Credit: Purdue University

Purdue University professor Laura Pyrak-Nolte (background) and physics graduate student Liyang Jiang (foreground) use a 3D X-ray microscope to examine additively manufactured gypsum rocks to better understand fracture formation.

The open-access paper, published in *Scientific Reports*, is "Mineral fabric as a hidden variable in fracture formation in layered media" (DOI: 10.1038/s41598-020-58793-y). ■

Effects of bioactive glass ionic dissolution on the immune system

In a new open-access study by researchers from the University of Erlangen-Nuremberg and the University Hospital Erlangen in Germany, scientists investigated in vitro how different borate bioactive glasses affect mice dendritic cells.

Though bioactive glasses are considered biocompatible, there still exists a lot of unknowns surrounding how and what responses bioactive glasses trigger, so understanding these responses better helps scientists improve the healing abilities of bioactive glasses and avoid possible toxic responses.

One type of immune response of which scientists lack clear understanding is how bioactive glasses affect the function of dendritic cells (DCs).

DCs are specialized immune cells that play a crucial role in initiating primary immune responses by processing and presenting antigens (a toxin or other foreign substance) to a type of white blood cell called lymphocytes, which then triggers an immune response. If scientists can learn how bioactive glasses affect DC functions, it could provide a means of control over a body's immune response during healing.

The researchers of the recent study specifically investigated how DC phenotype and function are impacted by bioactive glass ionic dissolution products (IDPs).

When a bioactive glass is placed in the human body, the physiological environment causes the bioactive glass to dissolve, triggering two main things to occur:

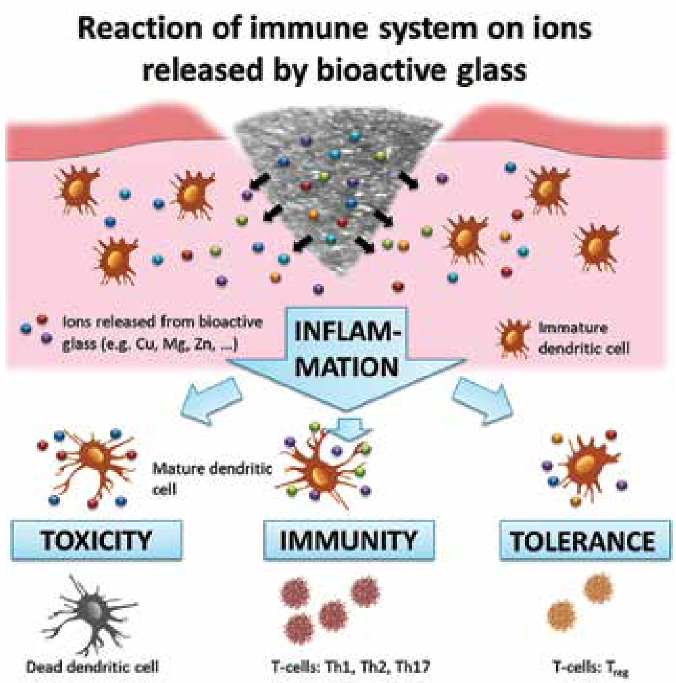
1. The formation of an apatite layer on the tissue surface,
2. The release of biologically active ions, i.e., IDPs.

The particular IDPs depend on the glass composition, but much is known about the effects of certain ions. For example, calcium and silicon favor osteoblast differentiation whereas boron is known to stimulate fibroblast cells and angiogenesis. These effects are significant, and thus an important place to begin investigation of how bioactive glass affects DCs.

For the study, the researchers focused on bioactive glasses doped with copper and/or zinc.

"The main idea was to develop a bioactive glass suitable to be used in wound healing applications," Aldo Boccaccini, ACerS Fellow and head of the Institute of Biomaterials at the University of Erlangen-Nuremberg, says in an email. "Therefore we chose zinc, which is known to be important in wound healing and to have some anti-inflammatory and bactericidal properties. In addition, we chose copper since it has been shown that copper is efficient against various bacteria and it provides additional angiogenic properties, which are two properties especially interesting in the treatment of chronic wounds."

In the case of zinc-doped bioactive glass, the researchers discovered the IDPs provided several positive effects on DC function. In particular, the zinc ions increased the number of certain DC surface markers, i.e., molecules involved in antigen presentation and activation of lymphocytes. As a result, the researchers saw an increased capacity of these DCs to stimulate T cells (a type of lymphocyte) to action against the antigens.



Credit: Katharina Schuhladen, Institute of Biomaterials, University of Erlangen-Nuremberg

Graphic illustrating how ions released during bioactive glass dissolution affect dendritic cells.

However, Boccaccini emphasizes that the same results were seen for bioactive glasses without doping as well. "It should be mentioned that no statistically significant difference between the cells being in contact with bioactive glass with and without zinc could be found (most probably due to the minor, not detectable amount of zinc being released)," he says.

In contrast, Boccaccini says the results for the copper-doped bioactive glasses were "especially interesting" because "the immune reaction can be fine-tuned by changing the concentration (and therefore the release) of copper."

Specifically, the researchers found that high concentrations of copper ions reduced the number of certain DC surface markers, thus reducing the capacity of DCs to stimulate T cell proliferation.

"This offers several interesting possibilities such as actively inducing an immune reaction (as shown by the 1% B3-Cu BG) or to actively dampen an immune reaction (as shown by the 10% B3-Cu BG)," Boccaccini says.

Boccaccini says they plan to repeat the experiments using human cells and also further investigate the possible bioactive glass effects on B-lymphocytes as well as macrophages.

The open-access paper, published in *Biomaterials Science*, is "Cu, Zn doped borate bioactive glasses: Antibacterial efficacy and dose-dependent in vitro modulation of murine dendritic cells" (DOI: 10.1039/C9BM01691K). ■

ceramics in manufacturing

Ultrafast high-temperature sintering opens the door to AI-driven materials discovery

Artificial intelligence-based methods are poised to help identify possible new ceramic and glass compositions in the coming years, but there still lies the challenge of creating these new materials after identification. Now, researchers at the University of Maryland and colleagues from Virginia Tech and the University of California (San Diego and Los Angeles) developed an ultrafast high-temperature ceramic sintering method that could overcome previous sintering limitations.

For ceramics, the conventional ceramic sintering process often requires hours of processing time, which limits how quickly new compositions can be experimentally tested. This process causes particular problems for development of ceramic-based solid-state electrolytes—a technology considered critical for improving battery energy efficiency and safety—because of lithium and sodium's severe volatility during sintering.

Researchers have devoted substantial effort to developing innovative sintering technologies, such as microwave-assisted sintering and spark plasma sintering (SPS). However, both these processes face limitations.

"Microwave-assisted sintering of ceramics often depends on the microwave absorption properties of the materials or uses susceptors," the researchers write in their recent paper. "The SPS technique requires that dies are used to compress the ceramic while sintering, which makes it more difficult to sinter specimens with complex three-dimensional (3D) structures."

They add that while more recently developed methods such as flash sintering, photonic sintering, and rapid thermal annealing (RTA) display a high heating rate, "flash sintering conditions depend strongly on the electrical characteristics of the material … Photonic sintering temperatures are normally too low to sinter ceramics … [and RTA] can only provide a sintering temperature of up to ~1200°C with expensive commercial equipment."

In the new paper, the researchers propose a new sintering method—ultrafast high-temperature sintering (UHS)—which they say overcomes many of these limitations.

Senior author Liangbing Hu, Herbert Rabin Distinguished Professor of the Department of Materials Science and Engineering and director of the Center for Materials Innovation at UMD, describes the method in a UMD press release.

"With this invention, we 'sandwiched' a pressed green pellet of ceramic precursor powders between two strips of carbon that quickly heated the pellet through radiation and conduction [~10^3 to 10^4°C/min], creating a consistent high-temperature environment [up to ~3,000°C] that forced the ceramic powder to solidify quickly," Hu says.

Compared to other methods, the researchers note UHS:

• **Prevents volatile evaporation and undesirable interdiffusion** due to short sintering time, unlike conventional sintering,

• **Allows general and rapid synthesis and sintering of a broad range of ceramic (and metallic) materials** by decoupling intrinsic properties of the material (such as the electric response) from the process, unlike flash sintering,

• **Enables the potential for scalable, roll-to-roll sintering of ceramics** because the precursor film can quickly pass through the heating strips, and

• **Is compatible with 3D printing of ceramic precursors**, unlike SPS.

Credit: Liangbing Hu's group at University of Maryland

Researchers at the University of Maryland and colleagues developed an ultrafast high-temperature ceramic sintering method that could overcome previous sintering limitations.

In an email, ACerS Fellow Jian Luo, coauthor and professor of materials science and engineering at UC San Diego, says, "I think that this work not only represents a technology breakthrough in ultrafast sintering technologies because of its general applicability, but also is scientifically significant in verifying and understanding the critical roles of ultrahigh heating rates in fast sintering."

The UHS technology is being commercialized through HighT-Tech LLC, a UMD spinoff company with a focus on high-temperature technologies.

The paper, published in *Science*, is "A general method to synthesize and sinter bulk ceramics in seconds" (DOI: 10.1126/science.aaz7681). ■

ceramics in energy

Tellurium stabilizes lithium deposition in Li-S batteries

In a new study, three researchers at the University of Texas at Austin believe they found a way to overcome one of the main challenges holding lithium-sulfur (Li-S) batteries back from achieving their full potential.

Li-S batteries consist of a sulfur cathode, a lithium metal anode, and a liquid electrolyte. These batteries hold great potential for enabling the next generation of high-energy-density rechargeable batteries due to sulfur and lithium's large gravimetric capacities (1,675 mA·h·g^{1} and 3,861 mA·h·g^{1}, respectively).

However, there are two particular features of Li-S batteries limiting them from reaching their full potential—polysulfides and unstable lithium deposition.

Polysulfides are sulfides that contain two or more atoms of sulfur in the molecule. During charge and discharge of Li-S batteries, lithium sulphide (Li_2S) and lithium polysulfides (Li_2S_n, $3 \leq n \leq 8$) form at the sulfur cathode.

While sulfur and Li_2S are relatively insoluble in most electrolytes, many polysulfides are not. So when intermediate polysulfides are formed, they diffuse away from the sulfur cathode to the lithium metal anode—a process called the polysulfide "shuttle" effect—and lead to irreversible loss of the sulfur cathode and deposition of sulfur-containing species on the anode.

In an ideal battery, ions would travel freely between the cathode and anode during charge and discharge cycles. However, in lithium-based batteries, lithium ions tend to leave and return to the surface of the anode unevenly, causing growth of dendritic or mossy formations. Lithium ions are "trapped" in these formations, meaning fewer ions are flowing between the two electrodes—causing the battery's efficiency to degrade.

In conventional lithium-ion batteries, anodes made of graphite are used because they can store lithium ions during charge, preventing uneven deposition. However, Li-S batteries use lithium metal anodes—so the risk of lithium dendritic or mossy formation is ever-present.

In an email, Arumugam Manthiram, ACerS Fellow and Cockrell Family Regents Chair in Engineering and director of the Texas Materials Institute at the University of Texas at Austin, says a large volume of literature on combating the polysulfide "shuttle" effect has been built up over the last decade. "In comparison, there have been only a few attempts at stabilizing the lithium metal anode in Li-S batteries," he says.

Manthiram and his graduate students Sanjay Nanda and Amruth Bhargav explored a way to stabilize the lithium metal anode and prevent unstable lithium deposition—by adding elemental tellurium to the sulfur cathode.

How does modifying the cathode improve stability of the anode? The reasoning circles back to the polysulfides mentioned above—and the solid-electrolyte interphase (SEI) layer.

The SEI is a layer between the liquid electrolyte and anode in lithium-based batteries. It forms when the liquid electrolyte reacts with lithium in the anode.

Credit: University of Texas at Austin

A battery cycler in Arumugam Manthiram's lab at the University of Texas at Austin for testing multiple coin cells at the same time.

The SEI helps ensure stable lithium deposition by serving as a protective layer that prevents further reactions from occurring, such as the reactions that cause dendritic and mossy formations. However, if the SEI layer grows too thick or uneven, it will block the flow of lithium ions in and out of the anode—and could promote dendritic and mossy formations as well.

In Li-S batteries, when the polysulfides migrate from the cathode to anode, they react with the lithium anode to form a SEI made of Li_2S. Li_2S is an insulating material, so the SEI blocks lithium ion flow.

To modify the SEI so that lithium ions can flow through it, Manthiram, Nanda, and Bhargav knew they needed to modify the polysulfides involved in creating the SEI. And that is where the elemental tellurium comes in.

They found that when elemental tellurium was added to the cathode, it combined with the polysulfides to form a soluble polytellurosulfide species ($Li_2Te_xS_y$). When these polytellurosulfide molecules migrated from the cathode to anode, they formed a novel bilayer SEI structure consisting of Li_2TeS_3 and Li_2Te.

Unlike Li_2S, Li_2TeS_3 is a semiconductor and a better lithium ion conductor. This property means lithium ions could flow through the new SEI, leading not only to better conductivity but a smoother, planar deposition of lithium—and less chance of dendritic and mossy formations.

The researchers have filed a provisional patent application for the technology, but Manthiram says the research is far from over.

"We are currently running experiments to see if our strategy can be extended to elements other than tellurium as well to stabilize lithium deposition. The initial results have been very promising," he says. "We are also combining different strategies for improving the electrochemical performance of Li-S batteries to further improve the energy density and cycle life."

The paper, published in *Joule*, is "Anode-free, lean-electrolyte lithium-sulfur batteries enabled by tellurium-stabilized lithium deposition" (DOI: 10.1016/j.joule.2020.03.020).

Examination of processing techniques in cultural heritage objects with radiography

Blythe McCarthy

X-ray imaging is not just for medical applications—such radiographic imaging methods can offer insights into materials composition and processing techniques as well, especially for historical artifacts.

The black-and-white image of an X-ray is no stranger to most of us. It is used extensively in medical applications to identify changes to bones, such as decalcification and arthritis, and in failures, such as chips and breaks. But medicine is not the only application of radiography—readily available X-ray imaging methods,[1] with their ability to reveal information not visible on the surface of an object, can offer insights into materials composition and processing methods as well.

The use of X-rays in the field of cultural heritage were popularized by Alan Burroughs, who traveled through Europe for Harvard's Fogg Museum with a portable X-ray instrument to image firmly attributed paintings and develop an understanding of the working methods of artists.[2] Unlike the film-based methods used by Burroughs, most X-rays are now made using digital techniques. This article focuses on 2D X-ray methods, in particular computed radiography, which is a common successor to film-based methods due to the similarity in both use of the flexible image plate to film and the resultant resolution as well as its increased ease of use. 3D methods, not discussed here, were discussed in volume 93, issue 7 of the *ACerS Bulletin* (2014).

From cradle to cradle: Steps in the production process of ceramics

In the 1960s, the term *chaîne opératoire* was coined in French lithic studies[3] to describe the steps involved in the life of a stone-based tool or object, from the sourcing of raw materials to its production, use, and eventual disposal. In defining a technology using this model, each step is examined from its place in creating the object but also from the point of view of the society that produced it. In other words, the constraints and choices by the maker can be placed in the greater context of workshop organization and the role of craft specialists, extending out toward the place of the technology in society and the interactions with the local environment.

This methodology of investigation now is used in studies of archaeological ceramics as well. For unglazed ceramics, the first step in the model is the sourcing of necessary clays, temper, and other additives. This step is followed by material preparation, including preparation of clay and mixing it with temper; forming methods, such as slab building or coiling; decorative methods, such as slip application, burnishing, or painting; and then firing. The production is followed by the use life of the object, its disposal, and then rebirth in its second "cradle," i.e., its use in the museum to inform and educate.

When studying materials from archaeological sites, information from geological surveys combined with environmental surveys at the sites provides information on local material sources. However, museum objects generally lack the context available for scientifically excavated archaeological objects, and so information on raw materials is not available. In addition, we often have little first-hand knowledge or textual information on the materials and methods used to make cultural heritage objects. We rely on reverse engineering the objects themselves to understand the technological choices that were made in their manufacture. In these cases, the object is the primary evidence for the technology and, often for ancient technologies, the only evidence.

X-ray radiography is a useful method for examining the fabric of ceramics, providing information on the materials used and the ability to rapidly survey a collection of objects. Radiography is especially useful when the ceramics are slipped, burnished, or glazed and the body itself is not visible.

An example of X-ray radiography's usefulness is in investigating temper. Temper, a nonplastic inclusion, is added to clay to reduce shrinkage during firing and/or change the properties of the fired ceramic during use. Temper shape and size distribution are visible in an X-ray radiograph as well as variations in temper type, which are determined by variations in radiodensity.

Mineral temper is visible as bright spots (it has higher radiodensity than the clay) in this sherd from a Ban Chiang culture ware (Figure 1).[4] The Ban Chiang culture flourished in prehistoric Thailand and ceramics were produced at several sites. The computed radiograph tells the fabric of the upper part of the vessel, containing a higher amount of mineral temper, is different from the fabric of the lower body. While we can suggest the lower amount of temper and higher porosity in the lower body of the vessel may help prevent cracking due to thermal shock during use, from a single example such as this one it is not possible to say if it was done purposefully or simply because the potter ran out of his first batch of clay. The study of a single museum object provides limited data. More certain findings are only possible when examining the larger numbers available from an archaeological site. This approach, unfortunately, often is not possible with objects in museum collections, which generally lack this context.[i]

While it is not possible to identify the materials of the ceramic using this technique—unless you have a limited number of known materials composing an object and have carried out calibrations—it can help to identify locations for fruitful further studies. In this case, a sample spanning the wall of the ceramic was removed from the body and a thin section prepared for petrography and later scanning electron microscopy. The identified temper materials included grog (previously fired clay fragments) and minerals characteristic of sand (i.e., quartz,

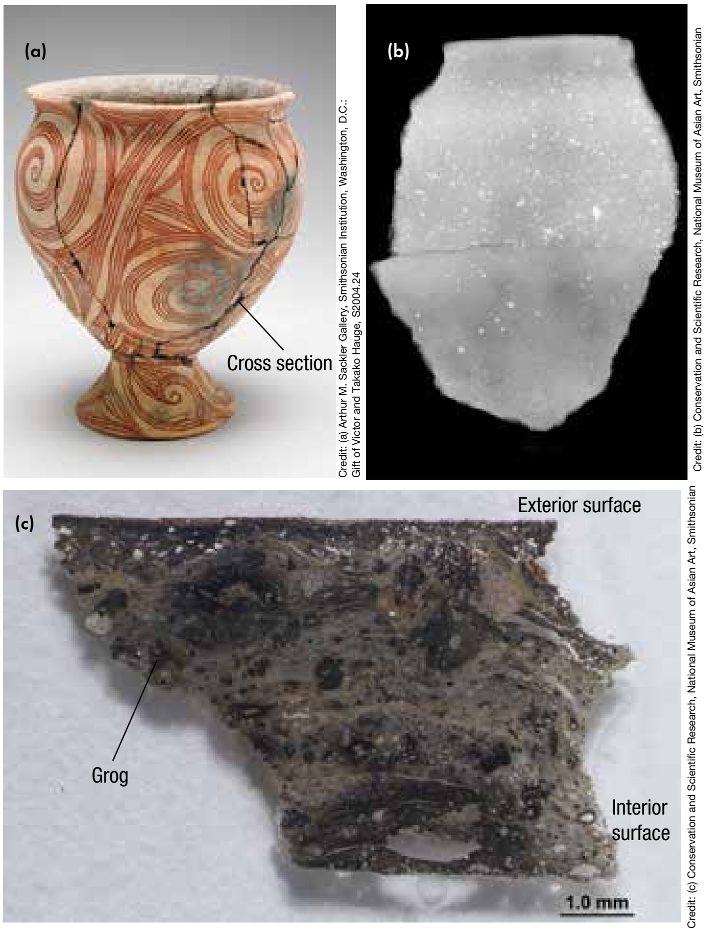


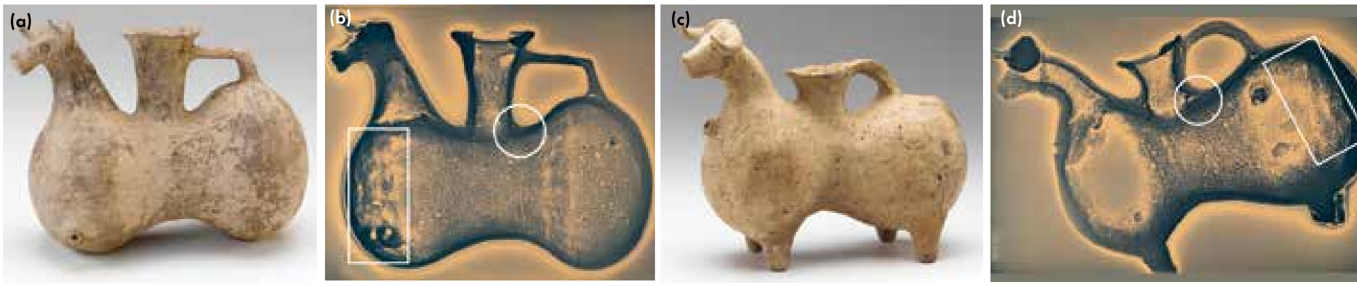
Figure 1. a) Vessel on pedestal foot, Late period 300 BCE–200 CE, Ban Chiang culture, northeast Thailand dimensions: H x Diam (overall): 30 x 27 cm Arthur M. Sackler Gallery, S2004.24. b) CR of sherd visible in (a); and c) Optical microscope image of polished thin section.

iron silicates, and zircon). In addition, the clay has high porosity with small amounts of added organics and a nonuniform clay matrix that suggests the clay(s) and other components were not well mixed, which is not surprising given the uneven distribution of temper seen in the CR.

Radiographic techniques also reveal information on forming methods used. For the Ban Chiang culture vessel, the observed variation in radiodensity (small undulating areas of lighter and darker grays, especially visible in the lower half) is consistent with the paddle and anvil method of shaping the clay used in southeast Asia, i.e., a method in which an anvil is held by the potter on the interior of the vessel and a paddle is pressed against it. (For a video including the technique, see https://youtu.be/fl9KbNYK6xY.)

People have studied forming methods of ancient ceramics since the 1970s using the technique of xeroradiography, a type of X-ray imaging, due to excellent edge definition between materials of similar radiodensity, low sensitivity to scattered X-rays, and its wide exposure latitude.[5] In this technique, an electrically charged selenium coated aluminum plate is placed behind the object of interest and exposed to X-rays. Similar to other radiographic techniques, differences in X-ray absorption by the object define the amount of radiation reaching the plate. This difference in

[i] An exhibition is planned for 2021 at the Smithsonian's National Museum of Asian Art around Ban Chiang culture wares to highlight the importance of archaeological context and the information that is lost when materials are removed from their original location. Exhibition date TBD due to COVID-19.



Credit: Arthur M. Sackler Gallery Smithsonian Institution, Washington, D.C.: Gift of Arthur M. Sackler, S1987.94 and S1987.95. Xeroradiographs taken at Smithsonian's Museum Conservation Institute.

Figure 2. Zoomorphic rhytons (drinking vessel), Northwest Iran, Parthian period ca. 160 BCE–224 CE, and side-view xeroradiographs (acquisition conditions: 75 KV, 5 mA, 1 minute). Arthur M. Sackler Gallery. a,b) S1987.94 (H x W x D: 20.3 x 25.6 x 14.1 cm); and c,d) S1987.95 (H x W x D: 23 x 29.2 x 12.3 cm). Square around mottled area; circle around neck join.

turn is proportional to loss of the negative charge, forming a latent image on the plate. Negatively charged powder particles are attracted to positively charged parts of the plate, then transferred to coated paper under heat and pressure.

The two ceramic bull drinking vessels called rhytons shown in Figure 2 are both burnished on the surface and xeroradiography was useful to examine them for differences in forming methods. Xeroradiography determined these vessels shared some construction techniques but varied in others. Both are multicomponent constructions with separate pieces used for the body, head, legs, vessel neck, and handle. Both are formed of coils (indicated by the thin white vertical lines in the sides of the vessels on the xeroradiograph). However, the hollow bodies of the bulls were closed differently, with S1987.94 (Figure 2a,b) closed at the front and S1987.95 (Figure 2c,d) at the rear. This difference is shown by the rougher interior wall and the mottled appearance that indicates greater manipulation of the clay in these areas.

The join of the vessel neck to the bull's body is very well finished, appearing as a continuous clay corner in S1987.94. The join is much less continuous in S1987.95, where the clay from the vessel neck sits over the clay from the bull's back. This observation suggests that the first bull's neck was attached before the body of the vessel was closed and the other was added after the body was closed when further finishing was not possible. The two handles both contain elongated pores coincident with their length, indicating the clay was pulled (if the clay had been rolled, but not pulled pores would either have a circular cross-section or show elongation across the handle), but they are attached differently—S1987.94 has one end of the handle attached to the vessel neck and the other to the wall of the body, while S1987.95 has a loop with both sides of the handle attached to the walls of the bull's body (note the perception of greater thickness caused by the handle at the rear of the vessel neck relative to the front wall of the neck). Each of these small differences is a technological choice that the craftsman made and can be used together with other elements of the production process to define cultural groupings. In addition, by comparing the xeroradiographs with the shape of the object, it is possible to use the knowledge gained to aid interpretation on other zoomorphic vessels when X-ray imaging is not available. In this case, the side that is closed by hand is not as evenly rounded as the other side.

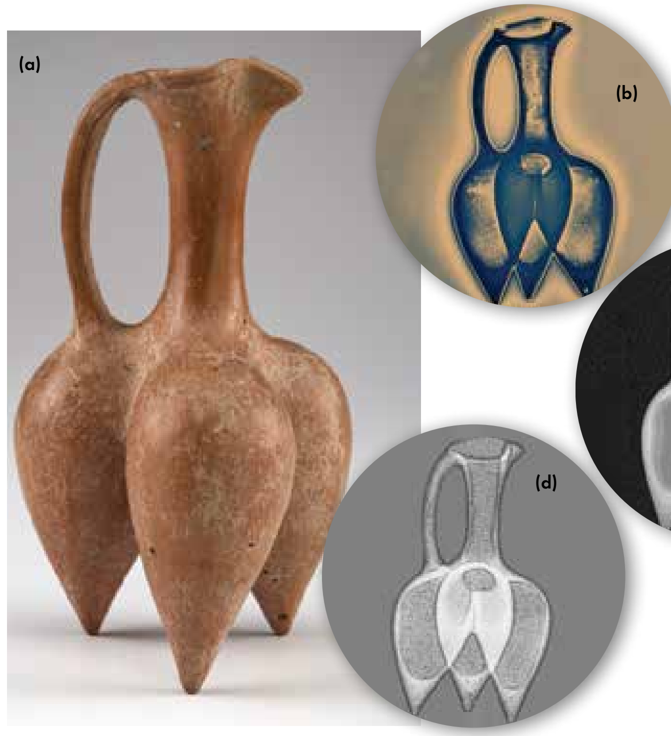
Xeroradiography was once popular for mammography due to its wide exposure latitude and edge enhancement that made it possible to image over an area of varying thickness while resolving features that varied little from the matrix, but it has been supplanted by digital radiography techniques. The technique is no longer readily available, with the last holdouts being instruments that individual labs have managed to keep running and in veterinary applications, in which short exposures made possible by the wide exposure range are an advantage. A more modern X-ray technique called computed radiography (CR) uses a standard X-ray tube as a source and a flexible phosphor image plate as the detector.[ii] After exposure, the plate is scanned, providing a born digital X-ray image.[6] CR has more of the advantages of xeroradiography than film did with a large dynamic range allowing broad exposure latitude, but computed radiographs do not have the edge definition seen in xeroradiography.

Figure 3 shows an ancient near eastern tripod ewer and radiographic images of it. As can be seen in the xeroradiograph (Figure 3b), each leg is a separately formed vessel, and the three are joined at the center of the vessel. The join appears as a dark vertical line at the center and cannot be seen on the object itself. Elongated porosity at the tips of the legs as well as in the handle show that these areas were stretched. The xeroradiograph has a white halo effect that formed due to migration of the charged powder particles toward the charged edges of the image. One advantage of CR, as seen in Figure 3c, is that it lacks the halo. However, with CR, the details of the image are a bit washed out. Digital processing of computed radiographs sharpens the image and aids interpretation. A great advantage of CR over film-based methods is the ability to adjust brightness and contrast individually for areas of interest of different thickness to see the evidence of joins or of pores and inclusions in the fabric of the ceramic.

Unlike the bright smaller temper particles, the dark larger void is a cylindrical hole from sampling for thermolu-

[ii] Computed radiographs were acquired using an Isovolt Titan X-ray tube with a 1.9 mm focal spot. Images were acquired with GE IPS phosphorous plates, which were scanned at a 50 µ resolution and a low gain setting, using a GE CR50P Pegasus scanner. A 0.004-inch lead screen was placed below the phosphor plate to absorb any scatter and improve resolution. Lead screens in cassettes are not traditionally used in film at these low KVs, but with the increased sensitivity to any type of scatter of the phosphor plates, it is standard practice in the lab to use them. Once scanned, the images were manipulated using GE Rhythm Radiography software and Adobe Photoshop. Although only one orientation is shown here, it is standard practice to take shots with the test object in several orientations.

minescence dating and is visible in the middle leg near the bottom (Figure 3c). Processing the image with edge filters and expanding it to make use of all channels increases the areas of differing thickness that are visible together and results in similar information to that possible with xeroradiography, as seen in Figure 3d. The rough edges of the interior profile and variations in the ceramic are most easily visible in this image. The high resolution of the CR plate, 50–100 micrometers or even higher, can surpass that of the xeroradiograph and, if the original X-ray was optimized (i.e., included use of lead screens and filters to minimize scatter and use of proper acquisition conditions), more information generally is present in the CR than the xeroradiograph.



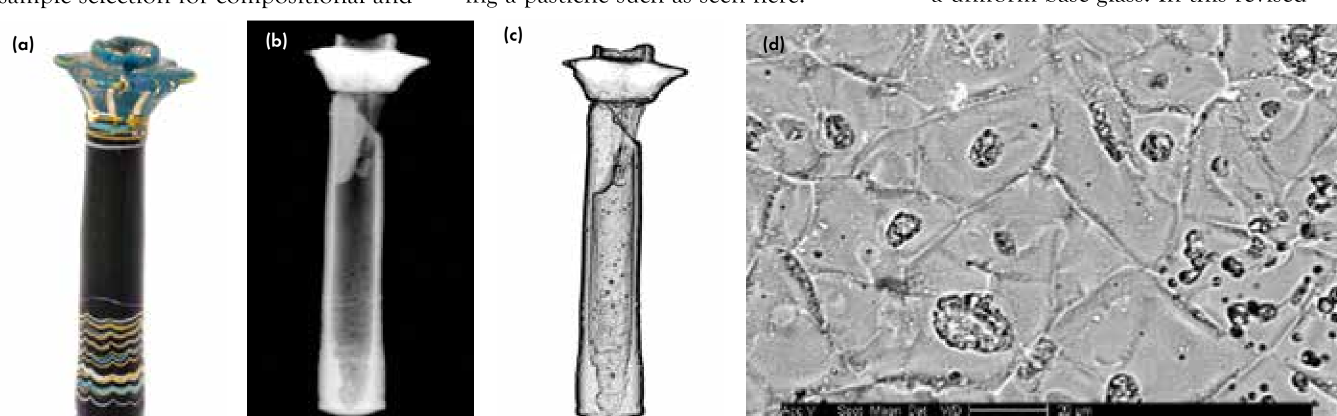
Credit: (a) Arthur M. Sackler Gallery, Smithsonian Institution, Washington, D.C.: Gift of Osborne and Gratia Hauge, S1998.169. (b) Xeroradiographs taken at Smithsonian's Museum Conservation Institute. (c-d) Conservation and Scientific Research, National Museum of Asian Art, Smithsonian.

Figure 3. a) Tripod ewer, ca. 1350–800 BCE, Northwest Iran H x W x D: 21.6 x 11.5 x 12.2 cm (8 1/2 x 4 1/2 x 4 13/16 in) Arthur M. Sackler Gallery S1998.169. b) Xeroradiograph (55KV, 5mA, 60 seconds), image reversed for easy comparison. c) Computed radiograph. d) Computed radiograph after digital processing with Adobe photoshop (Adjust levels to expand channels used, filter: Find edges, adjust levels to expand channels used a second time).

Rethinking the technique of core-formed Egyptian glass vessels

Previous radiography on glass objects conducted in the laboratory is scant, as it is often true that most features visible in the X-radiograph can be seen through careful observation of the glass or through a microscope, thus making the use of a radiograph unnecessary. However, radiography can enable one to see bubbles in opaque or corroded glass, as well as providing information on vessel contents, interior shape, and wall cross-section. We also have used radiography as a survey technique to quickly group glasses of similar composition, discriminating between, for example, lead glasses and soda lime glasses on the basis of their radiodensity prior to sample selection for compositional and trace element analysis. The different brightness at the top (turquoise capital) and bottom (dark blue tube) of the broken and repaired core-formed Egyptian glass kohl tube in Figure 4 indicates two different glasses are present. This object, purchased by Charles Freer in 1909, is comprised of parts of two different objects. Sometimes a dealer or collector, when confronted by several small fragments, would assemble them to have one complete whole object, whether or not the pieces belonged together, forming a pastiche such as seen here.

In the study of this piece and other core-formed objects,[7] CR provided support of a recent revision in understanding how these objects were made.[8,9] Long thought to have been made by wrapping threads of glass around a clay core, Egyptian core-formed vessels are now believed to be made using sintered powdered glass with added wrapped glass threads for decoration. This significant revision was hypothesized due to the appearance of the objects, with bubbles scattered randomly throughout a uniform base glass. In this revised



Credit: (a) Freer Gallery of Art, Smithsonian Institution, Washington, D.C.: Gift of Charles Lang Freer, F1909.427. (b-d) Conservation and Scientific Research, National Museum of Asian Art, Smithsonian.

Figure 4. a) Flask in the form of Lotus column, New Kingdom Egypt ca. 1390–1300 BCE, H x W: 9.5 x 3.3 cm, Freer Gallery of Art, F1909.427. b) Computed radiograph, 55KV 2mA, 60 seconds, focal spot 1.9 mm. Adobe Photoshop "Find edges" filter applied and levels maximized using "Adjust levels." c) Backscattered electron image of sample removed from turquoise capital.

Credit: (a) Freer Gallery of Art, Smithsonian Institution, Washington, D.C.: Gift of Charles Lang Freer, F1909.416. (b) Conservation and Scientific Research, National Museum of Asian Art, Smithsonian.

Figure 5. a) Light blue Lentoid flask, New Kingdom Egypt, ca. 1539–1295 BCE, H x W x D: 8.4 x 6.7 x 3.8 cm (3 5/16 x 2 5/8 x 1 1/2 in) Freer Gallery of Art, F1909.416. b) Computed radiograph, 55KV 2mA, 60 seconds, focal spot 1.9 mm. GE Rhythm Radiography "Enhance Edges" filter applied.

thinking, a preheated refractory core in the form of the interior of the vessel is coated with glass powder and the whole reheated to form the glass object.

Randomly scattered throughout the digitally processed CR of a lenticular core-formed vessel are bubbles of circular cross-section (Figure 5). The random location and great variation in size of the circular bubbles is consistent with a process involving application of a powdered glass to a core with subsequent heating step(s) to melt and merge the glass into a continuous piece. No striae or other differences in composition, as might be expected from wrapped threads used for the base glass, were seen in the radiographs. The CR gave an overall view of the nonuniform wall cross-section. This knowledge can be used to differentiate the core-formed vessel from one of blown glass, in which the surface tension results in a smooth uniform wall.

The use of powder was confirmed, at least for the capital of the kohl tube, by examination of a small sample. It exhibited a microstructure of angular sharp-edged grains that appear to preserve the shape of the original powder particles when examined with backscattered electron imaging. A sample taken from a replicate vessel[iii] made from crushed glass applied to a core also exhibited a microstructure of sintered glass particles under backscattered electron imaging. In both replications and ancient glass vessels, however, the glass particles generally were not visible as the glass fully melted during reheating.

Once the glass is heated, the softened glass is marvered or rolled on a flat, smooth surface to shape and smooth the vessel. Evidence of marvering is present in the kohl tube—it has an approximately 90 degree corner from the wall to the base on the exterior but exhibits more of a "U" shape on the interior. Walls are thinner at the upper edge of the capital, and other examples of this type of kohl tube provide evidence that glass in this area was pulled upward to form petals around the mouth of the container.

Decorative glass threads are added and are marvered to flatten the threads and secure them to the vessel. Additional glass may be used to form handles or decorative elements, and the core is removed when cool. As support for using glass powder, we know the ancient Egyptians used powder processing methods to make faience, a ground quartz-bodied ware.

Role of substructure in the response of East Asian lacquer to environmental changes

Chinese and Japanese lacquers are composed of a substructure that is commonly made of wood coated with multiple layers of modified lacquer formed from the sap of the tree *Toxicodendrum verniciflua* that, when cured, results in a polymeric material that is virtually insoluble even in modern solids. The lacquer layers vary in composition and contain additives such as minerals, oils, fibers, and colorants. Often a textile layer is applied over the wood substrate. Next, a foundation layer composed of clays and minerals bound with protein glue is applied to the wood support. After the foundation, a series of lacquer layers containing additives of increasing fineness are applied in succession with polishing steps between the lacquering steps to form a smooth, durable coated surface.

In a study of Japanese and Chinese lacquers, CR was used to image the wood substrate, determine the presence or absence of textile layers, and find the location of joins between pieces of wood in the substructure. These factors are key to understanding the behavior of a lacquer object when exposed to environmental changes and provide insights into the mechanisms of mechanical deterioration. One challenge was imaging the low radiodensity wood substrate when the overlying lacquer was colored by the higher density red pigment mercury sulfide or when there were decorative metal inlays. We had the best results in these cases by increasing the X-ray energy to approximately 200 KV and using lead filters at the X-ray source and lead screens before and after the image plate to absorb scatter. Joins seen in the bottoms and tops of boxes studied were generally parallel to the grain direction, as can be seen in the CR in Figure 6b, where the lid of a 17th century Chinese box is made from three pieces of radially cut (rift sawn) wood. This cut, radially outwards from the center to the exterior of the log, was chosen as it results in the most dimensionally stable piece of wood. Textiles were applied to the wood prior to the lacquer as an underlayer to provide stabilization.

With changes in relative humidity, the wood substructure and lacquer layers exhibit different amounts of hygroscopic (moisture) expansion, setting up stresses that can cause cracking.[10] In wood, moisture expansion is greater cross-grain than in the direction of the grain, which

[iii] Replication courtesy of Pamela Vandiver, University of Arizona.

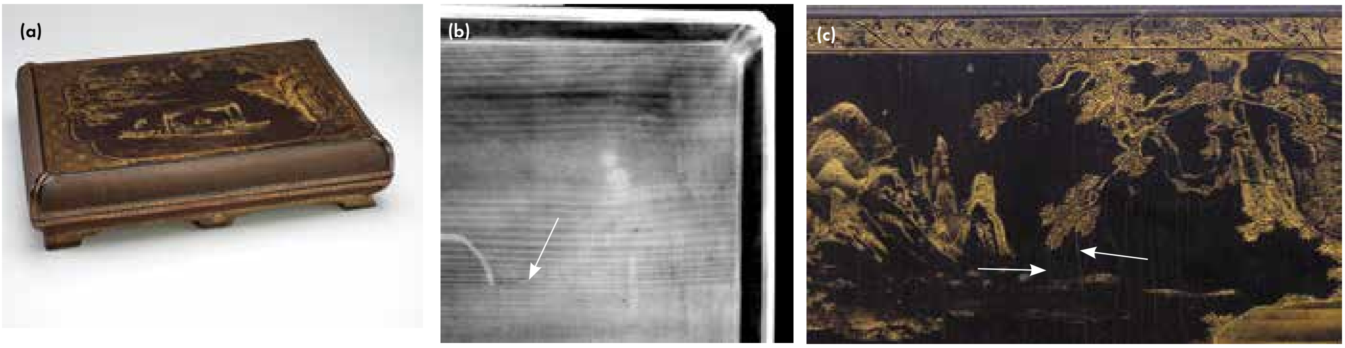


Figure 6. a) Rectangular box with basketry panels and painted design, Late Ming dynasty, probably Wanli reign, first half of the 17th century, H x W x D: 12.8 x 38.9 x 56.2 cm (5 1/16 x 15 5/16 x 22 1/8 in) Freer Gallery of Art F1956.4. b) Computed radiograph of side of lid. Arrow points to join; textile weave is visible as cross-hatching. c) Detail of lid, arrows point to cracks in the lacquer.

exhibits little to no change with changes in relative humidity.

At first glance with the wood constrained as part of the box, one might expect cracks to open in the cross-grain direction of greatest expansion. Yet cracks visible at the surface of the lid of the lacquer box shown in Figure 6c open perpendicular to this direction, suggesting that they did not form due to expansion of the wood. Lacquer also absorbs water and exhibits moisture expansion that must be considered. However, the directional dependence of the wood expansion relative to the isotropic behavior of lacquer is a clue that the wood is involved in formation of the unidirectional cracks.

Wood in the grain direction essentially remains fixed, not expanding or contracting with changes in moisture content. This fixation results in a greater difference in dimensional change between the wood and the coating (lacquer) layers in this direction and greater stress in the coating as compared to the cross-grain direction where the wood also expands and contracts. At some point in the history of the box, the strain in the coating in the grain direction was high enough to result in cracks (Figure 6c). However, the controlling material or layer for the failure cannot be determined without further knowledge. The lacquer box is composed of a complex multilayer composite, and understanding its behavior requires looking at all the lacquer layers and the specific additives in those layers that may affect the behavior of the aged lacquer and thus of the whole.[11]

Conclusion

Noninvasive radiographic techniques allow examination of the entire object and may be used both for initial surveys and for examination of processing techniques in greater depth. In addition to their utility in reverse engineering of processes, radiography reveals what is hidden under the surface. It aids in hunting for root causes in failure investigations. And, these techniques yield valuable information for a range of material types: polycrystalline, glassy, and mixed systems of materials. Commonly available, they are a useful addition to the analytical tool chest.

Acknowledgments

The Smithsonian's Museum Conservation Institute provided access to xeroradiography equipment. Kerith Koss and Ellen Chase collaborated on work on ceramics and Pamela Vandiver and Laure Dussubieux on the Egyptian glass work. I am thankful to Rose Thun, Allison Davies, Glenn Gates, Tim Flaherty, Eileen De Guire, Glen Gaddy, Alison Murray, and Donna Strahan for helpful discussions.

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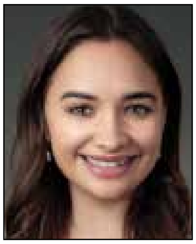
Graduate student survival in a COVID-19 virtual world

By Victoria Christensen



Christensen

Most of us grew up going to school outside the house. Leaving for kindergarten made our parents cry, then leaving for college brought more tears. Going out of our comfort zone is an important part of our growth as individuals. Along the way, we find out how we learn best and how we like to interact with others.

I found through my undergraduate education that I learn best by asking questions and discussing topics with others rather than relying solely on reading textbooks and working independently on assignments. Group projects and presentations are my favorites because they cater to my extroverted personality and my desire to expand my leadership skills.

In the wake of the COVID-19 outbreak, all academic communities are facing unprecedented challenges in re-shaping the education process. Online classes and virtual learning were used previously but were by no means universal like they must be now. Our professors and teaching assistants must find new ways to engage students without traditional in-person lectures, office hours, exams, and discussions.

How do educators ensure their students retain information while maintaining high academic standards? With the collective experience in remote teaching being what it is, some of our professors and teaching assistants will undoubtedly struggle with conveying content.

What can students do to ensure they get the same quality education in this new format? Surely, some level of self-reflection is necessary to make adjustments that work for you. Patience and communication from both sides are going to be crucial.

Speaking as a graduate student who spends a lot of time in the laboratory working on experiments and in meetings discussing results with others, self-isolation and social distancing is not easy. Practicing self-discipline is necessary to remain productive. We do not have a classroom of students surrounding us or an office of fellow graduate students working to keep us accountable.

To fully focus on my online classes, I turn my phone off or keep it across the room. I practice self-discipline by resisting use of other monitors to check email or multi-task in other ways during lecture. I would not be doing that if I was in class, so I should not be doing it now. If this self-discipline is hard for you, turn on your webcam. It is easier to keep yourself engaged when you know your professor and other students can see you listening intently (or not).

Even with the changes in format, graduate coursework remains an important element of our education, providing the foundation of scientific principles that help us contextualize our research findings. My advice to other students is to continue to take classes seriously. Although there will be some adjustment time, we are extremely fortunate to have technology that allows us to continue learning off-campus.

Outside of coursework, most laboratories have shut down, leaving experimentalists questioning what to do next to further their research goals. Personally, I am taking this time to think about the problems I am tasked to solve in alternative ways. For example, I am using mathematical models and existing databases to answer questions I was trying to answer experimentally. I am also using this time to summarize my thoughts and findings in writing. Writing is a task that is always on the backburner for me, and I am thankful that I have this opportunity to catch up.

What's on your backburner? Perhaps it is learning to code, learning a new language, building a better understanding of the literature, or taking steps to advance your professional development goals. Right now is an opportune time to tackle these tasks. After the quarantine is over, we will have taken steps to become more well-rounded researchers.

This time is also opportune to strengthen our relationships and communications with group members and advisors. Outside of virtual group meetings, I have weekly meetings with my advisor to discuss progress in a one-on-one setting. These meetings help to build accountability on my end, as it would if we were meeting in person. Accountability can also be built into regular meetings with groupmates, for example, by doing activities like journal clubs.

Meetings that keep up your social dynamics and friendships are also important. I have regular "Coffee Chats" scheduled with my office mates to simulate the refreshing chats we had in the office. In these meetings, we discuss our well-being, hobbies we are taking up, and goals that we have set for the quarantine period. These meetings remind me that I am not alone in adapting to this new normal.

Finally, maintaining healthy habits outside of work are essential to keeping your sanity during this time. My "normal" routine previously consisted of going to the campus gym early in the morning before heading into the office and spending evenings socializing with different groups of friends at trivia nights, hosting movie/television show viewing parties, and cooking or sharing meals.

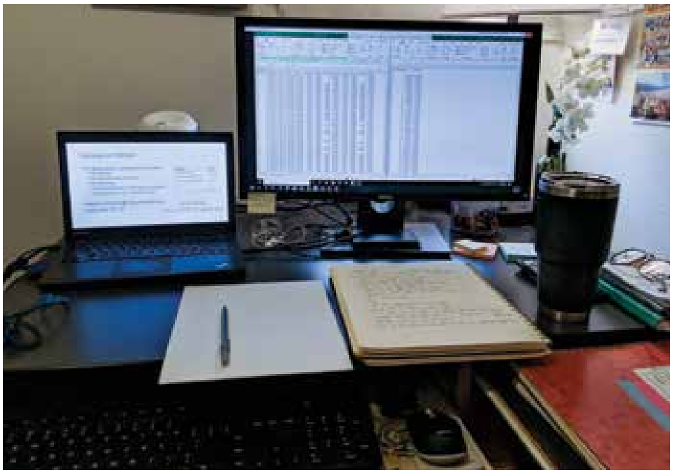
My "new normal" still incorporates exercise, but it now takes place in my apartment in the evenings (so as to not wake my roommates).

Credit: Victoria Christensen

Figure 1. Some members in Frank Zok's research group having our weekly group meeting over Zoom.

I've found new workouts that are fun and challenging and are a refreshing change of pace from my previous routines. Even my roommates join me, adding to the fun of what used to be a solo activity. Being at home also leaves time for cooking new healthy meals (and baking some yummy desserts). Social hobbies are still possible over Zoom, they just take slight adjustments. I joined a book club, started playing video games, and have happy hours with family and friends virtually.

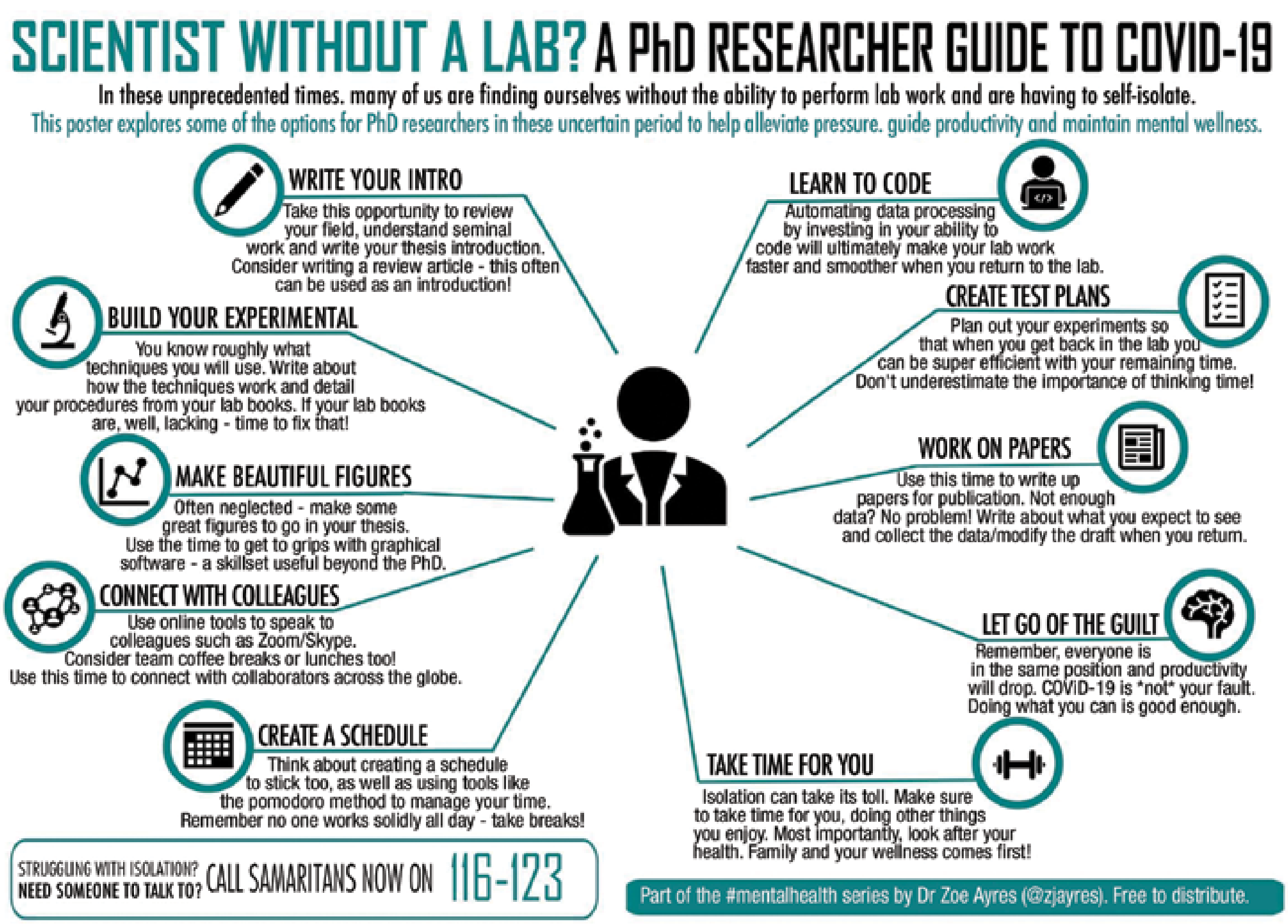
Most materials science graduate students are fortunate to have job security and institutional support for many of their needs during this crisis and should focus on the positive aspects of their circumstances. We can take this opportunity to work on personal growth and to develop skills in communication and self-discipline that we will bring with us throughout our careers. In the process, we will become more well-rounded individuals and researchers. Thanks to virtual communication technology, we can also continue to work toward our long-term well-being by strengthening support networks with mentors, advisors, group members, and friends. When we look back on this time in our lives, we should be proud of the adjustments we made to keep ourselves mentally strong both personally and professionally.



Credit: Victoria Christensen

Figure 2. My personal work-from-home setup.

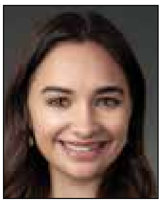
Victoria Christensen is a second-year graduate student at the University of California, Santa Barbara, working in Prof. Frank Zok's research group. Her research focuses on understanding the thermodynamics and kinetics behind oxidation of boron nitride coatings in silicon-carbide-based ceramic matrix composites. She is excited to get back into the lab after quarantine to run experiments and to organize in-person activities with her research group and friends. ■



Credit: Zoë Ayres, Hach Company

Figure 3. An infographic providing more ideas to help Ph.D. students research from home. I find the "letting go of the guilt" topic to be so important!

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



By Victoria Christensen
PCSA Chair

The 2019–2020 PCSA delegates at their annual business meeting prior to ACerS Annual Meeting at MS&T 2019 in Portland, Ore.

Credit: ACerS

In the following pages, readers will find articles that focus on the topic of risk in research.

Risk is inherent to all aspects of the research process, from deciding where to do research to performing the experiments and presenting the results. Student articles cover risks in all these different areas, such as the student who moved from India to the United States to pursue a Ph.D. and the student who has difficulty validating her research experimentally.

Taking risks in research and in life has the potential to lead to "failure." Failure has a negative connotation and, as scientists, we do not often present on or bring much focus to the failures that led to our successful results. To grow into successful researchers, we must redefine failures as learning experiences. Sometimes, looking back at past missteps allows for clearer hindsight of those learning experiences, such as the student who realized her fear of not being able to handle everything hampered her productivity.

ACerS President's Council of Student Advisors (PCSA) believes it is time for students to talk more openly about the risks they take, failures they learn from, and personal achievements they are proud of. We hope that through the student articles in this issue, you can learn from their experiences as well.

The PCSA currently consists of 42 student delegates from 28 universities in nine countries who are all extremely passionate about becoming active, long-term leaders within the ACerS community. The PCSA delegates are dedicated to using their positions to support ACerS mission in "advancing the study, understanding and use of ceramic and glass materials for the benefits of modern society."

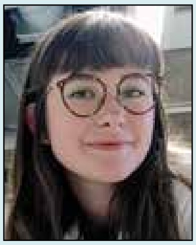
Our main activities for this year, in addition to organizing the student articles in this issue and the "Deciphering the Discipline" articles in every Bulletin, are described below.

- **"Day in the life" of a PCSA delegate**—This project aims to share our diverse backgrounds, research topics, hobbies, and career ambitions through social media channels to inspire younger students, answer questions, and demonstrate how we balance work and life to maintain our mental health. (Follow us @acerspcsa on Instagram for more!)
- **Mentoring program**—This program pairs established ACerS members and young professionals to PCSA delegates and other students in the Society to help students navigate professional development for a career in ceramics and glass, and it allows our more experienced ACerS members to give back.
- **K–12 outreach**—We use the Materials Science Classroom Kits developed by the PCSA and the CGIF to personally interact with K–12 teachers and students in our communities. This initiative is another opportunity for us to share the vision of the Society in the form of fun, hands-on science demos for students.
- **Fostering collaboration**—By collaborating with ECerS Young Ceramists Network, ACerS Young Professionals Network, and ACerS Divisions, we can share opportunities, create diverse networks, and build a pipeline for young leaders to stay engaged within the Society throughout their career.
- **Student conference engagement**—We help make attending conferences less daunting and more exciting and engaging for our fellow students by generating programming like the shot glass competition at ICACC and the humanitarian pitch competition at ACerS Annual Meeting at MS&T, as well as distilling large conference booklets into simple lists of highlights.
- **Travel funding for international students**—The PCSA and the Society as a whole benefit from its diverse group of students from all over the world, so we actively advocate for increased travel funding for international students to make it easier for them to travel to ACerS Annual Meeting at MS&T 2020.

Victoria Christensen is a second-year graduate student at the University of California, Santa Barbara. She is chair of the 2019–2020 PCSA and is particularly passionate about connecting students to Society members through networking and introducing professional development opportunities for students within ACerS. ■

Novel research and the risk in an undersupported conclusion

By Erin Valenzuela



Valenzuela

There are many common elements of risk within scientific research, especially where extreme temperatures are involved. (Such projects face thermal risks regularly.) However, a much unconsidered risk is the risk of the researcher feeling unable to provide the best answer possible to the question being asked.

When working on novel and potentially "blue sky" research topics, there are methods of supporting your work that cannot be taken for granted, such as validation testing. Although the conclusions may be fully supported by literature, the method of fully validating these theories you are executing may not yet exist.

This risk is something that has been a major struggle for my research topic since the very beginning. The current thermal limit of oxide-based ceramic matrix composites (CMCs) is 1,200°C, the temperature at which the grain growth within the oxide fibers causes mechanical failure. The aim of my project is to push these thermal limits to 1,500°C while adding multifunctional elements, such as being thermally dissipating or electromagnetically transmitting, within the system. These multifunctional properties must also operate at these extreme temperatures.

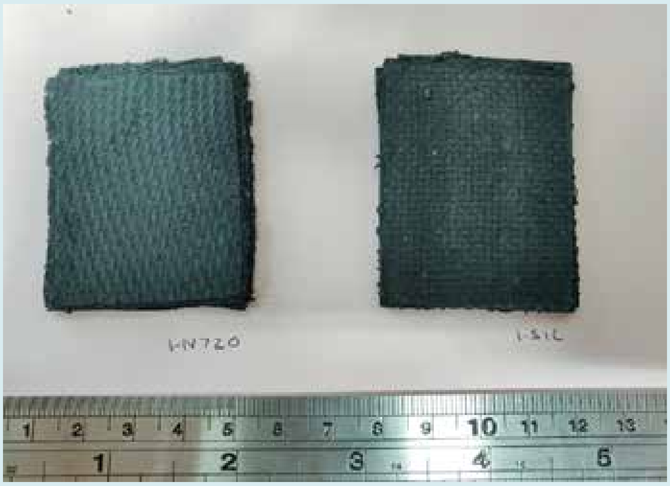
Testing properties of materials at room temperature, and some slightly elevated temperatures, is common practice for most materials scientists. When extreme temperature testing is required, we begin to see limited testing methods coupled with the difficulty of machining ceramics to precise dimensions needed for testing.

The most common practices for these high-temperature mechanical tests are three- or four-point bend tests, which can be conducted within chambers of controlled temperature. However, even these tests have their limits due to the materials from which the precision testing equipment is made.

This limit can be overcome by conducting the mechanical testing after exposing the CMC to temperatures that exceed thermal limits of complete testing systems, i.e., test the CMC after making only it, not the complete testing system, hot. This method of experimentation can be done in increasing dwell times to understand the impact of long-term thermal exposure.

When considering the multifunctional elements of the CMCs, there is no simple way of analysing the desired properties. Some elements can be engineered during processing and will not be impacted by thermal exposure after sintering; however, others will experience changes.

If we consider the CMC's multifunctional element to be electromagnetic transmission, there are several ways to test this element, such as waveguides, free space, and coaxial probes. Each of these methods is predominantly conducted between room temperature and 200°C, and each method has its own limitations.



Credit: Erin Valenzuela

Figure 1. The continuous fiber reinforced CMC samples that will be subjected to testing for their multifunctional elements.

When elevating the testing temperature of the materials past the operating temperatures of the equipment's measuring components, the results we gain will be neither accurate nor reliable. These problematic results then complicate the conclusions made regarding the material in test but also the ability of the researcher to fully answer their research question. Although the literature and scientific theories may support the decisions made to reach the final product experimentally, the results cannot be reliably attained to corroborate these theories.

As a student who entered into scientific research to assist in large, future scientific projects, being able to fully support a conclusion with experimentation and concluding data is important and something I entered into this project believing I could do. I learned, though, not all research can be fully supported with experimentation—but being able to form well supported conclusions from a wide range of literature and theories is an extremely valuable form of research.

Although conclusions reached this way may feel unsupported compared to other results confirmed experimentally in a project, the conclusion was formed to the best of your ability with the best methods available at the time, and thus is good enough.

Erin Valenzuela is a third year Ph.D. student at the University of Birmingham in the United Kingdom, working with Prof. Jon Binner on novel CMC processing. She enjoys cooking and playing guitar in her free time and uses these to help with her work/life balance.

Student perspectives

Journey of a researcher: Finding pleasure in the pathless woods

By Namrata Nadagouda

Nadagouda

"If we knew what it was we were doing, it would not be called research, would it?"

This quote by Albert Einstein sums up why academic research is a risky venture. Unlike coursework or working in industry, both of which have defined goals, associated deadlines, and a fixed way of doing things, academic researchers tackle open-ended problems, have more flexible time constraints, and, very often, define their own paths.

My research focuses on developing computational methods to draw inferences from observing the events happening around us. So unlike research that requires expensive and extensive equipment to conduct experiments, my research does not put me at huge financial risk—all I need is a pen, paper, computer, and internet connection, items which are readily available on a university campus.

But my research still has its own set of associated challenges. When the problems are open ended, there are no boundaries. So you must define your own boundaries and carve your own path. This approach to solving problems comes with the risk of going down rabbit holes and being unable to find the answers we initially set out to seek. It is very important not to get discouraged by such experiences and to understand the value of the extensive knowledge acquired along the way. The value in doing research comes not only from the end goal but greatly from the journey. And if you remember that open-ended questions will always come with some loose ends, you can move on to different things when certain paths prove unfruitful.

A researcher's journey can be compared to the life cycle of a technology illustrated by the Gartner Hype Cycle (Figure 1). Research is easier in the beginning when you are enthusiastic about getting started, and you reach a high level of confidence ("Peak of Inflated Expectations") very soon with the initial successes. As you dive deeper, things get harder and you might encounter some unsuccessful attempts ("Trough of Disillusionment"). At this point, you need to broaden your horizon and gain wider perspectives. You need to hang in there and, slowly and steadily ("Slope of Enlightenment"), you will reach a steady, comfortable phase ("Plateau of Productivity").

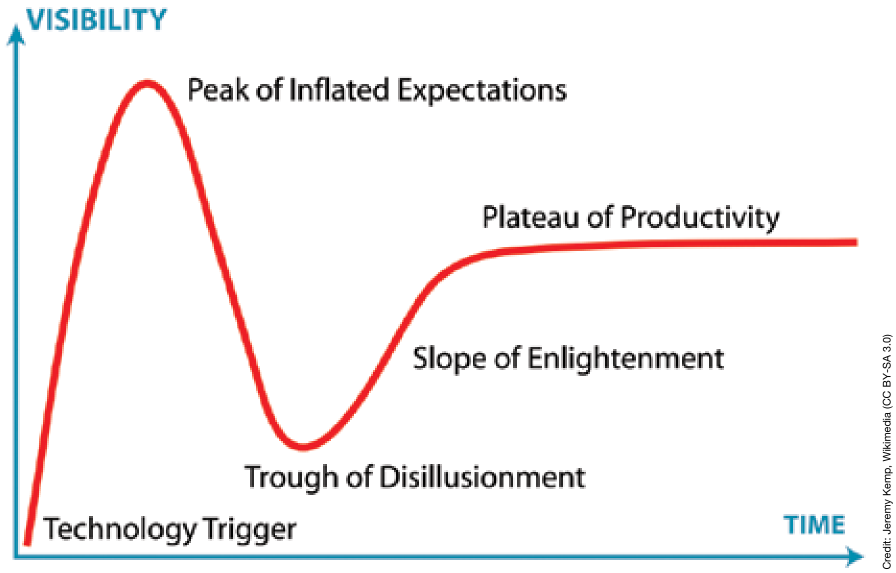


Figure 1. Gartner Hype Cycle.

At the beginning of my second year, I was at my "Peak of Inflated Expectations" after achieving some initial success. I rushed into doing everything that came by without giving the required time and effort. Very soon, I was swamped with things and could not make progress on anything. This rut went on until I realized I had taken upon myself more than I could handle and the fear of not being able to handle everything was hampering my productivity. I had to take a step back to get myself back together. It was a challenging time, but it passed.

Because of the isolating nature, uncertainty, and slower pace of academic research compared to industry, tendencies to feel frustrated, mentally fatigued, and depressed are very common. One way to help with this emotional toll is to have regular exercise and nutritious food. These activities ensure our physical well-being, which has a tremendous impact on our mental health. I am lucky to have found an advisor who gives utmost importance to the overall well-being of his students.

Though people in industry tend to progress faster in terms of their career and personal life, I feel spending the time and effort in academic research will be worth it. And now two years into my Ph.D., I feel I have learned a lot and grown extensively as a person—and as a researcher!

Namrata Nadagouda is a Ph.D. student in electrical and computer engineering at the Georgia Institute of Technology. Her research focuses on signal processing and machine learning. She enjoys cooking, dancing, traveling, hiking, running, and a wide range of sports.

Research—not a bed of roses

By Sadhana Bhusal

Bhusal

With the advent of COVID-19, people are looking to researchers to come up with a treatment plan or vaccine to contain the pandemic. The widespread health, societal, and economic impacts that result from not having this single vaccine demonstrate how important research is.

To achieve successful results, researchers face an arduous journey. The complications start right from the beginning of the thought process and last until the research is finally approved, published, and translated.

Research can be divided into three different phases—early phase, middle phase, and the concluding phase.

The early phase of research starts with brainstorming. Anyone doing research based on their interests and knowledge will not struggle as much during this phase as, say, students working under professors for credit. Without proper guidance, students frustrated at their lack of knowledge may give up in this phase alone. If an idea is successfully developed and proposed, though, pursuing it can be risky if the idea is brand-new because investors may not want to fund something without previous proof of success.

During my first year in graduate school, I had a hard time coming up with a research idea in the field of fluid dynamics. My professor wanted me to find a potential topic that could bring in grants. It was frustrating at times, and it made me wonder if I was a fit for research. But talking to my fellow researchers made me realize I was not alone and, over time, understanding the arcane research papers became easier as my knowledge increased.

The middle phase of research is when research begins. This phase requires vigorous work and focus to overcome the various challenges and failures inherent in doing research. For example, some research requires the use of high-risk equipment and chemicals, so a long exposure in the research environment can be detrimental to health. Also, results from research sometimes deviate from the expected norm, so rework is required to justify or check the procedure. Long working hours are required for some experiments, affecting the emotional and physical health of researchers.

For me, as an international student, working in a country far from home and away from loved ones is a challenge during this phase. When I work long hours and then return to my college housing, sometimes I am too tired even to eat, let alone exercise. However, the support of my family through digital communications and the support of my friends, lab mates, and professors on campus kept me focused and motivated to keep going.

The concluding phase of research is when the research task is complete and is on the verge of publishing. The publication sometimes can take a while, and it is agonizing when someone questions the need for your research or challenges the scientific proposition your entire work is based on. Also, determining the proper place to present the paper—e.g., conference, preprint server—is another challenge. Many conferences happen in faraway places and registration fees are high, causing some people to drop the idea of presenting their results. Even if you have the time and money to travel, if the research is funded by government agencies or industry, the research could be classified, and you cannot present or publish.

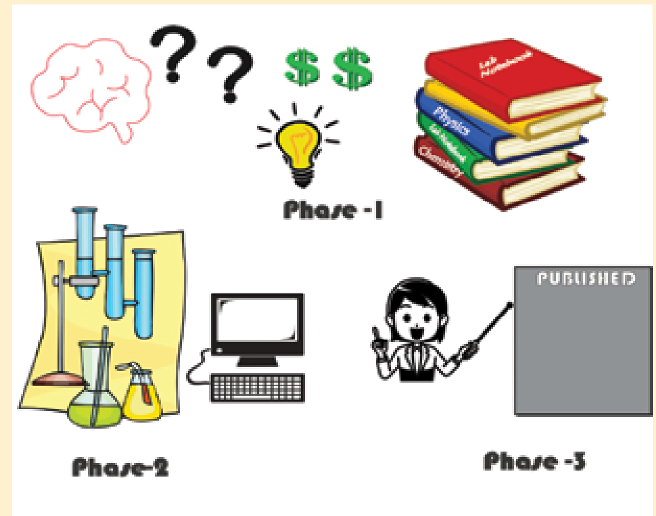


Figure 1. Schematic of different phases of research.

For my first paper related to the computational modeling of plasma sprayed ceramic oxide coatings, I got a lot of comments from the reviewers. I was worried about the comments, but fortunately I was able to address their concerns through revisions. I also remember being nervous during my first conference presentation. I was anxious about questions and comments from the audience, but my presentation was received well, and I was able to get a glance at research on which other people were working.

Research comes with a lot of problems and risks during each phase. But it is one of the most rewarding professions when we see the results drive technological advances that seep into every domain of our lives. To sum up, "Research is formalized curiosity. It is poking and prying with a purpose," as American author and anthropologist Zora Neale Hurston said.

Sadhana Bhusal is a Ph.D. student in the Department of Mechanical Engineering at Oregon State University. Her hobbies are hiking, reading books (especially fiction stories), and watching animated movies.

From full-time job to Ph.D.—The risks of returning to grad school

By Pragna Bhaskar

Bhaskar

I grew up having a very positive and enthusiastic outlook on life, but when I was 30, certain events caused me to lose that spark. A friend who noticed advised me, "Search the depths of your soul. Do something that you had always wanted to do."

My friend's advice prompted me to think about my dreams. In 2008, I had just completed my undergraduate in metallurgical and materials engineering from the National Institute of Technology Tiruchirappalli (India). Like many of my friends interested in research, I wanted to work for my Ph.D. in the United States. However, in Indian culture, such career decisions involve parents. And my parents were not supportive. I did the next best thing—a masters at the Indian Institute of Technology Madras and then a job in the research and development field.

I worked six years in R&D before applying for Ph.D. programs in 2016. My years holding a full-time job prepared me well in some ways for graduate-school life. I was more familiar with research methods and characterization techniques compared to a student who started graduate school right after undergraduate studies. However, there were quite a few risks to consider in returning to graduate school. Most important ones include giving up a well-paying job and leaving behind friends. Despite these risks, I decided to pursue getting a Ph.D.

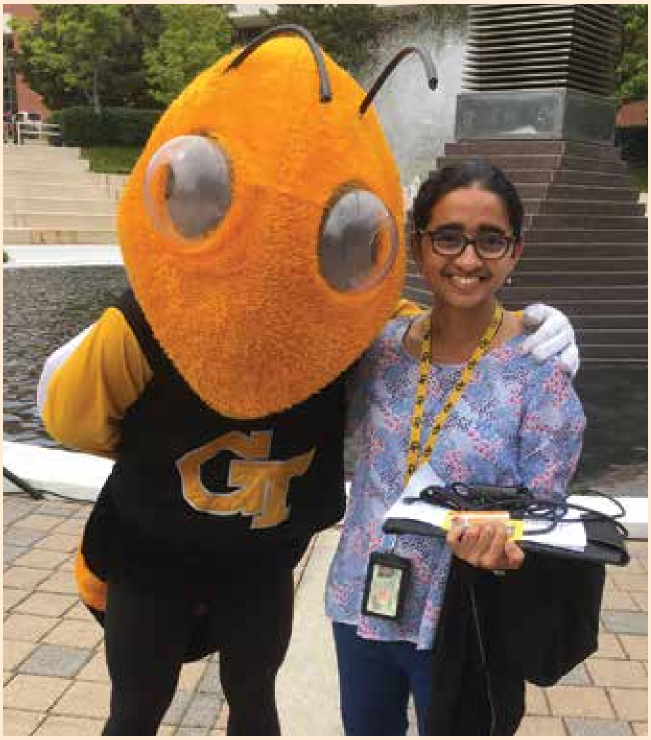
The obvious first step toward a Ph.D. was to take the GRE. It was challenging to prepare for the GRE while working full-time, but all efforts paid off when I got a decent score and was admitted to the Georgia Institute of Technology in 2017.

When I started taking classes at Georgia Tech, I faced a lot of challenges. For example, during the last seven years I was working, I lost my test taking skills. Though I attended lectures and seminars at my job, most of these sessions lasted for less than an hour, and we were never tested on the content. In my first semester at Georgia Tech, I started with three classes. It was hard to focus for more than 30 minutes, and it was even harder to write tests and exams. My test taking skills improved after a while, but it is nowhere close to my skill as a 17-year-old undergrad.

These class-related challenges are unique to me because I returned to graduate school having worked for a long time. But there are many other research challenges faced by many graduate students, such as equipment down time and limited funding available for projects, that I was already familiar with from my time in R&D.

"Two roads diverged in a wood, and I—
I took the one less traveled by,
And that has made all the difference."

–Robert Frost



Credit: Pragna Bhaskar

Figure 1. Georgia Tech mascot Buzz is glad to have Pragna back in school.

Was it worth coming to grad school despite these challenges? I find it worthwhile because I feel it is better to face challenges than to regret not having tried to follow my dream. If I do not have the courage and the conviction to follow my dreams, who else will? A quote from an Indian scripture inspires me in times like these:

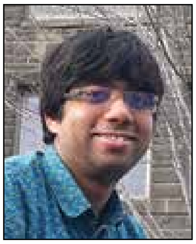
"A man must elevate himself by his own mind, not degrade himself. When a man does good deeds and improves his life, he is own friend. If he does something negative, he is his own enemy." Chapter 6, Bhagavad Gita

Someday when I receive my degree in the McCamish Pavilion at Georgia Tech, I know for certain that every struggle will be worth it. The last lines from Robert Frost's poem "The road not taken," which I read way back in middle school, give me some hope.

Pragna Bhaskar is pursuing her Ph.D. in materials science and engineering at the Georgia Institute of Technology. She worked as a scientific officer at the Indira Gandhi Centre for Atomic Research in India before returning to graduate school. Outside the lab, she likes reading fiction, traveling, and photography.

Pursuing Ph.D. in the United States: Will the risks lead to ultimate satisfaction?

By Arjak Bhattacharjee



Bhattacharjee

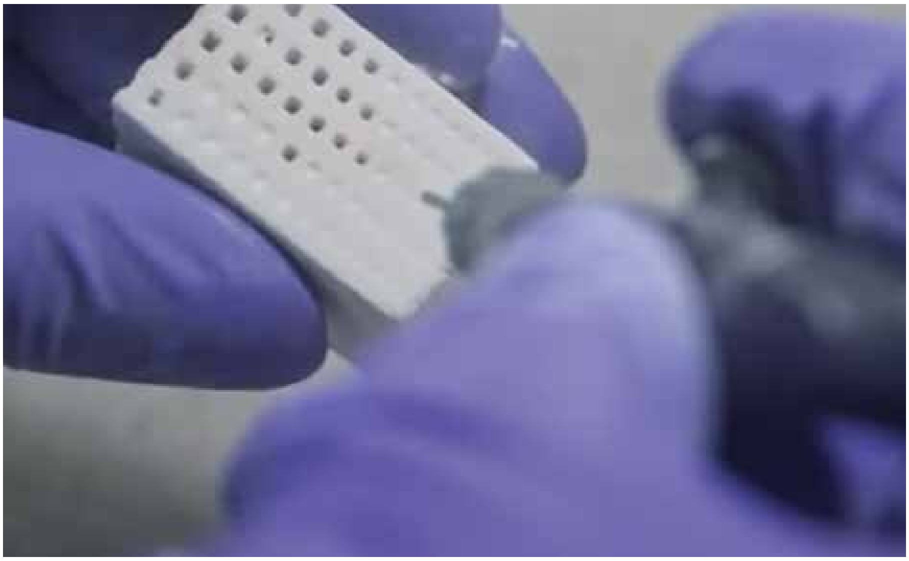
Doctor of Philosophy—Ph.D. Is it just a degree or simple phrase? Or is it something unique, describing the dreams of countless individuals? To find the most accurate answer, we have to dig a little bit about what actually is meant by research, one's dreams associated with it, and how research in a particular field can take a major role in shaping the face of humanity.

I am currently a second year Ph.D. candidate in the School of Mechanical and Materials Engineering at Washington State University. I come from a liberal Indian family who lives in the eastern Indian state of West Bengal. I moved to the United States for the purpose of higher education in 2018.

For many Asian researchers, pursuing a Ph.D. in the U.S. is a kind of heart calling, but few are blessed enough to achieve it. In the era of globalization, there is not much difference in research quality among universities and research organizations of equivalent standards around the world. However, the U.S. still is the first choice for most international students when it comes to pursuing a Ph.D. abroad because of its record offering more opportunities for post Ph.D. placements, excellent global recognition, great working environment, and high financial packages.

For me, a U.S. Ph.D. is about more than just earning a ticket to the job market. Rather, it is a lifelong experience to learn the cutting edge research works going on in my field and to learn the work ethics and professionalism, which will surely help me in any field I choose in the near future.

The first risk of pursuing a Ph.D. in the U.S. is to be accepted. Only a few Indian and other Asian candidates can secure a U.S. Ph.D. position, which can be attributed to huge competition among Asian students, visa cap per country, and availability of limited scholarships for international students.



Credit: Oneness with the infinite, directed by Arjak Bhattacharjee, produced by IIT Kanpur

Figure 1. Representative image of porous 3D-printed ceramic scaffold.

From my personal experience, I feel international students must understand the strategy to securing admission from a U.S. institution. A lot of international students think that high GRE and TOEFL scores will confirm admission from a U.S. institution. But I've seen a lot of cases where a candidate with average GRE and TOEFL scores was admitted to a reputed university while a person with excellent GRE and TOEFL scores was rejected from a tier 2. The secret to admission is applying to universities where the student's CV best matches the university's research area and funding. Networking also plays a very important role.

When I came to the U.S., I was very much excited to work on 3D printing of biomaterials for orthopedic application. I was quite lucky to receive confirmation about my research area when I got the offer letter—for many other students, they choose their research area only after joining the university.

3D printing currently is a very nascent field of research in many nations, including India, but it is quite mature in the U.S. 3D printing is expected to bring the fourth industrial revolution in manufacturing, biomedical, and many other sectors. Hence, having a hands-on expertise of 3D-printed biomaterials will help me to grow as a researcher, and I'm hopeful I will be able to apply my knowledge for the benevolence of humanity.

Though I have successfully navigated several challenges in pursuing a Ph.D. in the U.S., there are more risks in the future I will need to face, including securing a work permit visa, sponsorship, and job after graduation. But I feel the experience gathered in a foreign country is a life-time asset and will help me to grow in any job sector I choose.

I would like to conclude with an ancient Indian proverb, "Vasudaiva-kutumbakam," which means the whole world is a single family and we must grow together as a family to make this world a better place.

Arjak Bhattacharjee is a second year Ph.D. student at Washington State University. He is working with Prof. Susmita Bose and Prof. Amit Bandyopadhyay on additive manufacturing of ceramic-based implants for orthopedic applications. Apart from research, he is highly passionate in several leadership and humanitarian activities and in communicating science through documentaries. ■

Ceramic research in India: Unraveling the technicalities of entropy stabilized oxides

By Varatharaja Nallathambi

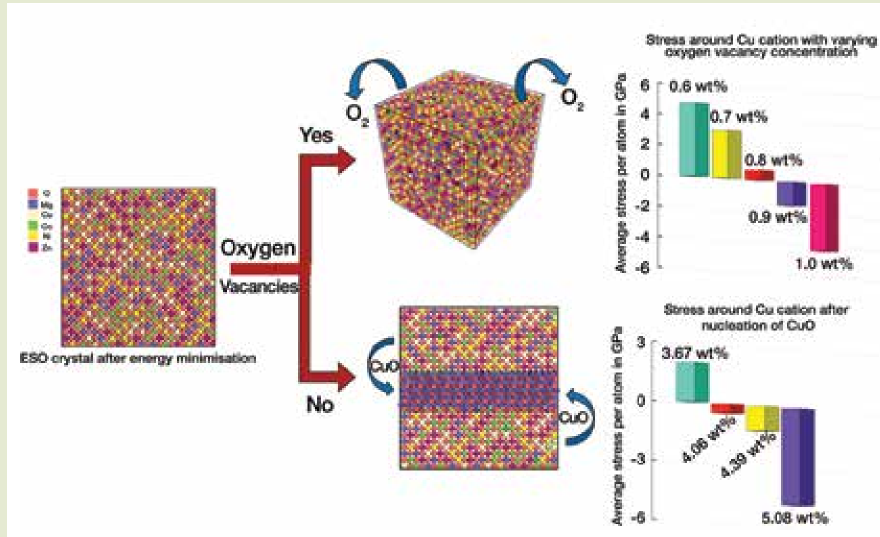
Nallathambi

When I began my M.S. in materials engineering at the Indian Institute of Technology Madras (IIT Madras), I was not well aware of the fields and opportunities to perform research in materials science because my undergraduate degree was specialized in metallurgical engineering. But after many intriguing discussions with several research scholars, I realized the field of ceramics—particularly precursor derived ceramics—piqued my curiosity.

My research deals with a fairly new ceramic material system, entropy stabilized oxides (ESOs). The possibility of altering the phase stability of solid solutions through precise control of configurational entropy introduced us to the new material system of high entropy alloys (HEA) in 2004. The concept of HEA was extended to nonmetallic systems in 2015, when Rost et al. synthesized and reported the first ESO system, $(Mg_{0.2}Ni_{0.2}Co_{0.2}Cu_{0.2}Zn_{0.2})O$.[1]

The particular system reported by Rost et al. is interesting. Recent research has revealed its characteristics, such as low thermal conductivity, high dielectric constant, and high lithium ion conductivity. These characteristics make it a suitable candidate for two-step thermochemical water splitting processes with reduced temperatures, reversible energy storage devices, and thermal barrier coatings, among other applications.

My research focuses on investigating the interplay between phase stability, segregation, and local stresses in nanocrystalline entropy stabilized transition metal oxides (Figure 1).[2] By playing with the thermal treatments, we found the thermal conductivity of the system can be reduced further without compromising on the elastic modulus. This ability serves as an important criterion for the system's applicability as a thermal barrier coating.



Credit: Bhaskar et al., Journal of the American Ceramic Society

Figure 1. Schematic illustration of interplay between oxygen vacancies, local stress, and phase segregation in (MgNiCoCuZn)O ESO.

Though summarizing my research results is easily done, the steps taken to collect those results were not. When dealing with a new material system, understanding its phase evolution will consume an indefinite amount of time. To study the phase stability, we needed to perform a series of systematic heat treatment studies with varying composition and temperature. We experienced difficulties in optimizing the process parameters for a new synthesis method called solution combustion synthesis.

There was a situation in which we needed to perform simulations using molecular dynamics to understand the role of cationic local stresses in the stabilization of ESO. As an experimentalist, I faced several difficulties in understanding the nitty-gritties of these computations. I also faced challenges using the LINUX operating system to perform the simulations, such as learning the right commands to get the simulations running without errors, because it was my first time working with LINUX. Fortunately, with substantial support from my colleague—and with access to sufficient computational resources from our supercomputing facility (P.G.Senapathy Centre for Computing Resource)—I was able to cope.

Constant motivation and support from my supervisor, Prof. Ravi Kumar, also helped me to cope with difficult times. His guidance toward approaching a scientific problem and his insights on the perception of results revamped my research career. Discussions and collaborations with my colleagues also helped me to progress in my research. Based on the constant support I received along with fruitful learning experiences, I can boldly vouch that my choice of pursuing research in IIT Madras was well founded, and I am looking forward to expanding my knowledge in the years to come.

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[2]Bhaskar, L. K., Nallathambi, V. & Kumar, R. Critical role of cationic local stresses on the stabilization of entropy-stabilized transition metal oxides. *J. Am. Ceram. Soc.* **103**(5), 3416–3424 (2020).

Varatharaja Nallathambi is pursuing his M.S. degree under the guidance of Professor N. V. Ravi Kumar in the Department of Metallurgical and Materials Engineering at IIT Madras. His research work mainly focuses on ceramics for energy, environment, and structural domains. Besides research, Varatharaja is passionate about photography and enjoys playing volleyball and badminton.

CERAMIC MANUFACTURING
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NEW DATE

SEPT. 22–23, 2020

The inaugural Ceramic Manufacturing Solutions Conference (CMSC) will feature practical programming covering solutions to critical aspects faced by the ceramic manufacturing community. CMSC 2020 will be held at Cleveland's I-X Center in conjunction with the Ceramics Expo.

THE 2020 CMSC PROGRAM WILL FOCUS ON THREE IMPORTANT AREAS:

Session 1. Testing, Quality, and Health & Safety

Session 2. Raw Materials

Session 3. Ceramic Processing

Conference registration includes 1.5 days of technical programming, a networking reception on Wednesday evening, and a networking lunch on Thursday. All events occur in the Ballroom at the I-X Center in Cleveland, Ohio.

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PLENARY SPEAKERS

Prof. Edgar Zanotto
Professor of Materials Science and Engineering, Federal University of Sao Carlos, Brazil
R&D on vitreous materials in the Americas: Current efforts and a look to the future

Prof. Darryl Butt
Dean, College of Mines & Earth Sciences, University of Utah, U.S.A.
The science of art: Metaphors on the value of diversity

Prof. Peter Littlewood
Department of Physics, James Franck Institute, and the College Fellow, Institute of Molecular Engineering, University of Chicago, U.S.A.
Functional materials for battery technologies

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

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

Panama FMAs 2020

The technical program consists of a wide range of invited and contributed talks and poster sessions important to ceramic and glass professionals who live or do business in the Americas. It will provide an information exchange on the latest emerging technologies and facilitate open dialogue and discussion with leading experts from around the globe. The conference fee includes lunch each day, two receptions, a conference dinner, coffee breaks, and more.

PUBLISHING YOUR PAPER AT PACC-FMAS 2020

Submit your manuscript to the *International Journal of Ceramic Engineering & Science*, the official journal for the Pan American Ceramics Congress, which replaces conventional Proceedings. *IJCES* is the ACerS-approved, open-access journal of sound science and engineering studies, making it ideal for reporting the progress you presented at the Congress. The article processing charge for PanAm presenters is $100 USD, thanks to generous underwriting from Wiley and The American Ceramic Society. Peer-reviewed and accepted papers presented at the meeting dealing with the topic of ferroelectrics will be published in the special volume of *International Journal of Ferroelectrics*.

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ACerS special rates:
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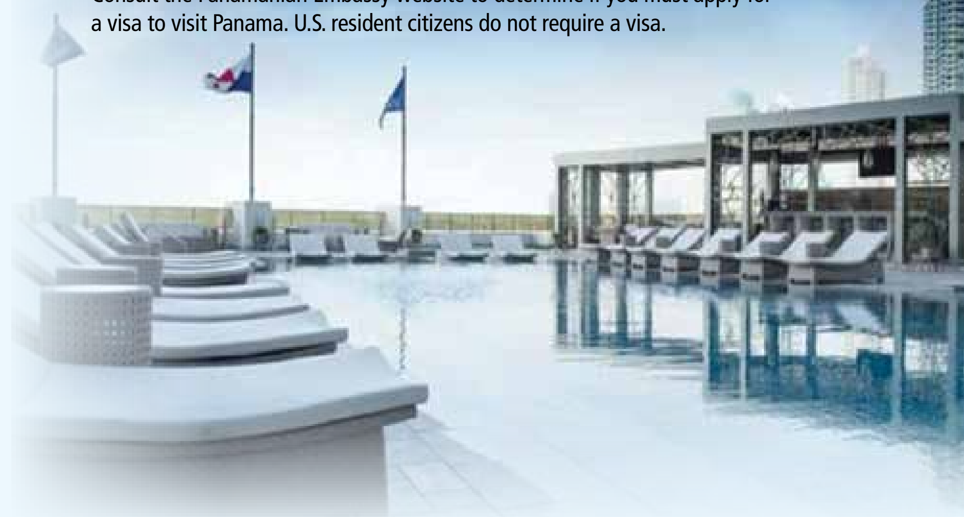
ACerS special rate cut-off date is Oct. 3, 2020.

Visa information
Consult the Panamanian Embassy website to determine if you must apply for a visa to visit Panama. U.S. resident citizens do not require a visa.



PACC TECHNICAL PROGRAM

1. Ceramics for Energy and Environment
2. Advanced Ceramics and Composites
3. Densification and Microstructural Evolution in Ceramics During Sintering
4. Bioceramics and Biocomposites
5. Advances in Cements, Geopolymers, and Structural Clay Construction Materials
6. Refractories
7. Science and Technology of Glasses, Glass ceramics, and Optical Materials
8. Novel, Green, and Strategic Processing and Manufacturing Technologies
9. Symposium for Young Professionals
10. Ceramics for Sustainable Agriculture
11. Materials Approach to Art, Architecture, and Archaeology in the Americas
12. Special Symposium: Ceramics and Materials Education in the Americas (Speakers by invitation only)

– **FERROELECTRICS MEETING OF AMERICAS**

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SCHEDULE OF EVENTS

Sunday, November 15, 2020

Conference registration	3:30 – 7 p.m.
Welcome reception	5:30 – 7 p.m.

Monday, November 16, 2020

Conference registration	7:30 a.m. – 5 p.m.
Opening ceremony and plenary session	8:30 a.m. – Noon
Lunch/Technology fair	Noon – 1:30 p.m.
Concurrent technical sessions	1:30 – 5 p.m.
Coffee break	3:20 – 3:40 p.m.
Technology fair and poster session, including reception	5:30 – 7 p.m.

Tuesday, November 17, 2020

Conference registration	8 a.m. – 5 p.m.
Concurrent technical sessions	8:30 a.m. – Noon
Lunch/Technology fair	Noon – 1:30 p.m.
Concurrent technical sessions	1 – 5 p.m.
Coffee break	3:20 – 3:40 p.m.
Technology fair and poster session, including reception	5:30 – 7 p.m.

Wednesday, November 18, 2020

Conference registration	8 a.m. – Noon
Concurrent technical sessions	8:30 a.m. – Noon
Technology fair	8:30 a.m. – Noon
Afternoon on own	Noon – 5 p.m.
Conference dinner	7 – 9 p.m.

Thursday, November 19, 2020

Conference registration	8 a.m. – Noon
Concurrent technical sessions	8:30 a.m. – Noon

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Calendar of events

June 2020

CANCELED

24–26 ➨ 11th Advances in Cement-Based Materials–Northwestern University, Chicago, Ill.

August 2020

CANCELED

2–6 2020 Glass and Optical Materials Division Annual Meeting – Hotel Monteleone, New Orleans, La.; www.ceramics.org/gomd2020

24–27 Electroceramics XVII – Online conference organized by the European Ceramic Society and Technische Universität Darmstadt (Germany); www.electroceramicsxvii.org

30–Sept.2 ➨ 2nd Global Forum on Smart Additive Manufacturing, Design and Evaluation (SmartMADE) – Osaka University, Nakanoshima Center, Japan; http://jwri.osaka-u.ac.jp/~conf/Smart-MADE2020

September 2020

NEW DATE

8–10 56th Annual St. Louis Section/Refractory Ceramics Division Symposium on Refractories – Hilton St. Louis Airport Hotel, St. Louis, Mo.

NEW DATE

22–23 6th Ceramics Expo – I-X Center, Cleveland, Ohio.; https://ceramics.org/event/6th-ceramics-expo

NEW DATE

23–24 Ceramic Manufacturing Solutions Conference – I-X Center, Cleveland, Ohio; https://ceramics.org/event/ceramic-manufacturing-solutions-conference

October 2020

4–8 ACerS 122nd Annual Meeting with Materials Science & Technology 2020 – David L. Lawrence Convention Center, Pittsburgh, Pa.; www.matscitech.org

26–29 ➨ 81st Conference on Glass Problems (GPC2020) – Greater Columbus Convention Center, Columbus Ohio; https://glassproblemsconference.org

November 2020

8–13 7th Int. Conference on Electrophoretic Deposition (EPD 2020) – Santa Fe, New Mexico; http://www.engconf.org/conferences/materials-science-including-nanotechnology/electrophoretic-deposition-vii-fundamental-and-applications

NEW DATE

15–19 Pan American Ceramics Congress and Ferroelectrics Meeting of the Americas (PACC-FMAs 2020) – Hilton Panama, Balboa Avenida Aquilino de la Guardia, Panama City, Panama; www.ceramics.org/PACCFMAs

29–Dec 3 2020 MRS Fall Meeting & Exhibit – Boston, Mass.; www.mrs.org/fall2020

January 2021

20–22 Electronic Materials and Applications (EMA2021) – DoubleTree by Hilton Orlando at Sea World Conference Hotel, Orlando, Fla.; www.ceramics.org

24–29 45th International Conference and Expo on Advanced Ceramics and Composites (ICACC2021) – Hilton Daytona Beach Oceanfront Resort, Daytona Beach, Fla.; www.ceramics.org

April 2021

NEW DATE

25–30 ➨ International Congress on Ceramics (ICC8) – Bexco, Busan, Korea; www.iccs.org

March 2021

NEW DATE

15–17 China Refractory Minerals Forum 2021 – InterContinental Dalian, Liaoning, China; http://imformed.com/get-imformed/forums/china-refractory-minerals-forum-2020

NEW DATE

27–31 ➨ The Int'l Conference on Sintering 2022 – Nagaragwa Convention Center, Gifu, Japan; https://www.sintering2021.org

May 2021

NEW DATE

16–19 ➨ Ultra-high Temperature Ceramics: Materials for Extreme Environment Applications V – The Lodge at Snowbird, Snowbird, Utah; http://bit.ly/5thUHTC

23–28 14th Pacific Rim Conference on Ceramic and Glass Technology (PACRIM 14) – Hyatt Regency Vancouver, Vancouver, British Columbia, Canada; www.ceramics.org

June 2021

NEW DATE

28–30 MagForum 2021: Magnesium Minerals and Markets Conference – Grand Hotel Huis ter Duin, Noordwijk, Amsterdam; http://imformed.com/get-imformed/forums/magforum-2020

August 2021

29–Sept 2 ➨ 17th European Ceramic Society Conference – Dresden, Germany; www.ecers2021.org

September 2021

14–17 20th Biennial Worldwide Congress Unified International Technical Conference on Refractories – Hilton Chicago, Chicago, Ill.; www.ceramics.org

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

Entries in **BLUE** denote ACerS events.

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

denotes Corporate partner

Ceramic & Glass MANUFACTURING

JUNE/JULY 2020 • VOLUME 1 • ISSUE 3

www.ceramics.org/ceramicandglassmanufacturing

SAFE PRACTICES: CORONAVIRUS AFFECTS CERAMIC MANUFACTURING BUSINESSES—AND PRESENTS NEW OPPORTUNITIES

SHARING KNOWLEDGE ACROSS THE CERAMICS SECTORS—REDUCING BATCH-TO-BATCH VARIATION IN ADVANCED CERAMICS USING PROCESS CONTROL

CASE STUDY: DIGITALIZATION OF AN ITALIAN CERAMIC TILE FACTORY

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INDUSTRY NEWS

Among Showa Optronics' products are optically-contacted polarizing beam splitters.

KYOCERA ACQUIRES OPTICAL COMPONENTS MAKER

Kyocera Corp. entered into a share transfer agreement with NEC Corp. to acquire all of NEC's shares in Showa Optronics Co., Ltd., an optical components manufacturer. Showa will operate as a subsidiary of Kyocera under the name Kyocera Showa Optronics Co., Ltd. Kyocera's optical components business produces lenses used in fields including automotive, office and factory automation equipment, and medical equipment, since Kyocera entered this business in 1983. Showa, established in 1954, has targeted high-value-added markets, including space-related products, semiconductor manufacturing equipment, and medical equipment.

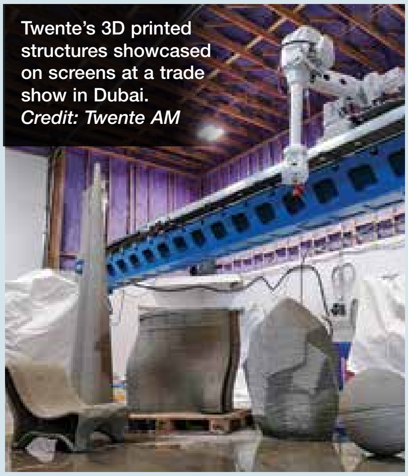
BATTERY CONSORTIUM SEEKS RESEARCH BIDS

The Consortium for Battery Innovation (CBI), which promotes research in advanced lead batteries, seeks research bids focused on energy storage applications, such as microgrids for renewable energy, load following for electrical grids, and demand response for commercial and industrial applications. CBI's technical innovation roadmap, issued last year, set the research goal of increasing the cycle life of lead batteries for energy storage applications by five times to 5,000 by 2022, a key technical parameter for renewable and utility energy applications.

CBI's request for proposals seeks research bids focused on innovation in advanced lead batteries for energy storage applications.

DUTCH STARTUP UNVEILS LARGE-SCALE CONCRETE 3D PRINTER

Twente AM, a Dutch startup focused on architectural 3D printing, unveiled its latest large-scale concrete 3D printer. It was developed and assembled at the company's research and development center in Nelson, Canada. Twente's goal was to develop a concrete 3D printer placed on a gantry-like structure capable of traveling 10 meters wide and five meters high. Parametric CAD/CAM software links directly to the machine to create shapes guided by algorithms. The reach of the printer coupled with its advanced articulation enables shapes that would otherwise be difficult with conventional formwork.



Twente's 3D printed structures showcased on screens at a trade show in Dubai. *Credit: Twente AM*

TOTAL S.A. LAUNCHES ITS LARGEST ENERGY STORAGE SYSTEM

A Total solar power plant in El Salvador. *Credit: Zylberman Laurent – Graphix Images – Total*

France-based energy company Total S.A. will launch a battery-based energy storage project in Mardyck, France. With a storage capacity of 25 MWh and output of 25 MW of power, the new lithium-ion energy storage system will be the company's largest in France. Scheduled for commissioning in late 2020, the storage system represents an investment of around $16.8 million. The project will provide reserve services to support the stability of the French power grid.

POWER METAL RESOURCES TARGETS RARE EARTHS DEPOSITS

The Ditau project may contain commercial deposits of rare earth elements.

Power Metal Resources said it planned to acquire a 51% interest in the Ditau project in Botswana from Kavango Resources. The company said it will fund the acquisition by issuing 35.7 million new shares. Power Metal said the "highly prospective" Ditau project targets commercial deposits of rare earth elements. It said due diligence for the acquisition will begin after the removal of coronavirus-related international travel and work restrictions, or Sept. 1. Power Metals would become the operator of the project following the purchase. Power Metal Resources is a London- based, African-focused metal exploration and development company.

EUROPEAN MANUFACTURERS COLLABORATE ON GREEN FURNACE PROJECT

Twenty European container glass manufacturers have agreed to build the first large-scale hybrid electric furnace to run on 80% green electricity. Called the "Furnace of the Future," it will be a hybrid oxy-fuel furnace running on 80% renewable electricity. It will cut CO_2 emissions by 50%. Ardagh Group, one of the largest glass packaging manufacturers, has volunteered to build the furnace in Germany. It will be built in 2022, with an assessment of results planned for 2023. The next steps will be to select a supplier, apply for a grant to the EC Innovation Fund, and set up a legal entity to manage the project.

The green furnace will cut CO_2 emissions by half.

GCL officials sign an agreement for the plant with the government of Feidong County in Hefei, capital of China's Anhui Province.

GCL TO RAMP UP SOLAR PANEL PRODUCTION

China-based solar manufacturer GCL System Integration Technology is planning to build a solar panel manufacturing plant with an investment of 18 billion Chinese yuan, approximately $2.5 billion. The facility will be built in eastern Hefei province and will have the capacity to make 60GW of solar panels annually. The plant will produce wafers, cells, modules, and other components such as junction boxes, back sheets, glass, EVA and aluminum frames. The plant is expected to increase GCL's panels production capacity by more than nine times.

CORNING PLANTS MEET EPA ENERGY CHALLENGE

Nine more of Corning Inc.'s global manufacturing facilities exceeded energy efficiency goals set by the U.S. Environmental Protection Agency's Energy Star Challenge for Industry program. Corning now has 27 facilities that have achieved the designation. To meet the challenge, industrial sites must increase energy efficiency by at least 10% in five years or less. The sites are: Corning Environmental Technologies plants in Port Elizabeth, South Africa, and Kaiserslautern, Germany; Corning Life Sciences facilities in Bedford, Mass., Salt Lake City, and Warsaw, Poland; Corning Specialty Materials sites in Fairport, N.Y., and Keene, N.H.; and Corning Optical Communications facilities in Gebze, Turkey, and Haikou, China.

Corning's Erwin, N.Y. plant. *Credit: Corning Inc.*

CORONAVIRUS **AFFECTS CERAMIC** MANUFACTURING **BUSINESSES—AND** PRESENTS NEW **OPPORTUNITIES**

By David Holthaus

Faced with a rising number of COVID-19 coronavirus infections, Pennsylvania governor Tom Wolf, like so many other government leaders, issued a stay-at-home order for his state in mid-March. Not long after the governor's order, phone calls and emails started coming in at Du-Co Ceramics' headquarters in Saxonburg, Pa.

Dozens of the family-owned firm's customers called wanting to know if the company would be able to continue supplying the components that are critical to making their products.

"The first call we got was from a company that makes ventilators," says Lora Cooper Rothen, Du-Co's CEO.

Ventilators, of course, have been in high demand as the respiratory illness spread and crippled the ability to breathe unaided for tens of thousands of people. The ventilators were needed to keep them alive, and Du-Co's ceramic components were essential to make the ventilators.

The ventilator maker wanted to double its usual order and wanted it expedited. "We were able to do that," Rothen said.

Rothen's company was able to pivot and meet the demands of its critical customer because of smart practices it had adopted long ago, practices that kept its operations running and its customers happy as the coronavirus pandemic affected the local, national, and global economies.

Manufacturers across the world were forced to respond quickly to business disruptions caused by a crisis unlike any other. Business worldwide essentially came to a halt as companies were ordered to keep their workers at home, if possible, to avoid spreading the highly contagious coronavirus.

Company leaders scrambled to protect their workforces, sanitize their workplaces, put into practice new guidelines on physical distancing, and plan for an uncertain future.

Du-Co has made it its practice to stock up on raw materials, such as alumina and magnesium oxide, which meant it could continue supplying the ventilator manufacturer and its other customers.

"We decided a long time ago that we needed to have the material in-house to prevent any shortages," Rothen says. "We probably have a year's supply of most of our materials in-house."

Many ceramic and glass manufacturers were declared essential businesses during the shutdown, which was a first step in managing through the pandemic.

Columbus, Ohio-based Harrop Industries, for example, makes industrial kilns and other products that are key links in the supply chains that ultimately serve the aerospace, defense, and transportation industries.

When Ohio governor Mike DeWine closed businesses in Ohio in mid-March, Harrop's offices and plant closed for two weeks, and everyone who could work from home did so.

At Du-Co Ceramics, managers served a pizza lunch to employees to boost morale. From left, Mike Crytzer, VP operations; Brel Saiber, general manager; and Tom Arbanas, president. *Credit: Du-Co Ceramics*

When the workplace reopened, physical distancing guidelines were in place to keep employees at least six feet from each other. In the plant, however, following those guidelines has been challenging and has slowed production, says Steve Houseman, Harrop president.

Steve Houseman
Harrop president

"When we're working on a kiln, building a kiln, there are times when people need to be close to each other," he says. "We've tried to adapt to that and keep people six feet from each other. That has slowed us down quite a bit."

To keep its employees safe, the company has reengineered some manufacturing tasks using only one worker where two were used before, or alternating workers, he says.

That's been difficult in the manufacturing areas at Reno Refractories, too, says James Hemrick, senior research engineer at the Morris, Ala.-based company.

The company produces refractories as well as finished shapes, mainly for the cement and steel industries. In the shape shop, it's been difficult to keep workers six feet from each other and still do their jobs, so the company adopted other safe workplace practices, including having the shop's employees wear full respirators and disposable clothing, Hemrick says.

Employee safety, always paramount in a manufacturing environment, became even more critical in light of the contagion's ability to spread easily. Employees tasked with looking after worker safety took on far-reaching new responsibilities.

"We've had to comply with other companies' safety requirements—our customers'," Hemrick says. "Our safety people have been tasked with that. That's been a whole other layer of added responsibility for those guys."

At Harrop Industries, some manufacturing tasks have been reengineered. *Credit: Harrop*

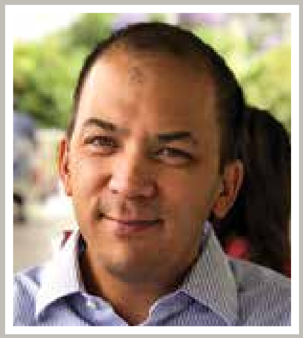
Reno is considering implementing a companywide COVID-19 testing program offered by Alabama's industrial health council. "Being a small business, it's feasible for us to get everyone tested and follow

Reno Refractories is considering a companywide COVID-19 testing program.
Credit: Reno Refractories

Reno Refractories has shelved a couple of capital projects it had planned for this year, Hemrick says. "We're definitely watching our capital and our funds," he says.

The company is focusing on existing business and meeting its current customers' needs, he says.

The same is true at Blasch Precision Ceramics, where the team keeps in touch with customers at least weekly to understand their needs and estimate future orders.



James Hemrick
Reno Refractories

up in a few weeks," Hemrick says. "That will give our employees a little bit of peace of mind."

In fact, compassion and promoting employee peace of mind has become a smart business practice that took on extra importance as employees navigate their workplaces and their daily lives with an invisible germ lurking.

"We're trying to be compassionate to everybody," Houseman says. "People that don't want to be here, we're not going to force them to be during this time."

Some chose to take unused vacation time all at once and stay home, he says.

Like other employers, Blasch Precision Ceramics is checking in more frequently with workers to make sure they feel healthy; has staggered breaks and lunch hours for all three shifts to keep workers at a distance from each other; has asked office staff, engineers and others who can to work from home; and has placed hand sanitizer stations around the office and plant.

"We want to make sure they're not overly stressed," says Keith DeCarlo, vice president of technology at the Menands, N.Y.-based company.

His company, like others, increased the frequency and intensity of plant and office cleaning done by a vendor and has accelerated the plant workers' use of N95 masks and P100 respirators that were already in stock.

The economic disruption caused by the pandemic and the uncertainty over how long it will last made business planning for the long-term difficult. Unnecessary travel was put on hold. Sales calls are being done remotely.

Long-term planning has become nearly impossible. "An annual forecast of markets is a very difficult thing right now," DeCarlo says. "That's a dynamic piece of paper as opposed to something we work to."

At Du-Co Ceramics, the company expanded the number of directors on its board and authorized considerable decision-making to a five-member executive team that is reaching out to insurance brokers, consulting with safety experts, and consulting with attorneys on potential personnel issues, Rothen says.

Because of the upstream position of ceramics manufacturers in the supply chain, many are still working off backlogs of orders. That may change as they look ahead to the second half of the year and the business slowdowns being experienced in the automotive, aerospace, steel, and other industries is felt.

"We've seen this before with a downturn in the economy where we're insulated for a couple of months, but eventually it does catch up with us," Hemrick says.

"Looking down the road, we're certainly going to plan to have less business than we have," says Harrop Industries' Houseman.

Some positive business developments have emerged from the crisis, although, as De Carlo says, "You definitely have to look for them."

Staff at his company became more efficient at administrative tasks, handling paperwork electronically and offsite.

In the production arena, they saw an opportunity to move into the medical equipment market with new high-purity materials its researchers have developed in the last year, he says.

With daily operations slowing, there's more time to focus on innovation.

Researchers at Reno Refractories have been working on a new product line for a couple years and that's taken on a new importance, Hemrick says.

"It's given us a little time to focus on some of that activity on the R&D side, where we don't have to support the day-to-day operations so much," he says.

Du-Co Ceramics prioritized a goal of becoming more self-sufficient, Rothen says. Its executives decided to manufacture more of the firing fixtures it uses and purchased equipment to do that.

That focus on finding new products, processes, and practices is one positive impact that may come about from the COVID-19 crisis.

"It's finding that opportunity," Hemrick says. "There is opportunity here even in the midst of all this."

Keith DeCarlo
Blasch Precision Ceramics

At Blasch Precision Ceramics, employees practice safe physical distancing. *Credit: Blasch Precision Ceramics*

A CHECKLIST FOR REOPENING SAFELY

By J. Douglas Jeter, PE, CSP

Here are some suggestions to help with initial reopening and longer-term preparedness planning in the wake of the COVID-19 pandemic. Best practices are ever-evolving, so be sure to follow current guidelines as set by your local, state, and national health departments.

UPON REOPENING:

1. Post signs at the entrances to your facility to remind people that social distancing protocols are in effect.
2. Make hand sanitizer available around building entry points, shop floors, lunchrooms, office areas, and other gathering spots. Be sure sinks are well supplied with soap.
3. Doors that can stay open without violating local fire codes should remain open, eliminating the need for touching them.
4. Sanitize frequently touched surfaces (light switches, copier, and microwave touch pads, remaining doorknobs and handles, etc.) at least daily.
5. Let employees who can continue to work from home do so, especially those with COVID-19 comorbidities such stroke, lung, heart, or kidney conditions, or those in an age demographic representing increased risk.
6. Stagger shifts to limit exposure of overlapping crews at shift change.
7. To the extent possible, reduce nonemployee access to your facility. Move locations for inbound receiving (including mail) to the periphery of your building.
8. Provide masks, gloves, and hand sanitizer for employees whose role requires public contact, such as field service and delivery personnel.
9. Anyone who travels by air should wear a mask for the duration of their time onboard the aircraft.

LONGER TERM: Since the 2003 SARS epidemic and 1918 Spanish Flu came in multiple waves, it is not unrealistic to expect that there will be some uptick in cases as restrictions are eased and the virus mutates over time. The following steps will help prepare your company should stay-at-home orders be reimposed:

10. Restock the supply of N95 masks, hand sanitizer, disinfectant, gloves, etc., and increase the minimum quantity of these items kept on hand.
11. Address any deficiencies in your remote IT infrastructure that surfaced during the March-April 2020 timeframe, such as issues with remote access to email or servers.
12. Provide training for those not yet comfortable with video conferencing.
13. Along with making your IT infrastructure more robust, make sure your IT security is up to the task. Computer viruses, hacking, and industrial espionage are all too prevalent.
14. Update disaster recovery and business continuity plans to include pandemics.
15. Beyond normal succession planning, consider how the role of key contributors and those fulfilling key positions would be covered in the event of their temporary or long-term absence. This takes on heightened importance for "essential" businesses.
16. Document processes and procedures for any critical functions.
17. Review your Employee Assistance Program. Does it adequately serve the mental health needs of employees in the current environment?
18. Put agreements in place now to secure supply chains in the event of future pandemics.
19. California has an occupational standard (the Aerosol Transmissible Diseases (ATD) standard, Title 8 CCR; Section 5199) for the prevention of worker illness from infectious diseases that can be transmitted by inhaling air containing viruses, bacteria, or other disease organisms. Depending on the work environment, it might be helpful to implement the measures called out in this standard. **https://www.dir.ca.gov/title8/5199.html**

ABOUT THE AUTHOR

J. Douglas Jeter is director of sales and marketing for Harrop Industries.

J. Douglas Jeter at work. *Credit: Harrop*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SHARING KNOWLEDGE **ACROSS THE CERAMICS** SECTORS—REDUCING **BATCH-TO-BATCH** VARIATION IN ADVANCED **CERAMICS USING** PROCESS CONTROL

By Andrew Perry

As ceramic processes leader at Lucideon, I'm in the privileged position of working with a wide range of clients who manufacture and process many different types of ceramics, covering all of the different ceramic sectors from technical ceramics through to building products and whitewares. Although the sectors are very different in terms of the products they produce, the issues they face are often similar with variation in product performance, processing, and yield issues being the key areas of concern.

While many of these sectors have little communication with each other, the Lucideon team, specialists in specific areas who come together to work as one to tackle a client's problems, has in-depth knowledge of challenges across all sectors. What is apparent to us is the very different approaches to processing in the different sectors and how cross-fertilization of knowledge across sectors could help to solve challenges. Simply put, what can they learn from each to improve their processing?

In this article, I'll look at where problems can occur with processing and how the technical ceramics industry might take up lessons learned in the more traditional, clay-based sectors to reduce those problems.

Andrew Perry
Lucideon

PRINCIPAL SOURCES OF VARIATION

For all production processes, the classic areas where problems can be introduced are man, material, machine, and process. Slight variations in each of these areas, and in the combination of these areas, can have a profound effect.

Man

People influence many areas in the process, including the design of the process itself, and the many process controls that are implemented. Starting at the beginning of the process, the operator needs to select the correct raw material and weigh the required quantity of each material to produce a batch, an area where we often see potential for error. Many advanced ceramic manufacturers produce items of relatively small dimension, therefore a "batch of material" may be a couple hundred kilos at the most. Compare this to other areas of ceramics manufacture where batch sizes of several tons are more typical, which

in turn have prompted greater use of automation. The direct effect of an operator weighing out the material, has a number of aspects:

- Correct material,
- Correct material quantity,
- Housekeeping/contamination between materials,
- Following the correct use of instrumentation,
- Testing regime and procedure.

Each one of these areas has the potential to introduce variation irrespective of the final product type.

Process

Process variation covers a huge potential area, for any part of the process that can be adjusted, intentionally or unintentionally, has the potential to cause variation. For example, a spray dryer can be adjusted by various parameters, or the speed at which the product moves through the process can be adjusted—both these would have a dramatic effect on final product performance.

These variables are often used by the many process improvement tools such as Six Sigma, lean manufacturing, and demand flow technology, all of which are excellent tools to benchmark and map the key process variables and the associated throughput by area. In the clay-based ceramic sectors, process design will often require quality control checking at various stages, something that is usually not seen as required when designing a process to produce a technical ceramic.

Material

Raw material type is normally what differs in processing routes and methodology across the ceramics manufacturers, and hence is normally the driver for the different approaches to material control. The term 'raw material' is also used in different ways, depending on how much material processing is performed by each client. For example, one site may purchase a blended suspension or even a dust/granulate, which is called the raw material by that site, whereas another may take individual materials that require further processing and storage, blending them into a slurry or paste with a range of additives and organics. Each component here may be termed the raw material. It is therefore important to understand what is defined by the term raw material.

Batch to batch variation of a single material or blend gives rise to investigations in the following areas:

- Particle size,
- Chemistry,
- Rheological properties,
- Firing characteristics,
- Forming variables.

At this stage, the material specification, and the associated tolerance during further processing, becomes the focal point. It is very common for both nonclay and clay-based manufacturers to find that the mate-

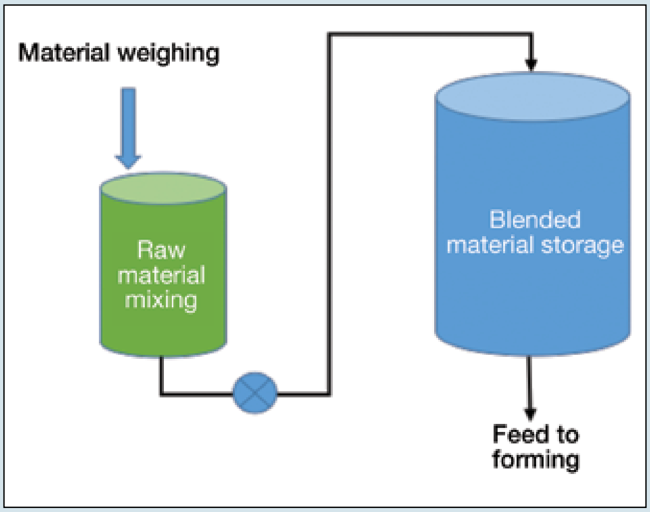

Figure 1. Schematic of typical material preparation for an advanced ceramic suspension.

rial is "within specification" and yet different enough from the last batch to cause problems in a process. This issue is normally because one particular aspect of the raw material is key to a given process and has less tolerance in a specific area than the raw material manufacturer provides. This point may lead to the raw material supplier being able to adjust or blend products for the manufacturer, provided the

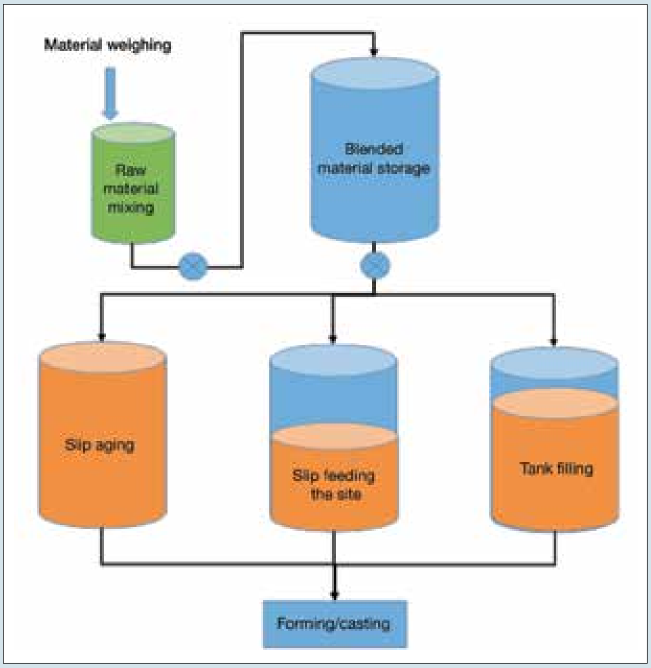

Figure 2. Schematic of typical three-tank slip storage system often utilized within clay-based production systems.

economies of scale make sense, a distinct disadvantage when very low volumes are being consumed, as in the case of the production of technical ceramics.

Raw material specification is normally a function of the level of processing a material undergoes. Materials for technical ceramics may have tighter specifications and higher purity requirements than the clay-based side of the industry. The added complication of particle shape and organics within the clay side of the industry then leads to different approaches to the processing of the required raw materials in the production of a blend.

THE PRODUCTION OF A CERAMIC SLURRY, COMPARISON BETWEEN TECHNICAL AND CLAY-BASED CERAMICS

Figure 1 shows a typical processing route for an advanced ceramic suspension or slip. In this technical ceramics example, the recipe of the blend will include any surfactants and required binders as functions of the dry weight of the primary materials. Here, the purity of all the materials is critical. The materials are blended in the mixer for a given time before being fed to the associated storage tank, often held overnight under constant agitation before being formed.

A similar system is used within the clay-based side of the industry, with additional storage facilities. Larger batch sizes also dominate, which correlates to the daily usage of each material type.

Figure 2 shows an example of the classic way in which clay-based ceramic systems ensure that the rheology of the final slurry is under tight control. The blend is produced in the same manner as with technical ceramics; however, the deflocculants/surfactants are treated as super-additions, such that the addition level can vary. The three-tank rotating system utilizes a feed tank that supplies the site, an aging tank, and a tank that is being filled. The rheology of the slip feeding the "filling" tank has been adjusted to the required target values, the rheology of the slip in the aging tank is monitored and adjusted if required, and the rheology of the feed tank to the process is recorded.

The key reason for the difference between the systems is the state of deflocculation of each ceramic system. Technical ceramics tend to operate with the maximum surfactant level controlling the final viscosity as a function of the solids loading.

Figure 3 shows the deflocculation curve for both clay-based and technical ceramics, plus the typical operating region used to produce the best results during forming.

The graph (Figure 3) shows that the clay-based systems do not typically operate at full deflocculation, and therefore require both measurement and control systems to ensure they are in the correct region of the curve. These differences have also led to a range of different rheology control systems, with technical ceramics being far closer to Newtonian than clay-based. Often, a single viscosity point will be measured at a relatively high shear rate, for example, using a Brookfield viscometer with spindle number 2 or 3, at 70 rpm to record a single viscosity. Clay-based measurement systems will consider the change in viscosity with time, and a range of different measurement systems are utilized, often performed at lower shear rates to allow the material to gel without the measurement device destroying the gel during testing.

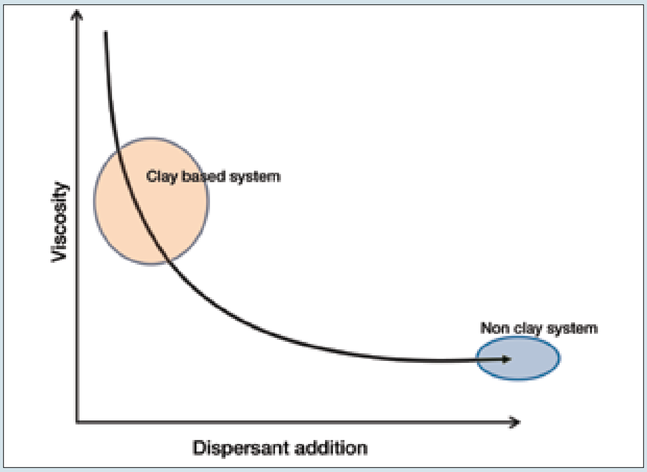

Figure 3. Deflocculation curve representation, showing the deflocculation level utilized for clay and non-clay slip in relation to the viscosity of the associated suspension.

WHERE DOES THIS COMPARISON TAKE US—KEY LESSONS

As with any other industry, process steps and controls are only in place because they have to be. Variation within an individual process is also built into the tolerance of the whole process. For example, a firing curve is normally longer than it needs to be, as is drying, which increases cost and timescales. It is often the interaction between process variations that ultimately leads to production issues. For example, an individual process may be within the agreed tolerance of the measurement system employed, however, that measurement system might not be delivering all the required information to ensure the material is suitable for the whole process. If it isn't, what correction steps are in place?

Six Sigma teaches the importance of measuring the measurement system, via Gauge R&R (reliability and repeatability) and the importance of data itself, especially within the analysis of multivariable systems. The effect of variation from the three key sources—man, process, and material, needs to be quantified with regard to the effect on a given process and its output. To understand this variation, it must be measured, and measured in a repeatable fashion.

In the example of suspension preparation discussed here, the clay side of the industry performs a large amount of rheology testing, and often adjustments associated with each measurement could be argued are a result of variation within the incoming materials, and the fact that the point of deflocculation is critical. On the technical ceramics side of the industry, though, the nature of the materials used and the deflocculation state mean that less variation will occur. While the effects of material variation are therefore rare, there are still man and process variations with which to contend. The lack of relevant testing after each process is often the primary cause of faulty parts. If tests were carried out, information could be used as part of a multi-vary analysis to better understand the most important variables in the system.

The effect of variation on the final product from each source must be evaluated to drive the required process controls, and to determine the key process requirements and capability of each process step. The best-performing sites within the clay side of the industry perform a series of tests after each process step—because they have to. While traditional ceramics manufacturers still have a lot to learn with regard to the correct testing regimes and interpretation of the associated data, in order to optimize processing times and yield, the technical side of the industry could learn a lot from them. Rather than relying on material purity and consistency, more selective and relevant testing could help them to understand the interaction of variation from each stage through the process, and each input variable.

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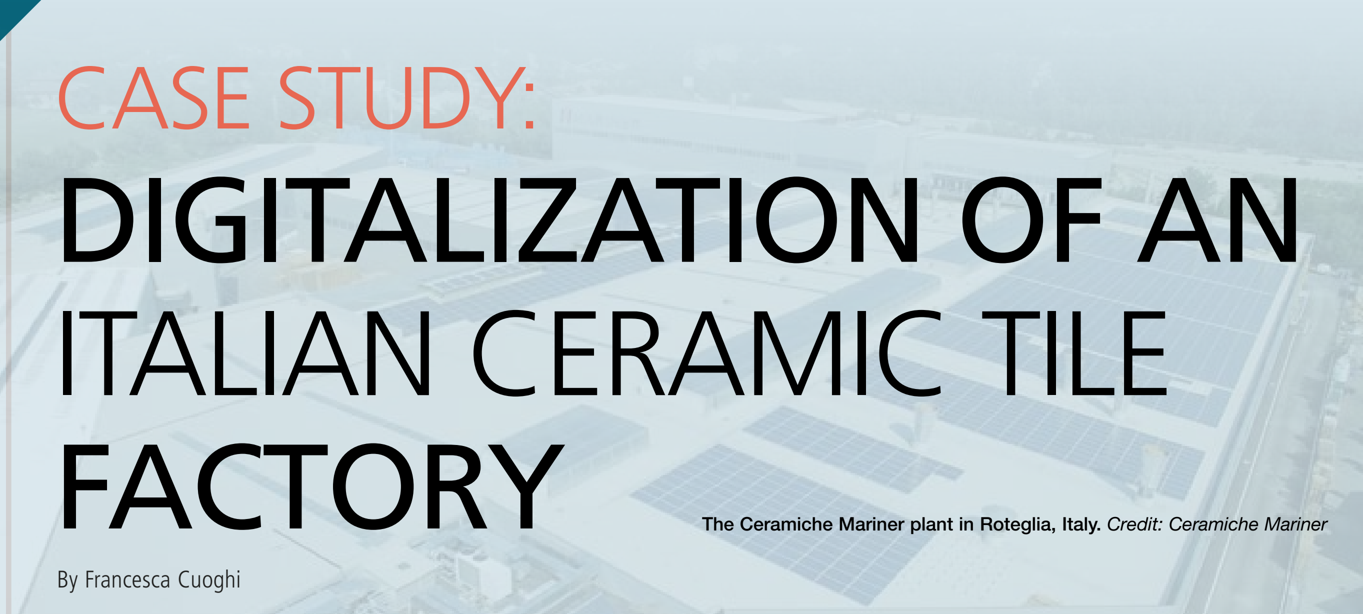
CASE STUDY: DIGITALIZATION OF AN ITALIAN CERAMIC TILE FACTORY



The Ceramiche Mariner plant in Roteglia, Italy. *Credit: Ceramiche Mariner*

By Francesca Cuoghi

The need for production customization, the reduction of lot sizes, and the possibility of producing a unique product are the new challenges facing the manufacturing industry.

The complete digitalization of processes, the use of shared resources, and the efficient management of data are fundamental elements for the development of a new industrial model designed for flexibility and sustainability.

The first completely digitalized factory for the production of ceramic tiles can be found in Roteglia, in the province of Reggio Emilia, in the heart of the Italian ceramics district.

Ceramiche Mariner SpA took on the role of promoter of this new industrial approach, and Prime is the software platform developed by System Ceramics that made it possible to implement this concept of digital manufacturing.

From the processing of raw materials to the finished product, Prime manages the entire production flow through IT systems that monitor the entire process, making use of a latest-generation graphic interface and 3D technologies.

System Ceramics adopted "edge computing" to implement this project. With edge computing, the information technology resources are positioned near the sources of data in a collaborative ecosystem where machines learn from people how to interpret and anticipate relationships between processes, giving rise to possible solutions.

Ceramiche Mariner is an example of horizontal integration and collaborative industry: the new factory represents the evolution toward an open architecture and an example of communication and collaboration that goes beyond the confines of the factory.

The choice to use Prime reflects a new, human-centered manufacturing concept, where the information generated inside the factory, managed and transformed through human intervention from a simple datum to useful knowledge for improving the process and value chain, is at the heart of the industry of the future.

This innovative approach represents a real evolution and transformation of System Ceramics' role. The company, a constructor of systems and machines for the ceramic sector, has become a supplier of cutting-edge services, where the organizational structure and business model are redesigned in keeping with the fundamentals of mechatronics, finding its winning ally in digital transformation.

With regard to hardware, System Ceramics focuses on robotized automation, through which its technologies can change settings via software, without the intervention of an operator.

The company has committed to a process of digitalization for some time to offer customers smart manufacturing solutions that were very complex until recently.

The computerization of production systems, the automatic reconfiguration of machines, and total traceability, besides being a reality today for System Ceramics, achieved success and recognition at an international level among various operators in the sector.

These developments represent a turning point for the ceramics industry. The company, based in Fiorano Modenese, has been a leader in its sector for 50 years, opening up application solutions in the manufacturing world and creating new standards.

"We are proud of what's been done so far and, most of all, of having developed real 4.0 manufacturing in our own territory, with our own workers and with a first-class technological partner such as System Ceramics. We have a 100% digitalized factory, demonstrating a farsighted entrepreneurial vision, envisioning a new way to do business," says Giulia Catti, CEO of Ceramiche Mariner SpA.

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