Celebrating 100 years

AMERICAN CERAMIC SOCIETY

bulletin

emerging ceramics & glass technology

JANUARY/FEBRUARY 2021

Quantum dots and nanocrystal-embedded glasses for display applications

ASTM standard tests for refractories | Federal FY21 budget proposals | Meet ACerS president

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Corrections

In the print edition of the December 2020 *Bulletin*, four companies' emails were listed incorrectly in the advertiser's index on page 59. The emails should be: Glen Mills, https://glenmills.com; Schott North America, https://www.us.schott.com; Verder Scientific, https://www.verder-scientific.com; and Xiamen Innovacera Advanced, https://www.innovacera.com. They are listed correctly in the digital version.

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http://bit.ly/acerstwitter http://bit.ly/acerslink http://bit.ly/acersgplus http://bit.ly/acersfb http://bit.ly/acersrss

As seen on *Ceramic Tech Today*...

Credit: Mario Roberto Durán Ortiz, Wikimedia (CC BY-SA 4.0)

Video: Remembering Arecibo Observatory

On Dec. 1, 2020, the instrument platform of the Arecibo Observatory in Puerto Rico collapsed on the radio dish below. In honor of the observatory's nearly 60-year run, this CTT highlights some of the important discoveries made using data collected from the radio telescope.

Read more at www.ceramics.org/Arecibo

Also see our ACerS journals...

Inversion of quartz solid solutions at cryogenic temperatures
By A. Zandona, G. Helsch, and J. Deubener
Journal of the American Ceramic Society

Influence of glass network ionicity on the mixed-alkali effect
By C. Calahoo, Y. Xia, and R. Zhou
International Journal of Applied Glass Science

Oxide ceramic fibers via dry spinning process—From lab to fab
By H. Scholz, J. Vetter, R. Herborn, and A. Ruedinger
International Journal of Applied Ceramic Technology

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

Read more at www.ceramics.org/journals

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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. 100, No. 1, pp 1– 48. All feature articles are covered in Current Contents.

Eileen De Guire
Editor

A centenary celebration of the *ACerS Bulletin*

Volume 1, Issue 1 of the *ACerS Bulletin* was published May 1922 within the pages of the *Journal of the American Ceramic Society* as "A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical and Scientific Questions and Promotion of Co-operative Research." It was edited by Ross Purdy, general secretary of the Society, with assistance from Society officers and the six industrial Divisions: Art, Enamel, Glass, Refractories, White Wares, Terra Cotta, and Heavy Clay Products.

That first issue focused on the value of Society membership. It also reveals that ACerS was an international society since the beginning—the new member roll included men from Spain, Germany, and Canada. And, yes, back then all members were men. However, as the Society grew and embraced diverse membership, the stated value proposition remains the same now as then:

> "Summing up the advantages of membership to individuals, it can be said in truth that the Society is necessary to the individual if he is to continue his present value or is to increase his value to the concern which gives him employment. A person in the ceramic industry cannot afford to be without a personal membership in the Society."

The *Bulletin* is the archival record of the Society and, now as then, reports on our members' activities, awards, and meetings. The technical articles have changed as our materials science footprint has expanded, and today articles focus on unique uses of ceramic and glass materials to solve the thorniest of grand challenges society faces.

When we created the *Bulletin Archive Online*, *Bulletin* editors—with the perspective of hindsight—categorized that evolution as shown in the table. As we begin a new publishing decade and century, we can already see that data science will be a huge influence on developing the next generation of new materials and applications.

Our theme for Volume 100, Issue 1—Ceramics for display—embraces the tradition of covering cutting-edge research with near-horizon applications. Professor Woon Jin Chung from Kongju National University in Seoul, Republic of Korea, describes his group's work on quantum dots and phosphors for advanced electronic displays.

Future issues of Volume 100 will cover ceramics and glass for sustainable energy, fast processing and characterization, joining of dissimilar materials, AI-driven research, materials for electronics, and materials for flight. Reflecting the expanding global nature of our industry, this year's international profile turns to Africa.

All year we will publish *Bulletin* highlights by decades for readers to follow our industry's progress, from its brickmaking beginnings to the diverse discipline it is today.

It is a great honor to be editor of the *ACerS Bulletin*, but I stand on the shoulders of those who came before me—two of whom were important mentors to me.

My predecessor, Peter Wray, viewed the *Bulletin* as the anchor for a suite of communications for our industry. He started the popular industry-leading *Ceramic Tech Today* blog and e-newsletter that publishes three times weekly. We have since launched *Ceramic & Glass Manufacturing* magazine and e-newsletter. And, our new podcast, Ceramic Tech Chat, traces its origin to Peter's vision.

I owe a debt of gratitude to the late Pat Janeway, who was editor of *Ceramic Bulletin*, 1994–2006. Pat made it her business to know the full spectrum of the ceramic and glass world, including industry, academia, national labs, students, and the international community. Pat's network was unparalleled, and she influenced a generation of ceramic/glass engineers in the pages of the *Bulletin*, including me.

What does the future hold for the *ACerS Bulletin*? Time will tell, but I hope it will continue to showcase the unique capabilities of ceramic and glass materials. I am sure it will continue to reflect the forward-looking science and engineering our members conduct. 100

Decade	Industry focus	Key topics
1920s	Establishing an industry	Clay, glass, brick, efflorescence, porcelain insulators, alumina, spark plugs, glass automobile windows
1930s	Focus on manufacturing	Raw materials, whitewares, refractories, brick, glazes, enamels
1940s	Electronics era begins	Capacitors, ferrites, raw materials, structural clays, refractories, whitewares, glass
1950s	Emerging tools	Characterization, spectroscopy, radiography, properties, coatings, whitewares, structural clays, refractories
1960s	Science-driven discovery	Properties, structure models, kinetics, carbides, nitride, bioglass
1970s	Characterization inspires new applications	Energy generation/storage, fibers, composites, castables, surgical implants
1980s	Space Age ceramics	Space shuttle tiles, engines, solar cells, fuel cells, high-temperature superconductors, bioceramics
1990s	Environmental influences	Sol-gel, nanostructure, joining, coatings, composites, electroceramics, raw materials, spray drying, heavy metals, armor
2000s	Nanotechnology arrives	Nanomaterials, sustainability, international, raw materials, bioceramics, armor, fuel cells, manufacturing
2010s	Pushing boundaries	Nanomaterials, additive manufacturing, modeling, simulation, biomaterials, international, engineered refractories, defects

By Lisa McDonald

Into the Bulletin Archives—A look back at our 100 years in print

Since May 1922, the *ACerS Bulletin* has served the ACerS community, providing them updates on member news, Division meetings, and the latest research in ceramics and glass.

In celebration of Volume 100 this year, the *Bulletin* editorial team is running a special column in each issue of the 2021 *Bulletin* that looks at the history of the *Bulletin* by decade, starting with the 1920s.

We hope you enjoy following the journey of the *Bulletin* from its early years to today. As an ACerS member, you have access to all 100 years of the *Bulletin* on the *Bulletin Archive Online* at https://bulletin-archive.ceramics.org. 100

Into the *Bulletin* Archives—1920s

The first *Bulletin* published in May 1922 and featured a very different layout from the *Bulletin* we are familiar with now. Unlike the current publication, these early *Bulletins* served much more the function of newsletters for Society members—the first programmable computer was still over a decade from creation, and it would take until almost until the turn of the century before emails would break onto the scene. As such, *Bulletins* of the 1920s contained a lot of information we would now search for in online databases, such as the "New Members Received" section, which listed the names, job titles, and locations of new Society members since the last issue.

Of course, the *Bulletin* was never meant to be just an archive for Society activities. A main goal was to provide a new forum for member discussion that could accommodate the ever-growing membership, as explained in the third issue of the *Bulletin*.

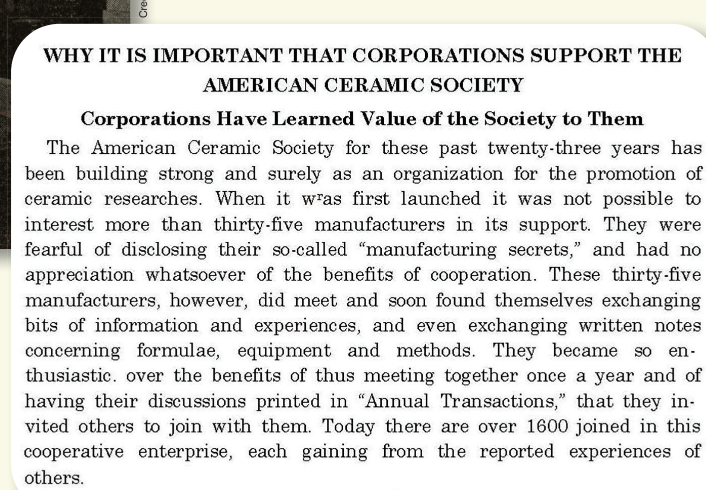
"Necessarily, with the remarkable increase in the Society membership,

1920s

Credit: *ACerS Bulletin* (May 1922) Vol. 1 Iss. 1, pp. 13

▲ The first time ACerS held an exhibition of various ceramic products was during the 24th annual convention in 1922. Pictured above is the Refractories and Terra Cotta exhibit.

As evidenced by this announcement in the first issue of Volume 1 of the *Bulletin*, ACerS cooperated with manufacturers since the very beginning to help support the ceramics and glass industries. ▶



WHY IT IS IMPORTANT THAT CORPORATIONS SUPPORT THE AMERICAN CERAMIC SOCIETY

Corporations Have Learned Value of the Society to Them

The American Ceramic Society for these past twenty-three years has been building strong and surely as an organization for the promotion of ceramic researches. When it wras first launched it was not possible to interest more than thirty-five manufacturers in its support. They were fearful of disclosing their so-called "manufacturing secrets," and had no appreciation whatsoever of the benefits of cooperation. These thirty-five manufacturers, however, did meet and soon found themselves exchanging bits of information and experiences, and even exchanging written notes concerning formulae, equipment and methods. They became so enthusiastic. over the benefits of thus meeting together once a year and of having their discussions printed in "Annual Transactions," that they invited others to join with them. Today there are over 1600 joined in this cooperative enterprise, each gaining from the reported experiences of others.

Credit: *ACerS Bulletin* (May 1922) Vol. 1 Iss. 1, pp. 3

Each issue contained an update on the current sports in which Society members were participating. In addition to more conventional company sports, such as baseball and American football, Society members also participated in sports such as hunting and skiing.

ACTIVITIES OF THE SOCIETY

OH, SHOOT!

Whether the season's sport is rabbit hunting or African golf, the record of the past two months is not to be sneezed at by those who have been taking a rest since the football team disbanded. Evidently a law has been passed prohibiting the bagging of more than one Corporation Member by an individual, and in eight weeks we have only five to show, but the smaller game has been plentiful and fifty-two specimens are ranged in the Secretary's office. W. E. Lemley has proved himself an all-round sportsman and heads the list. Ira Sproat reached up a little way into the sky and pulled down a big bird with one hand and a little one with the other. W. E. Dornbach and M. Ichiyo each came in with two, and thirty-six hunters have one apiece. C. L. Sebring, Geo. S. Tillotson, and A. Weber, Jr., are responsible for the big game. The score card follows:

	Personal	Corporation		Personal	Corporation
W. E. Lemley	4		F. A. Kirkpatrick	1	
Ira E. Sproat	1	1	J. H. Krusen	1	
W. E. Dornbach	2		R. D. Landrum	1	
M. Ichiyo	2		A. Malinovszky	1	
C. L. Sebring		1	C. R. Minton	1	
Geo. S. Tillotson		1	F. K. Pence	1	
A. Weber, Jr.		1	F. H. Rhead	1	
L. R. W. Allison	1		Will A. Rhodes	1	
F. H. Auld	1		R. F. Segsworth	1	
C. E. Bales	1		Mary G. Sheerer	1	
L. E. Barringer	1		C. Saxton	1	
G. H. Brown	1		A. Silverman	1	
Lawrence H. Brown	1		Harry F. Spier	1	
B. M. Burchfiel	1		W. E. S. Turner	1	
R. R. Danielson	1		K. E. Ward	1	
M. S. Gifford	1		R. V. Widemann	1	
R. B. Gilmore	1		W. J. Watkins	1	
Herbert Goodwin	1		W. W. Wilkins	1	
Chas. O. Grafton	1		W. S. Williams	1	
R. K. Hursh	1		Hewitt Wilson	1	
S. M. Kier	1		Office	8	1
R. M. King	1		Total	52	5

Credit: *ACerS Bulletin* (February 1923) Vol. 2 Iss. 1&2, pp. 7

the attendance at the meetings has become a matter of hundreds rather than the few score as at first. The affairs of the Society demand more time; there are more problems, but no more time. ... [In addition,] members who have not been present at the meeting ... have as many problems of vital importance to work out and as many ideas of worth to offer to others but without a medium of expression their aid is impossible.

And so the *Bulletin* herewith presents the opportunity for this exchange of ideas. It is the organ of expression for the fifteen hundred members of the Society. ... This is every member's opportunity to express ideas and ask questions."

–*ACerS Bulletin, Vol. 1., Iss. 3., July 1922*

The "Papers and Discussion" section of the *Bulletin* made up at least half of each issue and included, among many things, case studies on new materials, historical reviews of different manufacturing sectors, and responses to previously published papers. According to an editorial published in December 1929, the last issue of the decade, members greatly appreciated the section.

"We have had very gratifying comments on the value of these abstracts to those who are 'thinking' and striving to accomplish. Several have said that these alone are worth to them many times the annual dues paid."

–*ACerS Bulletin, Vol. 8., Iss. 12., December 1929*

DIVISIONS OF THE SOCIETY

During the 1920s, the Society had seven Divisions.

- Art
- Enamel
- Glass
- Heavy Clay Products
- Refractories
- Terra Cotta
- White Wares

news & trends

Federal budget 2021—Pandemic and election complicate negotiations

By Lisa McDonald

October 1 marked the official start of the United States fiscal year 2021 (FY21). Congress did not complete action on appropriations before the end of FY20 on September 30, so a continuing resolution to fund the government through December 11 was passed and signed by President Donald Trump just hours before the deadline to avoid a government shutdown. At the time of this magazine's printing, a second continuing resolution was passed December 11, again just hours before the deadline, extending the funding through December 18.

The ongoing coronavirus pandemic is complicating efforts to pass this year's appropriations. Since Congress passed a series of four coronavirus response bills this spring, negotiations to pass a fifth bill stalled over disagreements between Democrats and Republicans concerning the total amount of money to include and how it should be allocated. One proposal that both sides are receptive to, though, is including some recovery funds in the legislation for science agencies to address project disruptions.

The fact it was an election year also complicates the negotiation proceedings. The House released the drafts of their 12 appropriations bills this spring and passed most of them over the summer, but Senate appropriators did not release their drafts until Tuesday, Nov. 10, a week after the 2020 presidential election.

The Senate and House bills are similar in many regards, but there are some notable differences. The Senate proposes to allocate billions of dollars in additional spending to the National Nuclear Security Administration and National Institutes of Health. In contrast, the House proposes billions of dollars in one-time "emergency" stimulus spending at the National Institutes of Health and the Department of Energy.

A few highlights from the proposals:

Department of Defense

The Department of Defense's research, development, test, and evaluation (RDT&E) budget would drop by about 1% under the House and Senate's spending proposals for fiscal year 2021, capping off a five-year period in which funding surged from about $66 billion to $109 billion.

Within RDT&E, the Trump administration requested to roll back DOD's portfolio of basic research, applied research, and advanced technology development from $16 billion to $14 billion. The House and Senate bills would only partially overturn the proposed cuts. For example, the Senate proposes an 8% overall cut to basic research that would fall mostly on programs supporting university-based research.

In their bills, the House and Senate propose to channel resources to various high-priority technology areas, such as quantum information science, 5G telecommunications, and directed energy weapons. The House and Senate also propose to increase funding from $21 million to either $30 million or $26 million, respectively, for a recently established program called "Maintaining Technology Advantage," which focuses on developing security policies tailored to specific technologies.

National Science Foundation

House and Senate appropriators rejected the White House's request to shave 6% from the agency's current budget of $8.3 billion. Instead, the Senate and House proposed 2% and 3% overall increases, respectively, to about $8.5 billion.

A notable focus of this year's budget is funding for the National Quantum Initiative Act, which directs the agency to fund between two and five quantum information science centers, each at up to $10 million annually. In July, NSF announced it will evenly divide $75 million over five years among the first three quantum centers awarded in response to the act.

Table 1. FY20 budget proposals ($ in millions)

	DOD S&T total	NSF	DOE Office of Science	NIST	NASA	NIH
FY20 appropriation	16,074	8,278	7,000	1,034	7,139	41,684
White House	14,042 (-13%)	7,741 (-6%)	5,838 (-17%)	738 (-29%)	6,307 (-12%)	38,694 (-7%)
House	15,620 (-3%)	8,548 (3%)	7,050 (1%)	1,044 (1%)	7,098 (-1%)	41,959 (1%)
Senate	15,159 (-6%)	8,478 (2%)	7,026 (0.4%)	1,050 (2%)	7,196 (1%)	43,684 (5%)

Department of Energy

The White House requested to decrease DOE's budget from $38.2 billion to $35.4 billion. Both the House and Senate rejected the request, proposing to increase the total budget to $40.5 billion and $42.0 billion, respectively.

Office of Science: The Senate proposes raising the DOE Office of Science budget 0.4% to $7.03 billion, an increase slightly below the House's proposal of 1% to $7.1 billion. The bills would provide mostly level funding with similar allocations among the Office's programs, except for the Fusion Energy Sciences program, for which the Senate proposes a 5% cut to $640 million and the House a 1% increase. Both the House and Senate propose increasing funding for quantum information science across Office of Science programs, from $195 million to either $235 million or $271 million, respectively.

Applied energy R&D: Both the House and Senate propose mostly level funding for DOE's applied energy programs. However, the House "emergency" economic stimulus proposal also includes $7.78 billion for the Office of Energy Efficiency and Renewable Energy and $1.25 billion for the Office of Nuclear Energy. The House and Senate also differ on their approaches to several reactor projects. For example, the Senate proposes cutting the budget for the planned Versatile Test Reactor irradiation facility from $65 million to $45 million, whereas the House proposes level funding. In contrast, the Senate meets DOE's request to increase funding by $7 million to $30 million for the Transformational Challenge Reactor, whereas the House proposes zeroing out the funding.

National Nuclear Security Administration: In contrast to similar funding proposals in the previous two areas, the Senate's proposed 19% increase to $19.8 billion for the NNSA budget far exceeds the House's proposed 8% increase to $18.0 billion. The NNSA budget generated significant debate this year after disagreement within the Trump administration over its topline request spilled into public view. The dispute triggered competing proposals in Congress to overhaul how NNSA's budget is formulated. In terms of the FY21 budget proposals, the House's lower proposal stems from skepticism concerning the pace and scope of NNSA's plans to modernize the U.S. nuclear weapons stockpile, in contrast to the Senate bill, which fully funds the agency's requests.

National Institute of Standards and Technology

House and Senate appropriators rejected the White House's request to cut the agency's current budget of $1.0 billion by 29%. Instead, the House and Senate propose slight increases of 1% and 2%, respectively.

Both the House and Senate prioritize quantum information science and artificial intelligence, with the Senate specifying increases of $7 million and $4 million, respectively, for each area, while the House proposes increases of at least $8 million and $10 million.

news & trends

National Aeronautics and Space Administration

Despite the White House request to increase NASA's science budget by 12%, both the House and Senate proposed near level funding. The House proposes keeping NASA's budget at $22.6 billion while the Senate proposes a slight increase of 4% to $23.5 billion.

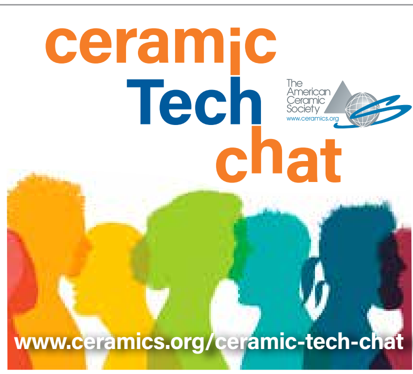
The release of the Senate's proposal for NASA's Artemis program effectively puts an end to the Trump administration's goal of returning astronauts to the lunar surface in 2024. The Senate's proposal of $2.12 billion for human exploration R&D activities exceeds the House's $1.56 billion proposal, but it still falls well short of NASA's $4.72 billion request. A delayed Artemis timeline could free up a Space Launch System rocket for the Europa Clipper's launch in 2025. Both the House and Senate rejected the Trump administration's proposal to terminate two earth science missions (PACE and CLARREO Pathfinder), the Roman Space Telescope, and the Stratospheric Observatory for Infrared Astronomy.

National Institutes of Health

Both the House and Senate's proposed appropriations for the National Institutes of Health would continue the agency's recent string of multibillion dollar budget increases. The Senate proposes a $2 billion increase to $43.7 billion while the House proposes a smaller boost of $275 million. However, the House bill also includes $5 billion in one-time "emergency" funding.

The House and Senate bills would distribute their proposed funding increases relatively evenly across NIH institutes and centers. But the two governmental bodies take different approaches to addressing the COVID-19 crisis. The House stipulates that the emergency funds "may be used to offset the costs related to reductions in laboratory productivity resulting from interruptions or shutdowns of research activity in fiscal year 2020." In contrast, the Senate states its bill focuses on "annual funding needs unrelated to the COVID-19 pandemic" and that it will address pandemic-related needs through separate supplemental appropriations that are passed as needed. However, the Senate does propose to distribute $55 million across NIH's network of 12 Regional Biocontainment Laboratories to support a range of disease outbreak preparedness activities.

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



Meet Carol Jackson

Hosted by ACerS Bulletin editors, Ceramic Tech Chat talks with ACerS members to learn about their unique and personal stories of how they found their way to careers in ceramics. New episodes publish the second Wednesday of each month.

In the most recent episode of Ceramic Tech Chat, chair and CEO of HarbisonWalker International Carol Jackson describes her pathway to becoming the CEO of a global refractories company, the challenges of operating during a global pandemic, and why she believes in cultivating a strong corporate culture.

Check out this preview from her episode, which looks at how HarbisonWalker and the global refractories industry responded to the COVID–19 pandemic.

"When the pandemic first hit and changed our lives... The first order of business was to elevate our position that we were an essential business because you may recall when not only Pennsylvania but other states were declaring that life-sustaining businesses were the ones to remain open and everyone else had to close the doors or go remote. In some states, in some countries, refractories were understood to be part of the critical value chain and essential or life sustaining. But in our case, and specifically in Pennsylvania, we were not. We were not viewed as a life-sustaining business.

So our first challenge, and it wasn't just HarbisonWalker, it was all refractory companies, we were quickly forced to do a lot of PR and a lot of phone calls to legislators trying to influence the decisions that were being made about declaring certain businesses essential.

And then that cause, by the way, became an industry-wide initiative

that the World Refractories Association took on and The Refractory Institute took on. To really advocate for the need for refractory and why if you declare that a steel company or an aluminum company or a pulp and paper company are critical supplies to medical products, for example. Well, in order to make that stuff, you need refractory. So that was really the first order of business."

Listen to Jackson's whole interview—and all of our other Ceramic Tech Chat episodes—at http://ceramictechchat.ceramics.org/974767.

Quantum dot LED lighting and display

By Abhigyan Sengupta

The global quantum dot LED (QLED) lighting market is expected to increase from $156.2 million in 2018 to $1.4 billion in 2024, at a compound annual growth rate (CAGR) of 42.3%. The television segment dominates the market, accounting for a market share of around 70% in 2018. However, during the forecast period, the smartphone QLED display market is expected to experience significant growth, growing at a CAGR of 67.1% to reach $404.0 million by 2024.

Quantum dots are man-made, semiconducting nanoscale particles. QLEDs, which are based on quantum dot technology, outperform organic light emitting diodes (OLEDs) in terms of color reproduction, reliability, cost, and power consumption. At present, the cost of quantum dot production is high compared to that of OLED, but in the near future, this cost will go down due to the development of cost-effective manufacturing methods.

Sales of QLEDs are expected to rise significantly in the main end-use product segments, including

- **Television:** Quantum dot technology does not currently exist in most products and applications, but most researchers and companies are expecting this technology to be commercialized in major applications within the next four to five years.
- **Lighting:** Quantum dot lighting is composed of QLEDs and quantum dot bulbs, among other lighting products. The latest quantum dot-based lights produce light with a color temperature of 2,700 Kelvin—same as that of an incandescent bulb—while also producing 65 lm/W, which is a drastic improvement over the 15 lm/W of incandescent bulbs and on par with that of compact fluorescent bulbs.
- **Smartphones:** The use of QLED displays in smartphones is currently in the research and development phase, but companies are expecting this technology within this major application segment to be commercialized within the next four to five years. Researchers still face some critical issues in incorporating QLEDs to deliver accurate color reproduction, such as balancing compactness with power efficiency.
- **Others:** Optoelectronics is one of the most promising markets for quantum dot technology, and it will prove to be a cash cow for quantum dot companies. Companies such as QD Vision (U.S.), Nexxus Lighting (U.S.), and Evident Technologies (U.S.) already launched their respective products based on quantum dots.

In terms of end users, the hospitality segment takes center stage in the QLED lighting market with a market share close to 40.3%, or a value of $91.3 million in 2019. The consumer segment held a market share of 10.1% in 2018, but this segment is the fastest growing segment in the QLED market and is expected to reach $432.6 million by 2024, growing at a CAGR of 73.5%. The others segment primarily includes solar cells, semiconductor chips, and sensors.

North America held the largest share of the QLED lighting market by region, at $81.4 million (52.1%) in 2018, and it is expected to remain a market leader during the forecast period. Europe, at this stage, is suffering from a debt crisis due to holding a large amount of public debt relative to GDP, so it will take a little time to become one of the major markets for quantum dot applications. In contrast, the Asia-Pacific region is the fastest growing region across the globe in terms of industrial development, technological development, skilled work force, and infrastructure.

About the author

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Resource

A. Sengupta, "Quantum dot LED lighting and display" BCC Research Report SMC121A, February 2020. www.bccresearch.com.

Table 1. Global QLED lighting market, by end use product, through 2024 ($ millions)

End Use Product	2018	2019	2024	CAGR% 2020-2024
Television	109.5	160.8	545.9	27.7
Smartphones	NA	NA	404.0	67.1
Lighting	31.4	56.7	372.4	45.7
Others	15.3	27.7	109.8	31.7
Total	156.2	245.2	1,432.1	42.3

Table 2. Global QLED lighting market, by geographic region, through 2024 ($ millions)

Geographic Region	2018	2019	2024	CAGR% 2020-2024
North America	81.4	117.9	460.0	31.3
Asia-Pacific	36.1	59.4	604.5	59.0
Europe	31.4	57.5	302.5	39.4
Rest of the world	7.3	10.4	65.1	44.3
Total	156.2	245.2	1,432.1	42.3

SOCIETY DIVISION SECTION CHAPTER NEWS

More than just a leadership transition at ACT: Great appreciation for Hua-Tay Lin and Monica Ferraris and great expectations for Young-Wook Kim and his team

Hua-Tay Lin

Monica Ferraris

The American Ceramic Society is honored to recognize the achievements of Hua-Tay Lin, FACerS, and Monica Ferraris, FACerS, the outgoing co-editors-in-chief of the *International Journal of Applied Ceramic Technology* (*ACT*). They leave having created and nurtured this successful journal dedicated to research that moves ceramics from the research bench to the production floor.

Lin and other notable leaders of the Engineering Ceramics Division conceived of *ACT* as a dedicated publishing venue for research beyond basic science, which was lacking at the time. The journal launched in 2004 as a self-published quarterly journal, which ramped up to six issues per year the following year. It now publishes more than 200 articles per year from researchers around the globe.

Inclusion of the term "international" in the journal's title put *ACT* and the ECD at the forefront of ACerS' goal to serve the global ceramics community as one of the most trusted sources of materials and applications knowledge. The Society continues to build on this foundation, launching two more international journals, developing international chapters, organizing international meetings, and much more.

As the founding editor of *ACT*, Lin brought great energy along with abundant respect from and connections to the applied ceramics community. ACerS executive director Mark Mecklenborg recalls that he "could not think of a better person to be the founding editor."

Ferraris joined *ACT* as an associate editor in 2014 and was elevated to co-editor-in-chief the following year. She came with new ideas for making the journal even better and expanded its global standing, especially in Europe. By recruiting high-quality guest editors for special issues along with devising and implementing the fast-track program for accelerating manuscript reviews, Ferraris attracted excellent papers from renowned authors on leading edge topics such as bioceramics, advanced energy, and sustainability. As a result, *ACT* achieved its highest journal impact factor ever in 2019.

Ferraris and Lin contributed so much more to the Society beyond their work on *ACT*. Both led the effort to establish their respective international chapters, Ferraris in Italy and Lin in Taiwan. Both served on the ACerS board of directors. Ferraris is currently serving and is recognized by Society president Dana Goski as "an excellent bridge builder, great with feedback and perspectives, and committed to doing a quality job." The many accomplishments of Ferraris and Lin helped make the Society stronger.

Ferraris and Lin hand over an outstanding journal with positive momentum to Young-Wook Kim, the incoming editor-in-chief. We welcome Kim, who has worked in the background for several months transitioning the editorial process of *ACT*. Joining Kim are three very strong co-equal editors: Amit Bandyopadhyay, Antonio Feteira, and Chang-An Wang. The Society looks forward to Kim and his team having great success guiding the journal into its next phase. 100

Remembering Pat Janeway, former editor of *ACerS Bulletin*

Former *ACerS Bulletin* editor Pat Janeway died on Nov. 27, 2020, after an illness.

Janeway began her long career in publishing at Cahners Publishing Co. in Des Plaines, Ill., as a circulation manager, working her way through the editorial ranks to editor of *Ceramic Industry* magazine. She stayed with *CI* as editor when it was sold first to Corcoran Communications and then to Business News Publishing Co. She came to the Society in 1994 as editor of *Ceramic Bulletin* (now called *ACerS Bulletin*), a role she served for 12 years.

Janeway made the switch to "the other side of the desk" in December 2006 when she took on the role of associate publisher and selling advertising, exhibit booth space, and sponsorships for the *Bulletin*, *ceramicSOURCE Buyer's Guide*, and ACerS various meetings and exhibits. She retired in December 2013.

Having spent her entire career in publishing for the ceramic and glass industry, Janeway knew the industry intimately. Mark Mecklenborg, executive director, recalls, "Pat built and maintained a rich network in the industry. She was an outstanding editor because she really knew our industry and its information needs. Pat was a keen reporter, and she knew exactly who to call for the latest scoop."

As editor, she influenced an entire generation of ceramic and glass professionals. She guided the *Bulletin* through its transformation from a manufacturing emphasis to a broader content profile that included emerging technologies, more emphasis on business trends, and industry perspectives. At the same time, she raised the profile of ACerS members and corporate members. Pat adapted as the internet emerged and disrupted traditional publishing business assumptions, embracing the new opportunities of online platforms.

Janeway's knowledge was invaluable to new staff. "When I first joined the staff, Pat was a mentor, helping me understand not only the Society, but the industry as a whole. She was thoroughly versed in the community, and a good communicator," says Charlie Spahr, retired executive director.

Mecklenborg says, "Pat was an invaluable resource for the Society, but also for the ceramic and glass industry. Her legacy persists today, and we miss her greatly."

more SOCIETY DIVISION SECTION CHAPTER NEWS

A worldwide presentation on the International Year of Glass 2022

The International Commission on Glass (ICG), along with the Community of Glass Associations and ICOM-Glass presented a proposal to the United Nations to declare 2022 an International Year of Glass to underline the technological, scientific, and economic importance of glass. On Dec. 3, Alicia Durán, research professor at CSIC and president of the ICG, led a YouTube livestream presentation to the UN General Assembly. The 30-minute presentation includes a video on the role of glass in building an equitable and sustainable society.

Anticipating adoption of the proposal, extensive planning is underway to celebrate a UN Year of Glass in 2022 with a kick-off event in Geneva, Switzerland, an ICG Congress in Berlin, a worldwide congress on glass technology in Shanghai, and a global art/history congress.

Organizers hope to seed dedicated journal issues and exhibitions in museums, public, and private glass collections, and provide material for universal dissemination throughout education.

To date, planners have received 1,140 letters of endorsements from 76 countries representing art and scientific glass-themed societies; glassmakers, fabricators, and suppliers; academia, R&D centers, and museums.

Documents and information are available on the IYOG website at www.iyog2022.org. The presentation is available at https://www.youtube.com/watch?v=A6ZEaWvlz6k.

ACerS offers members new online communities

ACerS Member Community is a new online community that offers you another way to connect with other ACerS members who share your same interests. You can post questions, seek solutions, and share information in the community and reach hundreds, even thousands, of other ceramic and glass professionals around the world.

Member groups within the community exist for all 11 ACerS Divisions, the Young Professionals Network, President's Council of Student Advisors, and a Diversity & Inclusion Community.

As the name implies, ACerS Member Community is for members only. You must be logged in with your membership credentials to gain access. Simply log in to your current ACerS membership account at www.ceramics.org, and the Member Community link will appear in your homepage menu.

This platform is your place to connect with other members—and a lot more. Make the most of your ACerS membership by logging in and begin making connections with members around the globe. Welcome to your new ACerS Member Community!

IN MEMORIAM

Sunai Dutta
George Gazza
Peter Gielisse
Jyoti P. Guha
Patricia Janeway
N. Eric Johanson
Robert Lowrance
Curtis Mabie
John McNear
Charles Rickey
David Schulz
Min Tsai

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

ACerS to launch two new webinar series

In line with the mission of ACerS to advance the study, understanding, and use of ceramics and related materials for the benefit of our society, beginning January 2021 ACerS will present its new *Frontiers of Ceramics & Glass* technical webinars and *Enrich your Ceramics & Glass* professional development webinars series. The monthly webinars will inspire researchers during the global pandemic, while offering important professional development opportunities for members.

Volunteer spotlight

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

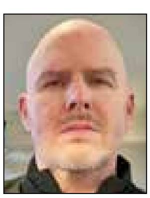
DeCarlo

Keith DeCarlo earned his B.S. (2006), M.S. (2008), and Ph.D. (2011) from Alfred University in ceramic engineering. He also earned an M.B.A. in finance from SUNY Albany in 2015.

DeCarlo is currently vice president of technology at Blasch Precision Ceramics in Albany, N.Y. Research completed under his direction in the Product Development department includes the development of cermets, synthesis of polymeric cryogels, modeling of particle packing, and finite element analysis of chemical reactions at high temperature in the Claus process.

DeCarlo has been an active member of ACerS for more than 15 years and is an active member of the Manufacturing, Refractories, and Basic Science Divisions. He helped lead the creation of the Manufacturing Division as a member of the executive committee, culminating with service as the Division chairperson. Recently, he participated on the advisory board for the Ceramic Manufacturing Solutions Conference.

DeCarlo currently serves on the editorial advisory board for the Ceramic & Glass Manufacturing magazine and the Technical Books Subcommittee. He is also involved in the Young Professionals Network.



Bowman

Keith Bowman is dean of the College of Engineering and Information Technology and Constellation Professor at the University of Maryland, Baltimore County. He earned B.S. and M.S. degrees from Case Western Reserve University and a Ph.D. in materials science and engineering from the University of Michigan.

Bowman is a former ACerS Board member, and he most recently served as the chair of ACerS Diversity & Inclusion Subcommittee and chair of the Multi Society Diversity Council, of which ACerS is a member. He was a panelist representing ACerS at the MS&T20 Town Hall meeting on Diversity & Inclusion.

We extend our deep appreciation to DeCarlo and Bowman for their service to our Society!

St. Louis Section/RCD 56th Annual Symposium on Refractories set for March 24–25

The 56th Annual Symposium on Refractories takes place in St. Louis, Mo., at the Hilton St. Louis Airport Hotel on March 24–25. The theme is "Properties and Performance of Refractory Ceramics – A Tribute to Richard C. Bradt." Plan to attend the kickoff event on March 23. Co-program chairs are Kelley Wilkerson and Jeff Smith (both from Missouri University of Science & Technology).

For complete details about the event including vendor information, registration fees, and hotel reservations, visit https://bit.ly/2021RCDStLouis. Contact Patty Smith at 573-341-6265; fax, 573-341-2071; or psmith@mst.edu with questions.

Thank you, members!

As we welcome a new year, ACerS thanks its members around the world for being a part of The American Ceramic Society. Especially after a year like 2020!

Members are the reason the Society exists. "That's great thing about professional societies like ACerS," says Kevin Thompson, membership director. "Unlike for-profit organizations, nonprofits are owned and governed by the members, with profits given back to the members through benefits and services."

Members are encouraged to get the most value from their membership with these benefits, including:

- 24/7 access to four ACerS journals
- Print and online access to the *ACerS Bulletin*
- *Bulletin Archive Online*—unlimited access to *Bulletin* articles dating back to 1922
- New online ACerS Member Community
- *Ceramic Tech Today*
- Professional development opportunities
- Networking and volunteering
- Opportunities to present your research
- Recruitment and job search assistance
- Professional and peer recognition
- Reduced rates for meetings and products
- And much more!

We look forward to serving our members in 2021 and wish you all a healthy and prosperous new year.

more SOCIETY DIVISION SECTION CHAPTER NEWS

Names in the news

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.

Fleming

Keith Fleming joined Gasbarre Thermal Processing Systems as business development manager.

Haile

Sossina M. Haile, FACerS, was awarded the 2020 David Turnbull Lectureship, which recognizes career contributions of a scientist to the fundamental understanding of the science of materials through experimental and/or theoretical research. Haile is on the faculty at Northwestern University.

Cato T. Laurencin received the 2020 Herbert W. Nickens Award. During his acceptance, he announced the release of

Laurencin

"The impacts of racism and bias on black people pursuing careers in science, engineering, and medicine" by the National Academies, a proceedings from an eponymous workshop he chaired. Laurencin holds multiple appointments at University of Connecticut.

Mauro

John C, Mauro, FACerS, will be inducted into the National Academy of Inventors 2020 Class of Fellows, during NAI's 10th annual meeting in June 2021 in Tampa, Fla. It is the NAI's highest professional distinction awarded to academicians. Mauro is professor of materials science and engineering at The Pennsylvania State University.

AWARDS AND DEADLINES

FOR MORE INFORMATION:

ceramics.org/members/awards

2019–2020 Global ambassador awardees

The Global Ambassador Program recognizes dedicated ACerS volunteers worldwide who demonstrate exceptional leadership and/or service that benefits the Society, its members, and the global ceramics and glass community.

ACerS 2019–2020 president Tatsuki Ohji presented the following 15 volunteers with the Global Ambassador Award.

Csaba Balazsi; Centre of Excellence of Hungarian Academy of Sciences

Ruyan Guo; University of Texas at San Antonio

Vijay Jain; Savannah River Remediation LLC

Young-Wook Kim; University of Seoul

Hagen Klemm; Fraunhofer Institute for Ceramic Technologies and Systems IKTS

Walter Krenkel; University of Bayreuth

Reginaldo Muccillo; Energy and Nuclear Research Institute

Tadachika Nakayama; Nagaoka University of Technology

George Quinn; National Institute of Standards and Technology

Joaquin Ramirez-Rico; University of Seville

Kiyoshi Shimamura; National Institute for Materials Science

Federico Smeacetto; Politecnico di Torino

Gerard Vignoles; LCTS-Université de Bordeaux

Pietro Vincenzini; Council Chair, World Academy of Ceramics

Weimin Wang; Wuhan University of Technology

Last call for 2021 award nominations

Nominations for several ACerS Society and Division awards are due **Jan. 15, 2021**. Nominations are encouraged for deserving candidates from groups that are underrepresented in ACerS awards relative to their participation in the Society, including women, underrepresented minorities, industry scientists and engineers, and international members.

For more information, visit www.ceramics.org/awards or contact Erica Zimmerman at ezimmerman@ceramics.org. 100

ECD best poster awardees from ICACC 2020

The ECD announced the Best Poster awardees from the ICACC 2020 meeting held last January in Daytona Beach, Fla. The awardees will be honored during the plenary session at ICACC 2021. Congratulations to the authors of these award-winning posters!

2020 Best Poster Awards:

First prizes

Growth of high purity zone-refined boron carbide single crystals by laser diode floating zone method
Michael Straker et al., Morgan State University, USA

DFT study of the impact of impurities in sic bulk and grain boundaries
Shawn P. Coleman et al., U.S. Army Research Laboratory, USA

Second prize

Biomass derived carbons and PDC functionalized carbon composite for electrochemical energy storage
Shakir Bin Mujib et al., Kansas State University, USA

Third prizes

Processing and characterizing Al-doped boron carbide bulk ceramic
Qirong Yang et al., Rutgers University, USA

Hydrothermal sintering: a low temperature densification process of ceramics
Lucas Villatte et al., Institut de la Chimie et de la Matière Condensée de Bordeaux - UMR 5026, France

Trustee awards

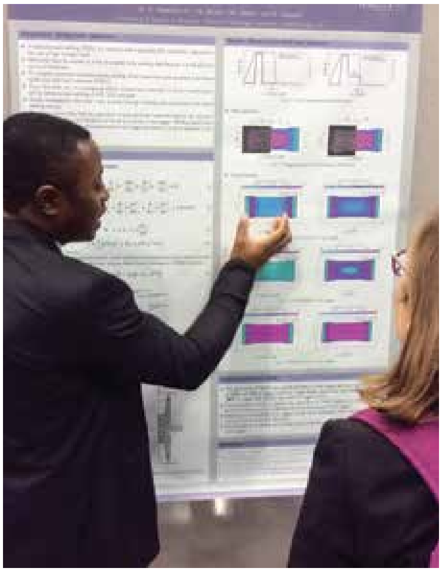
Processing and mechanical characterization of ice-templated alumina-epoxy composites
Justine Marin et al., Old Dominion University, USA

Mechanical properties of spark plasma sintered B_4C
Ruslan Kuliiev et al., University of Central Florida, USA

Partial amorphization and phase control of Cobalt nickel sulfide for an efficient oxygen evolution reaction
Sungwook Mhin et al., Korea Institute of Industrial Technology, Korea

Electric potential change of glasses by polishing with thermally oxide silicon
Ryo Fukuzaki et al., Shizuoka University, Japan 100

STUDENTS AND OUTREACH



Registration open for Winter Workshop 2021?

The 2021 ACerS Winter Workshop will be held virtually on **Jan. 28–29, 2021**. Noted scientists will share progress and perspective in key areas of ceramics research, from additive manufacturing to ceramics for space applications.

Attendees will participate in presentations and group discussions on the topics of diversity, inclusion, and research in a global environment. Participation is limited to 50, so be sure to register today at https://ceramics.org/winter-workshop-2021.

Career resources at your fingertips

Looking for some guidance to help begin or advance your career? As part of the Career Resources site, accessible on the online Ceramic and Glass Career Center, you can connect with expert career coaches and resume writers who can answer your questions and help prepare you for your job search.

The Career Resource Center also provides

- ACCESS to relevant career content to assist with career development,
- MATERIALS to help you prepare for job interviews,
- JOB searching tips, and
- ADVICE on how to efficiently change careers.

Take advantage of these valuable career resources and upload your resume today at https://careers.ceramics.org.

Apply anytime for a PACK fellowship

PACK is a National Science Foundation funded international research fellowship opportunity for graduate students (U.S. citizens or permanent residents only) to conduct research at the University of Kiel, Germany.

Applications are accepted year-round and applicants can be from any science or engineering discipline. Review the PACK website at http://packfellowship.org for more information and to apply.

ACerS GGRN for young ceramic and glass

Put yourself on the path toward post-graduate success with ACerS Global Graduate Researcher Network, the Society's network for addressing the professional and career development needs of graduate-level research students who have a primary interest in ceramics and glass.

GGRN aims to help graduate students

- Engage with ACerS,
- Build a network of peers and contacts within the ceramic and glass community, and
- Have access to professional development tools.

Are you a current graduate student who could benefit from additional networking within the ceramic and glass community? Visit www.ceramics.org/ggrn to learn what GGRN can do for you, or contact Yolanda Natividad, ACerS membership engagement manager, at ynatividad@ceramics.org.

FOR MORE INFORMATION:

ceramics.org/students

CERAMICANDGLASSINDUSTRY FOUNDATION

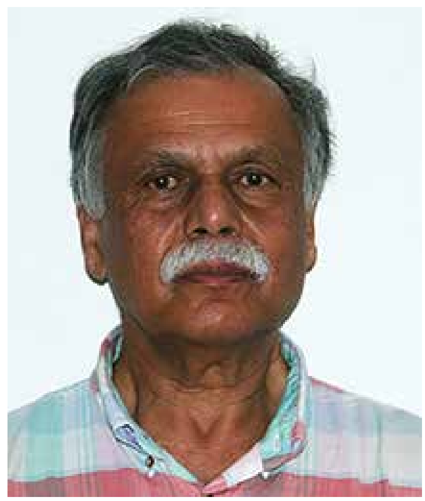
Appreciation of basic science is key to member's generosity

ACerS member Rishi Raj, FACerS, with a career of more than 45 years and counting, has not forgotten his roots in basic science. Although he is known as a pioneer of flash sintering, an emerging subfield in the general area of field-assisted sintering of ceramics, he remains exceedingly grateful for his basic science background.

Raj explains, "I have an interdisciplinary background and very deep commitment to fundamental research and the belief that if the research is really fundamental, then it will certainly have meaningful applications."

It is that appreciation for basic science that inspired Raj to endow ACerS with $100,000 for the establishment of the Rishi Raj Medal for Innovation and Commercialization, which is awarded annually to recognize an individual for an exceptional discovery or invention(s) that can, or have, led to innovative products and/or processes in a field related, at least in part, to ceramics and glass.

The recipient of the Rishi Raj Medal for Innovation and Commercialization receives a medal, $2,500 award, and registration waiver to attend ACerS Annual Meeting.



When asked what inspired him to give so generously to ACerS, Raj says "I've been wanting to do something to promote the Society. I grew up with very basic science and I still do very fundamental work. I also realized that applications and the development of technologies really emanate from fundamental work."

The recently established Rishi Raj Medal for Innovation and Commercialization was presented for the first time in October 2020 to George Beall, FACerS and a Corporate Fellow in Corning's Research Group. Throughout his career, Beall was granted more than 100 U.S. patents and was the first Corning employee to achieve this milestone. He has used cross-disciplinary knowledge of minerals and glasses to create new materials with unusual properties that led to transformational products at Corning.

Raj says, "George Beall is incredible and is just the right person to get this medal off the ground. He came from a very basic science background. I know him, and he thinks in very fundamental ways and is always thinking of applications. I think he is just the right model for this kind of award."

Raj also is deeply committed to outreach to promote materials science through the work of the Ceramic and Glass Industry Foundation and by ACerS reaching out to other materials organizations.

"My desire is to have our Ceramic Society broaden our reach throughout the scientific and technological landscape by continuing to look beyond just ceramics—how we take these materials and use them by connecting ceramics to other materials," says Raj. He explains that outreach is one of the main reasons for donating the endowment for the Rishi Raj Medal. "The emphasis isn't so much on the medal, but rather on the growing culture in the Society to connect with other materials organizations." As such, nominees for the award do not have to be ACerS members.

Raj encourages other members of ACerS to support the broader activities of the Society for the common good, which will benefit our Society in the long term. "I have seen the huge impact that donations have on the direction of programs, because when people give money, as is the case with this medal, they don't just give money but they also provide ideas and energize the institution. It's not just the money, but it is also the commitment and dedication of the donor. Even if someone gives $10, they are still making a statement of supporting the wellness and wellbeing of the Society," he says.

Raj's support of ACerS and the CGIF clearly demonstrates his commitment to the future by recognizing today's innovations while honoring the past and his roots in basic science. 100

Meet ACerS president Dana Goski

By Eileen De Guire


(Credit: ACerS)

As often happens, a series of unexpected opportunities led Dana Goski to a career in refractory ceramics. Originally from Canada, Goski went to college at Dalhousie University (Halifax, Nova Scotia) to study chemistry. After completing an honors degree in nuclear analytical chemistry, her plans for graduate school shifted when funding for a master's degree in nuclear analytical chemistry was delayed. Instead, she went to work on an immediately funded opportunity in physical chemistry.

"It turned out to be a joint project in colloidal chemistry related to ceramic processing with the National Research Council of Canada," says Goski.

From there, she did a Ph.D. in the department of mining and metallurgical engineering, where her group processed natural minerals for incorporation into advanced ceramics. "And that's how I ended up getting into the whole ceramics field," she says.

In 1996, she joined Allied Mineral Products in Columbus, Ohio, while she also wrote and defended her thesis for her Ph.D. at Dalhousie University. Today, she is vice president of research and development.

"I didn't realize the scope and how big [the refractories industry] was and what a critical industry it actually is to making other things possible. The fact that we can impact the future industries is sort of awe-inspiring," she says.

Goski joined the Society in 1995 while a graduate student. Her first ACerS event was the Cocoa Beach meeting (now ICACC), which she attended twice during graduate school, and where she also got to watch two space shuttle launches.

"However, I really got involved and recognized the benefits of networking with other Society members when I moved to Columbus, Ohio, in 1996. The old Central Ohio Section would meet at pubs to plan activities, and that is also where I met our current Society treasurer, Steve Houseman," she recalls.

She has been a member of the Refractory Ceramics Division since 1996 and served in its leadership chain 2006–2007. She served on numerous Society and Division committees and was a Society director 2016–2019. She was elevated to Society Fellow in 2015, awarded the prestigious St. Louis Section Theodore Planje Award in 2019, and the Marquis Award in 2020.

Besides ACerS, she was a leader in UNITECR, the Unified International Technical Conference on Refractories. She is an advisor to the Edward Orton Jr., Ceramic Foundation board of trustees, and is a member of the External Advisory Committee for the Department of Materials Science & Engineering at The Ohio State University.

> **"The future of ceramic and glass engineering is BRIGHT,' and I do believe that," she adds.**

When nominated for Society president, she did not hesitate. "I enjoy leading and participating in organization, opportunity, and planning processes, so it seems fortuitous that this is the year I take the helm. However, I absolutely look forward to our first in person conference and being able to travel safely and easily again," she says. "My tag line and vision for my presidency is, 'The future of ceramic and glass engineering is BRIGHT,' and I do believe that," she adds.

Goski plans to focus her energy on strategic planning, risk management, and expanding the reach of the Society while strengthening its core. Her first goal is to develop and implement a strategic plan by September 2021.

"We already planned the strategic planning process for this year, but the coronavirus pandemic raised the level of urgency to making sure our businesses and business practices are aligned optimally to meet the needs of our members, as well as grow and sustain the Society into the future," she says.

"We'll be looking at how to strategically grow and retool our traditional business areas, such as conferences. ... There's a lot of opportunity, and this process will prioritize how to invest the Society's limited resources optimally," she adds.

Along with the strategic planning exercise, Goski directed a risk management assessment by Society staff.

Goski also will continue work begun by past-president Tatsuki Ohji to support the mission and activities of the Society's Diversity & Inclusion Subcommittee and the International Ceramic Arts Network, the Society's member organization for clay artisans and potters.

Goski, her husband, Keith Souchereau, and their son, Reid, live in Upper Arlington, Ohio. When not working or volunteering, the family enjoys their season tickets to the NHL Columbus Blue Jackets. In nonpandemic environments, they enjoy traveling to historic sites and snorkeling. 100

Highlights from ACerS 122nd ANNUAL BUSINESS MEETING

By Lisa McDonald

Because of the coronavirus pandemic this year, The American Ceramic Society held its 122nd Annual Business Meeting virtually on Monday, Oct. 5, a month before the rest of ACerS Annual Meeting at MS&T took place virtually in November. ACerS Annual Meeting at MS&T brings together members from the whole Society as the meeting's technical content spans all aspects of ceramic and glass science, from refractories and aerospace to bioceramics and more.

Credit: ACerS

Tatsuki Ohji shows off his newly received past president pin, which arrived to him in Japan before the Annual Business Meeting. ACerS past president Sylvia Johnson (top right) says the Society was "very fortunate" to be led by Ohji's "calmness, thoughtfulness, and care for the Society." Dana Goski (bottom right) was sworn in as the Society's next president.

At the Annual Business Meeting, the ACerS president reports on the state of the Society, and the new president outlines plans for the coming year. President Tatsuki Ohji summarized the Society's 2019–2020 accomplishments, including the establishment of a new Energy Materials and Systems Division and the successful pivot to a virtual format for several ACerS meetings.

Treasurer Stephen Houseman reported that the Society's financial position remains stable, and the Society carries no debts. New officers were sworn-in, and out-going officers were recognized and thanked for their service. Incoming president Dana Goski outlined her vision and goals for her year as president (see details on previous page). During her opening speech, Goski noted that she looks forward to continuing improvement of ACerS' online learning programs and continuing to meet the needs of members through virtual/hybrid meetings until we can once again safely hold in-person meetings.

Instead of the usual in-person Annual Awards Banquet, ACerS staff created a special 2020 Virtual Awards Celebration video honoring all of this year's awardees, which include 23 members elevated to Fellow Status and three members awarded the distinction of Distinguished Life Member.

In addition to the Annual Business Meeting, other events that provide updates on different parts of the Society took place virtually as well, including meetings of the Board of Directors, division executive committee and business meetings, and meetings of ACerS working committees and subcommittees. The Society's student leadership group, the President's Council of Student Advisors, also held its annual meeting. This year PCSA includes 43 students from 26 universities, representing four countries.

View the 2020 Virtual Awards Celebration video at https://www.youtube.com/watch?v=7L9sRTTNVeI.

ACerS 123rd Annual Meeting at MS&T21 will take place Oct. 17–21, 2021, in Columbus, Ohio. 100

Tough beetles reveal secrets that could help join dissimilar materials

An international group of scientists used advanced microscopy and spectroscopy to reveal that a mixture of macrostructure and microstructure elements combine to make the diabolical ironclad beetle's exoskeleton incredibly strong.

Materially speaking, their analysis of the beetle's exoskeleton shows that it is composed of aligned chitin fibers in a protein-rich matrix. That matrix has a higher protein content than other comparable beetles, which the scientists speculate contributes to the diabolical ironclad beetle's stunning ability to withstand crushing by forces up to 39,000-times its body weight.

The team specifically focused on a part of the insect's exoskeleton called the elytra, which are two hard, protective blades that armor a beetle's back to protect a set of more delicate wings used for flying. Elytra act like a protective outer door, opening to allow a beetle's wings to extend in flight and then closing to protect the delicate structures when not in use. (To be clear, the diabolical ironclad beetle has lost the ability to fly, but it maintains a set of protective elytra.)

Beyond the material composition of the insect's exoskeleton, the study also shows that macrostructural elements of the elytra also contribute to the beetle's toughness—namely, a series of lateral support structures along the perimeter of the insect's body, and a robust suture that holds the two elytra together.

First, the lateral supports. Located around the edges of the insect's body, these structures help buoy the elytra when the insect is being compressed, preventing its body cavity from being crushed. Stress concentrates around the perimeter of the insect's shell, so these structures provide critical support precisely where it is needed most.

The team's analysis of these structures using computed tomography shows that the diabolical ironclad beetle incorporates three different types of support structures around its shell.

Credit: Jesus Rivera; University of California, Irvine

The diabolical ironclad beetle is tough—in addition to the ability to play dead and a rough exoskeleton that resembles a rock, this little beetle hides some interesting secrets within its exoskeleton that could help design more robust fasteners.

The most robust support structures, located near the front of the insect's body, have an architecture that interlocks and stiffens under strain. These structures are closest to the insect's internal organs, so the interlocking structure provides maximum support to help prevent the insect's guts from being squished when it is compressed.

Supports further back along the shell do not interlock but rather feature a latching design, while supports still further toward the back of the insect's shell are entirely free-standing and feature no mechanical connection.

Research News

'Sparkling' clean water from nanodiamond-embedded membrane filters

Researchers reported that embedding amine-enhanced nanodiamond particles into membranes can purify hot wastewater. Researchers have embedded extremely tiny nanodiamonds onto such membranes in previous studies, but they were not optimized for use with hot wastewater. In this study, the researchers attached amines to nanodiamonds and bathed them in an ethyl acetate solution to prevent the spheres from clumping. Then, a monomer was added that reacted with the amines to create chemical links to the traditional membrane base, resulting in thicker, more temperature-stable membranes. For more information, visit https://www.acs.org/content/acs/en/pressroom.html. 100

A filter for environmental remediation

A team of researchers at Osaka University developed a new method to create highly efficient sodium titanate filters. They used a template-free alkaline hydrothermal process to produce the mats, and they found that increasing the hydrothermal synthesis time caused the initially round crystals to become elongated and fibrous, forming seaweed-shaped mats consisting of the randomly oriented nanofibers. This seaweed-like nanoscale morphology increased the surface area of the mats, which improved the removal efficiency of Co^{2+} during sorption tests. The method is expected to be applied for other purification systems that remove heavy metals and radionuclides from wastewater. For more information, visit https://www.eurekalert.org. 100

Although the team characterized three types of support structures, it is important to note that these different structures are not disparate elements. Rather, they seamlessly transition from one to the next along the length of the beetle's shell, creating variable stiffness gradients.

This strategy of varying stiffness increases the exoskeleton's toughness by not simply allowing it to withstand pressure—it also strategically deflects energy away from critical areas, like where the internal organs are located, to other areas of the exoskeleton that can better dissipate energy without catastrophic failure to the beetle.

In addition to these differential lateral supports, the beetle's two elytra also are stitched together by a robust connection that resembles interlocking puzzle pieces. This architecture binds the elytra together, providing support at an otherwise weak location of a joint in the exoskeleton. This structure also incorporates a unique layered microstructure that prevents localized stresses, another way the beetle strategically dissipates energy to resist crushing.

"When you break a puzzle piece, you expect it to separate at the neck, the thinnest part," senior author David Kisailus says in a UCI press release. "But we don't see that sort of catastrophic split with this species of beetle. Instead, it delaminates, providing for a more graceful failure of the structure."

To confirm that these various scales of structure and architecture account for the beetle's toughness, Kisailus and the team mimicked the beetle's ironclad structures in 3D-printed composite fasteners and tested their mechanical strength in the lab. These tests showed that the beetle-based structures were slightly stronger but exhibited significantly increased energy displacement to avoid catastrophic failure compared to commercial aerospace fasteners.

The information from the mechanical tests extends beyond just expanding our knowledge of nature. It can help develop biomimetic strategies that translate into tougher materials design as well as engineering of robust structures. For instance, the scientists note that such information could be used to design more robust strategies to join different materials, which remains an engineering challenge in aerospace applications and beyond.

"These designs could be useful in joining other dissimilar engineering materials such as plastics and metals. Such materials are currently joined by mechanical fastening, which adds weight and introduces stress concentrators that degrade the strength and can lead to fatigue issues, corrosion and early failure," the authors write in the paper.

They also note that tuning material parameters could further enhance these structures, providing exciting possibilities for robust new strategies to engineer structures as tough as diabolical beetles.

The paper, published in *Nature*, is "Toughening mechanisms of the elytra of the diabolical ironclad beetle" (DOI: 10.1038/s41586-020-2813-8).

Atom-thin transistor uses half the voltage of common semiconductors, boosts current density

University at Buffalo researchers report a new, 2D transistor made of graphene and molybdenum disulfide that could help usher in a new era of computing. The transistor requires half the voltage of current semiconductors, and it also has a current density greater than similar transistors under development. It has these properties because the unique physical properties of graphene keep electrons "cold" as they are injected from the graphene into the molybdenum disulfide channel. For more information, visit http://www.buffalo.edu/news/news-releases.html.

Dynamic geometric modeling allows fabrication of complex-shaped ceramic bone implants

Researchers from three context-driven meta-modeling research groups at the Skolkovo Institute of Science and Technology (Skoltech) Center for Design, Manufacturing and Materials in Russia explored the design and fabrication of porous ceramic implants using laser stereolithography directed by function representation (FRep) modeling.

In the biomedical field, surface structure of implants and scaffolds is essential to successful osseointegration between the implant and the body. Additive manufacturing techniques would in theory allow for the creation of implants and scaffolds with structures that improve osseointegration.

Porous bioceramics in particular may benefit from additive manufacturing because it is difficult to control the design of internal porous structures using traditional methods. However, preliminary work in this field using conventional computer-aided design (CAD) modeling to design implants runs into several difficulties. For one, traditional CAD models use polygons as the building blocks to construct models, which limits structure variation. Additionally, the CAD model allows no easy changes in the grid-like implant topology, so tailoring the structure to a particular customer is cumbersome.

In contrast to CAD modeling, FRep modeling overcomes these modeling limitations. FRep modeling involves iteratively combining numerous mathematically described 3D objects like spheres, cubes, and cylinders to create complex geometric structures. New parameters can be introduced into the equations and mathematical operators at every level of FRep modeling, so it is easy to tailor the structure for each customer.

FRep modeling is not a novel method. Yet "there are no publications on such application of this approach" for designing porous bioceramics, the researchers explain in their open-access paper.

Skoltech researchers used function representation modeling and laser stereolithography to fabricate ceramic implants featuring complex internal pore structures. The first design on the left (BI001) showed highest compressive strength.

For this study, they focused on creating implants that could fill hole-like defects in trabecular bone, a light, porous type of bone that provides structural support and flexibility throughout the skeleton. The ceramics additive manufacturing team of senior research scientist Svyatoslav Chugunov and engineer Andrey Tikhonov developed the overall concept and design of the cylindrical implants. The team of professor Alexander Pasko, research scientist Evgenii Maltsev, and Ph.D. student Dmitry Popov prepared the FRep-based models, and the team of professor Alexander Safonov performed numerical validation of the implants' mechanical performance using the finite element method.

Based on the numerical results, the researchers decided on four different types of structures for the implants, which differed based on the unit cells used to construct them, with varying thickness and length.

Eleven specimens of each type were manufactured using 3DMix alumina paste as a ceramic feedstock in a Ceramaker 900 stereolithographic printer by 3DCeram (Limoges, France). Mechanical testing of the specimens showed that the BI001 specimen is almost three times stronger compared to the other three specimens. In particular, its effective compressive strength (65.1 MPa) is comparable to actual trabecular bone (~50 MPa), which makes "it a promising bone substitute able to withstand high operating loads."

The researchers attribute the higher strength of specimen BI001 to denser packing of the unit cells. Plus, "the BI001 specimen features three rows of contact surfaces in the upper part of the model, thus forming a larger area of contact with the loading plate and providing more uniform and less intense redistribution of load from the testing machine," they add.

In future studies, the authors intend to develop a novel method of ceramic additive manufacturing for porous structures to help reduce green body post-processing time and improve quality of the internal regions of the printed parts.

The open-access paper, published in *Applied Sciences*, is "Design and fabrication of complex-shaped ceramic bone implants via 3D printing based on laser stereolithography" (DOI: 10.3390/app10207138). 100

Ceramic resonators allow for targeted clinical magnetic resonance imaging

Researchers from several institutes and companies in Russia designed a modified magnetic resonance imaging (MRI) scanner that may overcome a limitation of conventional scanners.

A conventional MRI scanner resembles a large tube with a table in the middle for a patient to lay on. Within the tube, radiofrequency (RF) waves are transmitted to the patient via a large, human-sized birdcage coil. The MRI signal is detected by multiple receive-only surface coils that are located directly on a patient, and a cabling system delivers those signals to a spectrometer.

The conventional MRI design provides acceptable image quality for examinations of the whole body as well as certain body parts and organs. But for examinations that focus on smaller areas such as the head, spine, joints, and breasts, "The RF magnetic field of the body birdcage coil is distributed over its total volume, requiring higher power during excitation that limits the coil transmit efficiency for small areas," the researchers write in their open-access paper.

The researchers note that use of dedicated transceive coils, or coils that both transmit and receive, have proven useful to investigate some fine details, such as joints. But positioning of the coils can potentially breach the safety of the procedure during the transmit stage. "Also, the design of such coils restricts their only application to MR examinations of extremities," they add.

These limitations are detrimental to early disease diagnosis capabilities, particularly in terms of detecting breast cancer. Breast cancer is the most common cancer diagnosed in women in the United States, and it is the second leading cause of cancer death among women after lung cancer. However, when breast cancer is detected early and is in the localized stage, the 5-year relative survival rate is 99%, according to the American Cancer Society.

MRI is considered to provide the highest sensitivity to breast cancer, but unfortunately advanced magnetic resonance investigations are often unreliable or even unfeasible on a conventional clinical MRI scanner. So, the Russian researchers proposed an MRI scanner design that can examine smaller areas more efficiently.

The proposed scanner design involves electromagnetically coupling a dielectric resonator to the birdcage coil and passively focusing the RF magnetic field on a specific target area. The researchers created the dielectric resonator using five ceramic discs made from magnesium-doped $BaSrTiO_3$ separated by a low dielectric constant material, in this case plastic.

During in vivo studies performed on five volunteers, the researchers found that strong localization of the transmitting RF magnetic flux achieved using the new resonator led to an average 49-fold input power reduction compared to a conventional birdcage coil setup. Not only did this reduction result in seven times lower patient exposure to local RF electric fields, it meant "the presence of metallic implants outside the area of examination would not restrict the MR examination."

Credit: Mos.ru, Wikimedia (CC BY 4.0)

Researchers in Russia proposed a modified magnetic resonance imaging scanner design that may examine small areas more effectively.

They did observe some deviation in the breast shape image, which they attributed to geometrical design of the resonator and holder. "This limitation can be avoided in future work with a curved shape put in the soft foam with special anatomical cuts," they write.

The researchers filed a patent in December 2018 for their design (RU2018146803U).

The open-access paper, published in *Nature Communications*, is "Ceramic resonators for targeted clinical magnetic resonance imaging of the breast" (DOI: 10.1038/s41467-020-17598-3). 100

Evaluating clay soils for industrial applications

In a recent open-access paper published in *Heliyon*, three researchers from the National Mining Institute (Instituto Nacional de Minas) in Maputo, the capital of Mozambique, provide a nice case study of how to evaluate the potential of clay soils in a given area for use in industrial applications.

They evaluated clay soils from the Manjacazi district, which is in the Gaza Province in southwestern Mozambique. The area is composed of extensive alluvial plains, i.e., loose and unconsolidated soil or sediment deposited by surface water.

Despite the high proportion of clay soils, to date the soils from Manjacazi are only exploited for conventional pottery and local ceramic bricks because the suitability of the soils for industrial applications has not been evaluated. So three researchers—Vicente Albino Manjate, Zaquir Issufo, and Anastância Lucas Magenge—aimed to evaluate the suitability of Manjacazi clays as an industrial mineral for the ceramics industry.

The researchers analyzed 20 clay samples collected from exploited quarries a few kilometers from the town of Xai-Xai. Physical properties of the samples were determined using several methods, including

- Robinson's pipette method, to determine particle size distribution; and
- Casagrande apparatus, to determine liquid limit and plastic limit.

Mechanical properties were determined by measuring linear shrinkage, water absorption capacity, and compressive strength of fired briquettes made from the soil.

Severable notable findings emerged from the tests.

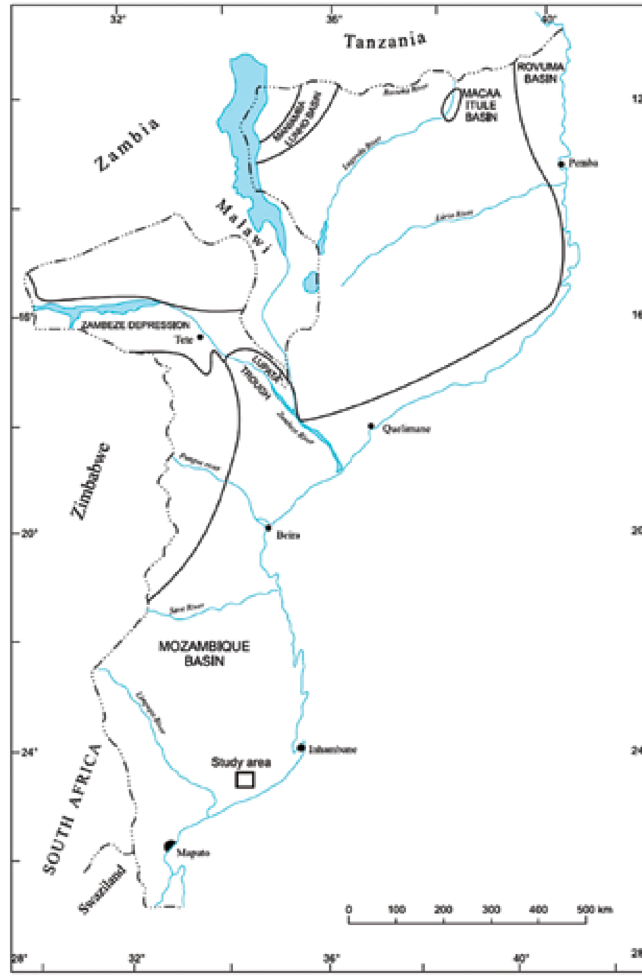
- **Manjacazi clays come in a wide range of grain sizes,** including loam, clay loam, clay, sandy clay loam, and sandy loam.
- **The clays come in a wide range of plasticity**, including low plastic organic silts with low compressibility, medium plastic inorganic silts with low compressibility, and high plastic inorganic silts with high compressibility.
- **Mechanical properties depend on firing temperature**. In particular, linear shrinkage was generally high and increased slightly with firing temperature, whereas water absorption and compressive strength decreased with firing temperature.

Taken together, the researchers conclude that the findings indicate "these clays have ceramic suitability for the manufacture of walled floor blocks, clay roofing tiles, checker bricks, and solid bricks."

Though the findings may appear inconsequential in a global context, the researchers emphasize the importance of the investigation to the local communities.

"In Manjacazi district, for economic reasons, the ceramics industry is controlled by the artisanal and small-scale miners and depends on clay soils from nearby deposits," they write. "It is then obvious that the physical and technological properties of the Manjacazi clay soils need to be analysed to ameliorate their use as ceramic raw material. ... [and to mitigate] various problems during the manufacturing process."

The open-access paper, published in *Heliyon*, is "Evaluation of clay soils from Manjacazi district (Mozambique) as potential raw material for the ceramic industry" (DOI: 10.1016/j.heliyon.2020.e05189).



Detailed map showing the sedimentary basins of Mozambique. The area is composed of recent alluvial and internal dune deposits. The alluvial deposits comprise gravel, sand, silt, and clay whereas the internal dune deposits contain reddish, brownish, and yellowish aeolian sands consolidated by vegetation.

Broad diffraction pattern offers reliable quality control of graphene

Typically sharper and clearer diffraction patterns indicate high-quality material, but Ames Laboratory researchers say in the case of graphene, broad patterns may indicate so as well.

Researchers at Ames Laboratory discovered a solution to reliably assess graphene quality by looking for broad, rather than sharp, diffraction patterns.

Conventionally, "Textbook diffraction states that the more flawless a material is, the sharper and clearer the diffraction spots, and imperfect materials have low intensity, broader diffraction spots," Ames senior scientist Michael Tringides explains in an Ames press release.

However, in the case of graphene, the Ames researchers observed the opposite—that broad diffraction patterns marked high-quality graphene.

In a paper published in *Physical Review B*, they explain that the broad diffraction occurs as strong bell-shaped components around the (00) and G(10) spots. The bell-shaped components are not seen in X-ray or helium-scattering scattering experiments, however, which suggests the component's origin is the spatial localization of graphene electrons within a single layer.

The paper calls out several examples of bell-shaped components appearing in other low-energy electron diffraction studies throughout the years, though at that time no one commented on the phenomenon. "It was a big, noticeable phenomena, and reproducible, and we realized it must be extremely important in some way," Tringides says.

This September, the Ames researchers published a new paper in *The Journal of Physical Chemistry Letters* that provides additional information confirming that the bell-shaped components are a measure of high graphene quality.

In particular, the researchers gathered information on graphene from several different types of experiments, including

Spot profile experiments (for determining the role of scattering interference)

These experiments, analyzed as a function of energy, show that measured parameters for the broad and narrow diffraction components do not follow variation of the profile shape expected from scattering interference.

- *Conclusion:* The bell-shaped components are not related to scattering interference.

Intercalation experiments (for confirming the origins of bell-shaped components)

These experiments, which decoupled graphene from the silicon carbide substrate, found the bell-shaped components appeared more strongly following intercalation.

- *Conclusion*: Further support for the suggestion that the bell-shaped component originates from electron confinement within a single layer.

Annealing experiments (for confirming the relationship between broad diffraction patterns and quality)

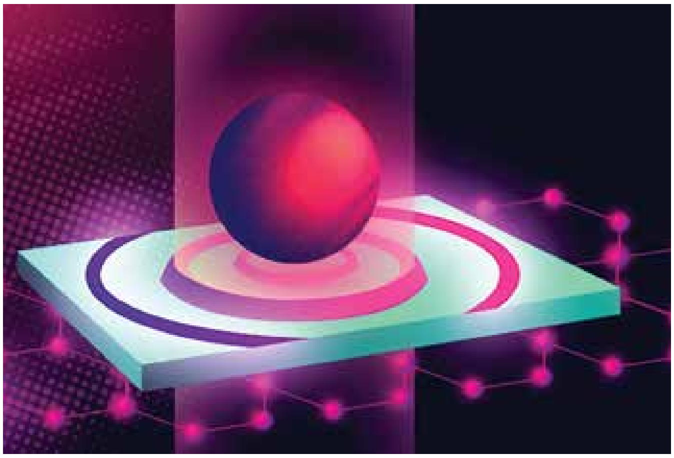
These experiments, which recorded the evolution of diffraction patterns from buffer layer to single-layer graphene, found that growth of the bell-shaped components closely mirrors the growth of sharp diffraction spots, which are the generally accepted indicators of quality.

- *Conclusion:* Similarity between the evolution of broad and sharp diffraction patterns confirms the relationship between broad diffraction patterns and graphene quality.

The authors emphasize their belief that the findings will extend to other 2D material systems, though that suggestion is still to be tested. Regardless, “the correlation between this strange phenomenon and high-quality graphene is unmistakable,” Tringides says in the press release.

The 2019 paper, published in *Physical Review B*, is “Diffraction paradox: An unusually broad diffraction background marks high quality graphene” (DOI: 10.1103/PhysRevB.100.155307).

The 2020 paper, published in *The Journal of Physical Chemistry Letters*, is “High layer uniformity of two-dimensional materials demonstrated surprisingly from broad features in surface electron diffraction” (DOI: 10.1021/acs.jpclett.0c02113).


Credit: Daria Sokol, MIPT Press Office

Artistic rendering of the proposed quantum dot and graphene scheme developed by Russian researchers to improve conversion efficiency of light into surface plasmon polaritons.

Proposed quantum dot–graphene scheme improves conversion of light into surface waves

Researchers at Moscow Institute of Physics and Technology (MIPT) and Vladimir State University in Russia propose a new scheme using quantum dots and graphene to more efficiently convert light into surface plasmon polaritons (SPPs).

SPPs are a type of surface wave that exist at the interface between a conductive material, such as a metal, and a dielectric material, such as air. The waves consist of free electrons in the conductive material (surface plasmons) coupled with electromagnetic waves in the dielectric material, and they propagate together along the conductive–dielectric interface.

Compared to incident light, SPPs are shorter in wavelength. So harnessing SPPs to analyze samples on the nanometer scale improves absorption and scattering signals on the sample’s small cross-section.

Scientists are interested in using 2D materials as the conductive material in an SPP system because 2D materials can support SPPs with shorter wavelengths, a phenomenon that allows analysis of smaller samples. However, “The existing schemes for converting light to SPPs on 2D surfaces have an efficiency of no more than 10%,” an MIPT press release explains.

It is possible that conversion efficiency can be improved by using intermediary signal converters, or nano-objects of various chemical compositions and geometries. So that is what the MIPT and Vladimir State researchers looked to do in their recent simulation study using quantum dots as their intermediary signal converters.

The researchers used ellipsoid-shaped quantum dots made from indium antimonide (InSb) that were 40 nm in diameter. In their simulations, they arranged the quantum dots on top of a 2-nm silica buffer layer, which serves as a thin separator between the dots and the graphene surface.

In an email, Alexei Prokhorov, senior researcher at the MIPT Center for Photonics and 2D Materials and associate professor at Vladimir State University, explains why they included a buffer layer.

“Besides exciting surface waves, some of the QD energy is spent on trivial heat losses due to phonon mode excitation in the system. If the distance [between the quantum dots and surface] is too small—and certainly if the QD is in contact with the surface—the effect of dissipation becomes dominant,” Prokhorov says. Thus, to improve coupling between the quantum dots and the 2D surface, they must be separated by a small distance.

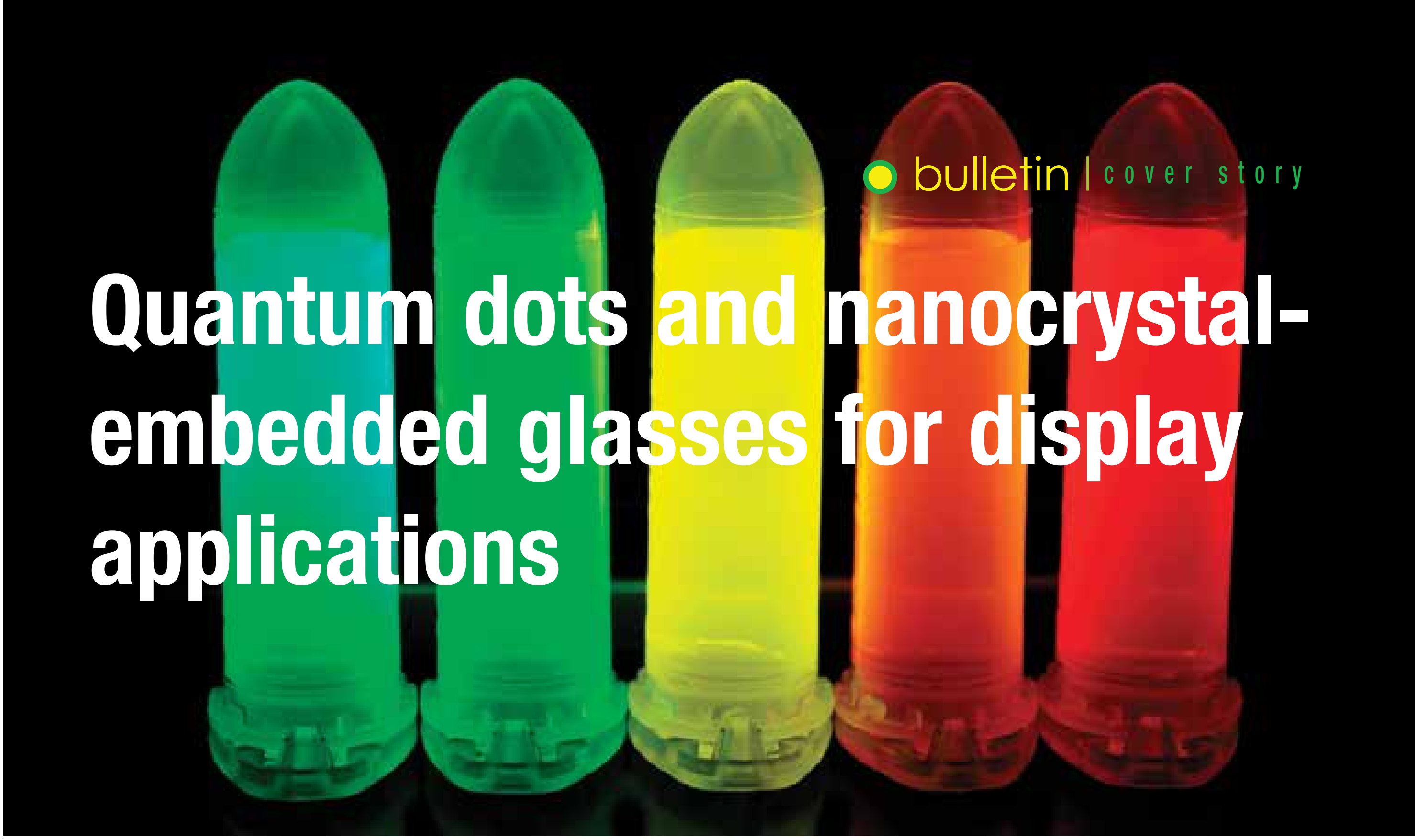
Using the simulations, the researchers determined an optimal arrangement for the quantum dots and graphene to achieve a strong coupling, which allowed a hybrid interaction to take place among the quantum dots, incident light, and SPPs.

“[The] quantum dot positioned above graphene interacts both with incident light and with the surface electromagnetic wave, but the frequencies of these two interactions are different. The dot interacts with light at a wavelength of 1.55 micrometers and with the surface plasmon-polariton at 3.5 micrometers,” Prokhorov says in the press release.

The researchers calculated the conversion efficiency of their setup to be as high as 90%–95%. When all potential negative factors that might affect this efficiency were accounted for, such as decreased chemical potential of graphene, the conversion efficiency remained above 50%—still several times higher than any other competing system.

In an email, Valentyn S. Volkov, director of the Center for Photonics and 2D Materials at MIPT and head of the Laboratory of Nanooptics and Plasmonics, says they are now working on the experimental realization of this system.

The paper, published in *Laser & Photonics Reviews*, is “Hybrid schemes for excitation of collective resonances with surface plasmon polaritons in arrays of quantum dots in the proximity of graphene” (DOI: 10.1002/lpor.202000237).



Quantum dots and nanocrystal-embedded glasses for display applications

By Yoon Hee Nam, Hansol Lee, and Woon Jin Chung

The current high demand and fast-growing market for more realistic images and vivid motion pictures drives the need for high-quality picture displays. Quantum dots and nanocrystal-embedded glasses show a lot of promise for this purpose.

Glasses are widely used in display applications, as substrates for thin film transistor arrays and color filters or cover windows. In addition, glasses and glass-ceramics now also are being considered as active materials for manipulating the primary colors of light sources, further expanding their potential application in display technologies.

Current cutting-edge systems, such as liquid crystal displays (LCD) using quantum dots (QDs) and organic light emitting diodes (OLED), rely on organic materials or QDs synthesized by wet-chemistry to produce and control the primary colors of lights, such as red, green, and blue (RGB). It is well known that organic materials suffer from inherently weak chemical and thermal stabilities and complicated synthesis process, while inorganic glasses or glass-ceramics possess high chemical and thermal stability. These properties give glasses durability as well as long-term stability, and their relatively easy fabrication process reduces production cost. These advantages are opening new opportunities for glass-based materials as light generating materials, replacing conventional QDs.

In this overview, the recent use of conventional QDs in displays is reviewed, and the development and current status of quantum dots and nanocrystal-embedded glasses for display applications are discussed, along with their challenges and future prospects.

Color gamut of displays

The current high demand and fast-growing market for more realistic images and vivid motion pictures is driving the need for high-quality picture displays, which rely on several key features, including resolution, brightness, high dynamic range, and color gamut. Color gamut, which represents the range of color reproduction within the visible color space, is especially important as displays with ultrahigh-definition (UHD) resolution (3840 × 2160 in pixels) become more popular in the market. The color gamut of a display is defined by a triangle area enclosing the primary RGB colors.

The standard color gamut for cathode-ray tubes was defined by the National Television Systems Committee (NTSC) within the CIE 1931 chromaticity diagram in 1953. With the development of new display technologies since the 1990s, such as plasma display panel and LCD, the International Telecommunication Union Radio communication organization recommended a new color gamut for high-definition TVs (HDTV) with 1920 × 1080 resolution, which is known as Rec. 709 (or BT. 709), as found in the chromaticity diagram of Figure 1c.

The International Electrotechnical Commission announced standard RGB (sRGB) for computer displays, and it has a color reproduction range similar to Rec. 709. Adobe and Digital Cinema Initiatives, LLC also suggested definitions for color gamut, those being Adobe RGB for publication and DCI-P3 for digital cinema colors, respectively. Thanks to technological advances in the display industry, a new standard was required for the UHDTV environment, and thus the International Telecommunication Union Radio suggested a wider color range, which is known as Rec. 2020 (or BT. 2020), whose area corresponds to 150% of the NTSC area.

It should be noted that the HDTV color gamut corresponds to about 72% of NTSC, which most conventional LCD-based HDTVs provide. Rec. 2020 for UHD was defined by monochromatic 630, 532, and 467 nm lights for red, green, and blue, respectively. Accordingly, to realize UHD color gamut, it is highly important to adjust the peak emission wavelengths of the RGB colors and reduce their emission bandwidth or full width at half maximum for high color saturation (or color purity).

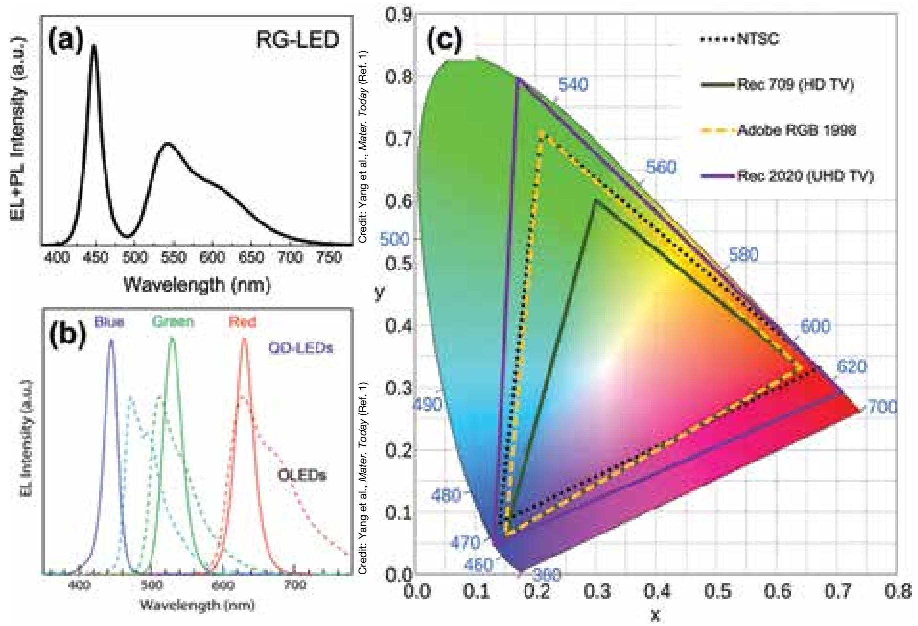


Figure 1. (a) Electroluminescence and photoluminescence (EL+PL) spectra of RG-LED. (b) EL spectra of QD-LEDs and OLEDs. (Reprinted with permission from Ref. 1. Copyright 2018 Elsevier Ltd.) (c) Color gamuts of NTSC, Rec 709, Adobe RGB 1998, and Rec 2020 standards within the CIE 1931 chromaticity diagram.

The RGB colors of conventional LCDs are determined by a combination of color filters and the emission spectra of a white LED, which is comprised of a blue LED with green and red ceramic phosphors (RG-LED). β-$Si_6AlON_8:Eu^{2+}$ and $CaAlSiN_3:Eu^{2+}$ (CASN:Eu^{2+}) were mostly used in commercial RG-LEDs as the green and red phosphors, respectively. However, because of their broad emission bands, the LCD with RG-LED have broad emission spectra, as drawn in Figure 1a. This emission spectra results in a color gamut of about 75% of NTSC.

Scientists achieved significant improvement of the color gamut using QDs, which have narrow emission bandwidth and tunable emission peak wavelengths. As schematically illustrated in Figure 1, when QDs are used as color converting phosphors, well separated emission spectra can be obtained, providing a wide color gamut higher than 100% NTSC.[1] QDs thus were applied by major panel makers such as Samsung in advanced LCD displays known as QLED-TVs.

Displays based on active-matrix OLEDs (AMOLED) also can supply RGB colors with narrower emission bands than conventional RG-LEDs and provide a high color gamut. However, for large sized panels, AMOLEDs are used with a combination of white OLED and color filters to produce RGB colors, and accordingly have a limited color gamut[1] following behind QD-based LCDs in terms of brightness and color reproduction range.

QDs for displays

QDs are semiconductor nanocrystals with diameters (typically < 10 nm) smaller than their Bohr radius, and they include group II-VI (e.g., CdS, CdSe, CdTe) and III-V (e.g., InP) compounds. Since their first discovery by Alexey Ekimov in the 1980s,[2] researchers extensively investigated QDs and made several observations. For example, QDs have a high theoretical quantum efficiency, up to 100%, and narrow emission bandwidth of less than 50 nm, thanks to their strong quantum confinement effect. Their emission peak wavelength can be easily tuned from ultraviolet to infrared by varying their shape, size, or chemical composition, as shown in Figure 2.[3]

QDs are normally synthesized in a colloidal form by wet chemical approaches using chemical reactors, such as batch reactors and continuous reactors.[4] Among batch reactors, hot injection organometallic synthesis is most widely used to obtain monodisperse colloidal QDs (cQDs),

Quantum dots and nanocrystal-embedded glasses for display applications

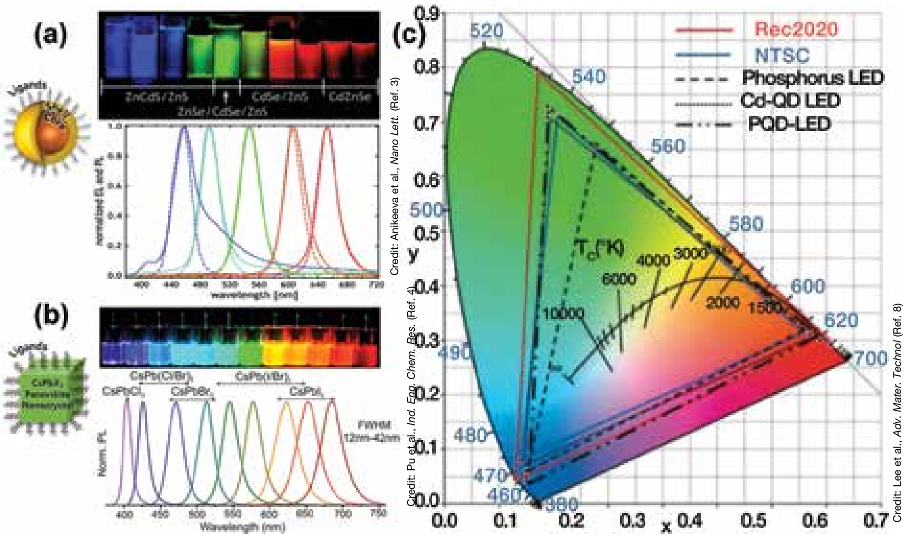


Figure 2. (a) Schematic diagram (left), actual photographs (top), and electroluminescence and photoluminescence (EL+PL) spectra (bottom) of colloidal QDs. Solid lines represent EL spectra while dashed lines represent PL spectra. (Reprinted with permission from Ref. 3. Copyright 2009 American Chemical Society.) (b) Schematic diagram (left), actual photographs (top), and PL spectra (bottom) of PNCs. (Reprinted with permission from Ref. 4. Copyright 2015 American Chemical Society.) (c) Color gamuts of RG-LED (phosphorous LED), QD-LED (Cd-QD LED), and PNC-LED (PQD-LED). (Reprinted with permission from Ref. 8. Copyright 2020 Wiley.)

which are obtained by the pyrolysis of organometallic precursors rapidly injected into a hot organic coordination solvent at a temperature of 120–360°C.[4]

To improve batch-to-batch reproducibility, a one-pot noninjection colloidal synthesis method at low temperature was also suggested for various QDs.[4] An aqueous synthesis method, in which QDs are directly synthesized within a water-based solvent, also was suggested for biological and clinical applications. Synthesis approaches in continuous reactors, which provide more controlled reactions in large scale production, include QD synthesis in microfluidics, high-gravity technique, and thermospray synthesis.[4]

Monodispersed cQDs with large specific surface area are highly vulnerable to environmental factors, which can degrade their luminescence conversion efficiency via the nonradiative recombination of excitons.[5,6] To protect cQDs from external environmental conditions and reduce nonradiative recombination, researchers developed core/shell structured QDs, including CdSe/ZnS and CdSe/ZnSe with an encapsulation layer and wider band gap energy.

The core/shell structured QDs successfully demonstrated improved chemical stability and photoluminescence quantum yield (PLQY). Multishell cQDs (e.g., CdSe/ZnSe/ZnS) or ternary/quaternary alloyed cQDs (e.g., CdS_xSe_{1-x}, $Zn_xCd_{1-x}Se$, $Zn_xCd_{1-x}S_ySe_{1-y}$) demonstrated significant enhancement of PLQY, up to 80~100%, by successfully decreasing defects caused by lattice mismatch.[5,6] Although cadmium-based QDs with core/shell structure showed highest QY, cadmium-free or heavy metal-free QDs were required due to the European Union's Restriction of Hazardous Substances regulations.

Among various alternative QDs, including copper indium sulfide (CIS) QDs, carbon nanodots, and InP-based QDs (e.g., InP (or InZnP)/ZnSeS and InP (or InZnP)/ZnSe/ZnS core/shell QDs), InP-based QDs showed wide color tunability, high quantum yield, and narrow emission bandwidth.[7] Accordingly, they are currently used in commercial QLED-TVs, in spite of their complicated synthesis process and relatively inferior emission properties, which are lower than cadmium-based QDs.

When QDs are used in LCD backlight units within conventional QLED-TVs, the green and red QDs are typically embedded within a polyethylene teraphthlate film to form a QD enhancement film, which is then placed on top of a light guiding panel film, which delivers blue LED light.[8] However, like OLEDs, QDs can also exhibit electroluminescence when they are used as an emission layer with an organic hole transport layer and electron transport layers, to create an LED (QD-LED or EL-QD).[5] Although QD-LEDs still need to overcome several obstacles, including low external quantum efficiency and long term stability, they are being extensively studied for next generation displays with high picture quality.

Recently, perovskite structured quantum dots or nanocrystals based on $CsPbX_3$ (X=Cl, Br, and I) have been extensively studied to replace conventional semiconductor-based QDs. Unlike conventional cQDs, perovskite quantum dots or nanocrystals (PQDs or PNCs) have intrinsic defect tolerance due to their characteristic electronic band structure, and thus exhibit high PLQY, up to 100%, without any shell-like passivation layers.[8,9] As shown in Figure 2, they also have high color tunability by varying size and composition, as well as a narrow emission bandwidth, covering wider range up to about 140% of the NTSC color gamut.[9]

PNCs have at least 2.5 times higher absorption coefficient than cadmium-based or InP-based QDs, and can be easily fabricated without core/shell structure even at room temperature, unlike conventional cQDs, which require high temperature (200~350°C) and multishells for defect passivation.[8,9] They are currently being considered as a cost-effective alternative for conventional QDs, and their potential feasibility as color converting materials in LCDs, or as emission layers in electroluminescence devices, were successfully demonstrated.[8]

Like cQDs, PNCs are mostly synthesized by hot injection methods, but other methods, such as ligand assisted reprecipitation for room temperature synthesis and mechanochemical methods for scalable production, were also suggested.[8,9] It should be noted that chemically synthesized cQDs and PNCs inevitably require an organic ligand-based passivation layer such as trioctylphosphine oxide to prevent agglomeration and oxidation of the

QDs, and to facilitate dispersion within various organic solvents.[1,9]

Due to the weak chemical and thermal stability of the organic ligands, it is highly important to prevent the permeation of air and moisture. Accordingly, conventional cQDs including QD enhancement films require multiple encapsulation layers, resulting in additional production cost. Moreover, due to the ionic bond nature of PNCs, they are vulnerable to exposure to light and heat as well as oxygen and moisture, and thus require various encapsulation strategies to improve stability. These strategies include inorganic or polymer encapsulation, perovskite shell engineering, ligand, and defect engineering.[8]

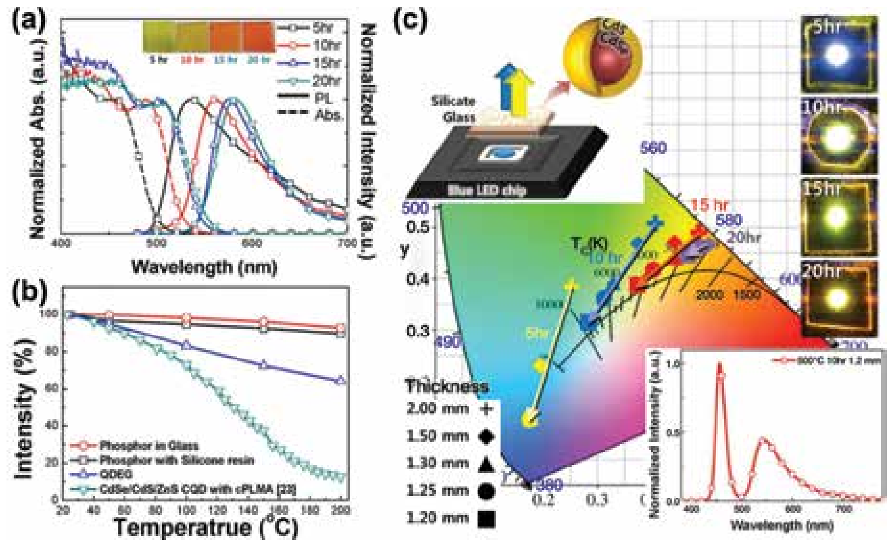
QD embedded glasses (QDEG) for displays

To improve the long-term stability of QDs, it is essential to avoid the use of organic ligands. This feat can be accomplished by using an inorganic glass matrix as an alternative.

Various semiconductor-based QDs can be formed within conventional oxide glasses via conventional nucleation and growth mechanisms, although so far they mostly are used as saturation filters or studied for infrared (IR) applications.[10] The potential feasibility of QD embedded glasses (QDEGs) as a white light source was only recently demonstrated, by the successful fabrication of CdSe/CdS core/shell structured QDs within silicate glasses.[11]

For example, silicate glass with a SiO_2-Na_2O-BaO-ZnO composition including CdO, ZnSe, and ZnS was prepared using a conventional melting and quenching method at 1,350°C and then heat treated at 520°C to form QDs within the glass. High-resolution transmission electron microscope (HR-TEM) and Raman spectroscopy revealed the successful formation of CdSe/CdS structured QDs. Thanks to the encapsulation of defect traps by the CdS shell, PLQY was significantly improved, from 3% without the CdS shell to 20%.

As seen in Figure 3, adjusting the heat treatment condition can change the QD size and the color of the glass as well as the emission peak wavelength. When the



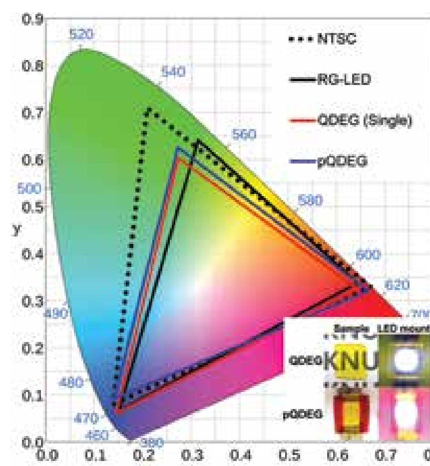
Credit: Han et al., *Chem. Commun.* (Ref. 11)

Figure 3. (a) Absorption (dashed lines) and photoluminescence (solid lines) spectra of QDEG, and actual photographs (inset figures) with varying heat treatment duration times. (b) Comparison of thermal stability of QDEG, cQD, and various color converting materials. (c) Schematic diagram of a QDEG mounted blue LED chip and changes in its color coordinate depending on the heat treatment duration time and the thickness of the QDEGs along with their actual photographs (right). (Reprinted with permission from Ref. 11. Copyright 2016 The Royal Society of Chemistry.)

QDEG was mounted on top of a blue LED as a color converter, the resultant color coordination of the LEDs could thus be tuned by changing the heat treatment condition and thickness of the QDEGs. Because the QDEG is comprised of completely inorganic materials, it showed highly improved thermal stability compared with cQDs and maintained its emission intensity up to 200°C. No meaningful degradation in photoluminescence intensity was observed even after almost two years in ambient atmosphere conditions, under which cQDs cannot survive without proper passivation layers.[11]

When the color gamut of a LED with a CdSe/CdS QDEG was inspected for display application after adjusting the heat treatment duration time and thickness of the QDEG, the QDEG-LED covered 74% of NTSC, which corresponds to the HD color range of conventional RG-LEDs (Figure 4). This performance demonstrated its practical feasibility as a color converting material for display applications.[12] However, the color gamut was limited due to a broad single emission band centered at about 530 nm. To improve the color gamut, the fabrication of the QDEG should produce separated green and red emission bands.

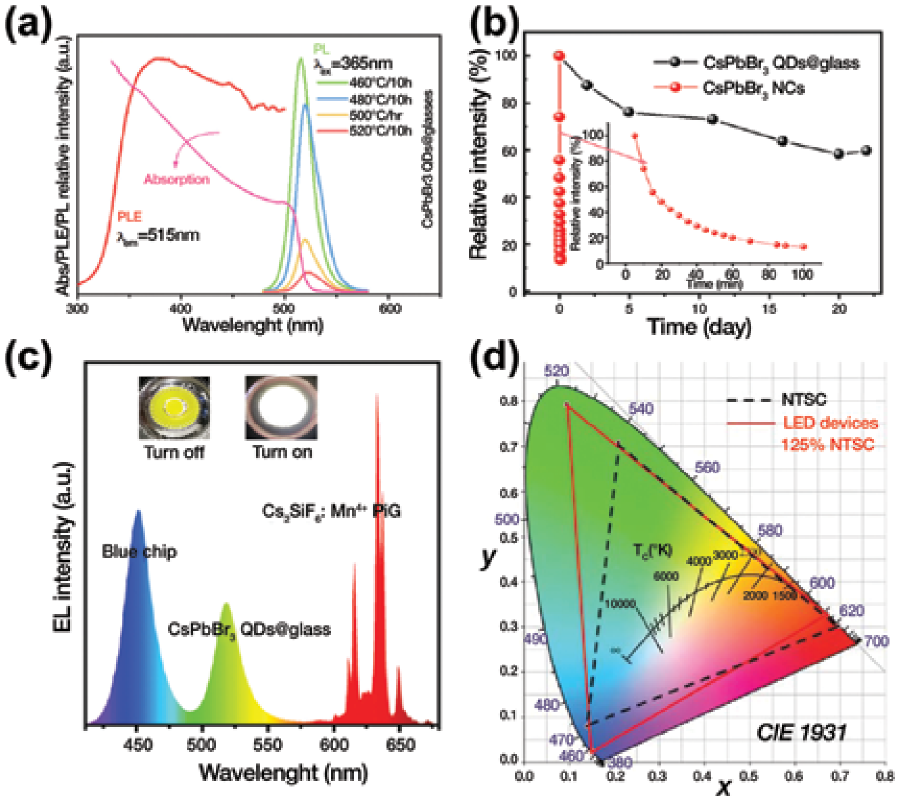
Unlike cQDs, it is hard to form QDs



Credit: Han et al., *Int. J. Appl. Glass Sci* (Ref. 12)

Figure 4. Color gamut of RG-LED, single QDEG, and pattern structured QDEG (pQDEG). The inset figures represent actual photographs of QDEGs and LEDs mounted with them.

of two different sizes within the glass matrix under the same heat treatment condition. Thus, to obtain dual emission bands, two QDEGs with different thermal history were prepared and bonded with each other to form a pattern structured QDEG. A QDEG for red emission was pre-heat treated and aligned with a second QDEG that was not heat treated. Bonding of the two QDEGs by viscous flow and QD formation within the QDEGs took place during the heat treat-



Credit: Pang et al., J. Mater. Chem

Fig. 5. (a) Absorption, photoluminescence, and photoluminescence excitation spectra of $CsPbBr_3$ PNEG. (b) Comparison of photostability of $CsPbBr_3$ PNEG and PNCs. (c) Electroluminescence and photoluminescence (EL+PL) spectra. (d) Color gamut of a wLED with $CsPbBr_3$ PNEG stacked with Cs_2SiF_6:Mn^{4+} phosphor in glass (PiG) as a red emitting converter. (Reprinted with permission from Ref. 20. Copyright 2019 The Royal Society of Chemistry.)

ment at the same time. The green and red emission bands were well separated when the ratio of green-to-red area was adjusted using the heat treatment condition. As a result, the color gamut of the pattern structured QDEG was improved, up to 79% of NTSC, as shown in Figure 4.[12]

However, despite achieving the dual band emission, it should be noted that the color gamut was not satisfactory for UHD applications because of the relatively broad emission bandwidth of the QDEGs compared to cQDs. The broad emission bandwidth of the QDEGs was attributed to the relatively broad distribution of QD sizes within the glass matrix and surface defect related emissions.

Management of QD size distribution within a glass matrix was observed with rare earth dopants, due to the preferential nucleation of QDs near rare earth oxide clusters.[13] Emission bandwidth narrowing by silver ion exchange was reported, after 532 nm continuous wave laser irradiation, producing a $CdSe/Cd_{1-x}Zn_xSe$ structure. TEM equipped with electron energy loss spectroscopy and local electrode atom probe confirmed the evolution of the $Cd_{1-x}Zn_xSe$ layer on the surface of the CdSe QDs, which effectively reduced the broad emission band related to surface defects.[14] Further increases in the color gamut of the QDEGs can thus be anticipated with proper manipulation of the emission bandwidth.

Considering the high PLQY of cQDs (higher than 90%), the relatively low PLQY of QDEGs (less than 20%) is another obstacle that should also be improved before their practical application. Compositions that form QDs within silicate, such as CdO, ZnSe, and ZnS, were optimized for quantum yield adjustment but showed little increase in quantum yield, up to 25%.[15] The formation of $CdS/Cd_{1-x}Zn_xS$ sandwich structured QDs within silicate glass successfully increased quantum yield up to 57%.[16] However, to compete with conventional cQDs, a novel approach to QDEG is required for quantum yield enhancement. This approach may include eliminating nonradiative quenching elements by reducing surface defects on the QDs or by sophisticated control of their size and distribution within the glass matrix.

Although ZnSe QDEGs were recently reported to exhibit visible emission under ultraviolet excitation,[17] meaningful color conversion of blue LEDs was only reported with cadmium-based QDs so far. Thus, cadmium-free QDEGs also need to be developed for practical applications.

Perovskite nanocrystal embedded glasses (PNEG) for displays

Like semiconductor-based QDEGs, PNCs or PQDs can be formed within oxide glasses via nucleation and growth. The first report of perovskite nanocrystal embedded glasses (PNEG) in phosphate glass has thus attracted considerable attention.[18] Due to the intrinsic insensitivity of PNCs to defects, high PLQYs of up to 80% were achieved in borogermanate glass with $CsPbX_3$ (X=Cl, Br and I) PNCs.[19] Varying the PNC size via heat treatment conditions, such as temperature and duration time, or by the compositional variation of halides such as chlorine, bromine, and iodine can easily manipulate the peak emission wavelength of PNCs, resulting in narrow bandwidths of less than about 30 nm, as shown in Figure 5. Moreover, complete inorganic glass passivation highly improved the stability of PNCs against heat, light, aging, and moisture compared to colloidal PNCs (cPNCs).[20]

While cPNCs can be easily decomposed after extended exposure by light and heat, the emission intensity of PNEGs can be restored after the external stress is removed, showing reversible properties. They also showed limited decay in emission intensity even after being in water for 45 days.[10] The robustness and high potential of PNEGs as a robust color converter were demonstrated by using them to compose a white LED.[10] Due to the weak stability of PNEGs with $CsPbI_3$, which can give red emission, $CsPbBr_3$ PNEGs were used as the green phosphor while ceramic phosphors such as CASN:Eu^{2+} or KSF:Mn^{4+}

are used as the red phosphor to prepare a white LED. Their color coordinate, color rendering index, and correlated color temperature can be easily tuned by adjusting the green-to-red phosphor ratio.

When $CsPbBr_3$ PNEG powders were mixed with CASN:Eu^{2+} and pasted on a blue LED using organic resin, almost pure white LED with color coordinates of (0.33,0.35), a high color rendering index of about 92, and reasonable luminous efficiency of up to 60 lm/W was obtained.[10] The wide color gamut of PNEGs for display applications was also successfully demonstrated when the $CsPbBr_3$ PNEG powder was mixed with KSF:Mn^{4+}.[10] The narrow emission band of the green PNEG and KSF:Mn^{4+} enabled a color gamut covering 130% of the NTSC, suggesting PNEGs were highly feasible for display applications.

To further improve the stability of PNEGs, our group recently introduced various structures, including phosphor in glass and remote phosphor, and investigated other glass matrices, such as borosilicate glasses, to demonstrate their practical feasibility with wide color gamut up to 131%.

Oxyfluoride glasses for displays

Oxyfluoride glasses with various fluoride nanocrystals including CaF_2, BaF_2, SrF_2, PbF_2, and LaF_3 are reported to improve the visible emission intensity and color conversion efficiency of various doped rare earth ions, including Pr^{3+}, Eu^{2+}, Eu^{3+}, Tb^{3+}, Dy^{3+}, and Ho^{3+}. Modification of the local environment near the rare earth ions by the formation of fluoride nanocrystals can provide lower phonon energy and increase the quantum efficiency of the doped rare earth ions. Additionally, the parity-forbidden 4f-4f transition of rare earth ions can result in a very narrow emission bandwidth, suitable for high color saturation. However, most of the previous reports used ultraviolet wavelengths or lasers for excitation, and white LEDs with a blue LED chip are not properly demonstrated yet due to the low absorption cross section of the rare earth ions (around 450 nm).

Recently, our group heavily crystallized a Pr^{3+}-doped oxyfluoride glass with LaF_3 to enhance blue LED absorption via scattering, and it successfully composed a white LED when the glass-ceramic was mounted on top of a blue LED.[21] Green (Pr^{3+}:$^3P_0 \rightarrow ^3H_4$) and red (Pr^{3+}:$^1D_2 \rightarrow ^3H_4 / ^3P_0 \rightarrow ^3H_6$) emissions with a narrow emission band were obtained using the single glass-ceramic plate, enabling a color gamut even up to 120% of NTSC, which clearly demonstrated its potential for display application. However, the weak conversion efficiency of the rare earth-doped glass-ceramics resulted in very low luminous efficiency, of less than few lm/W of the wLED, and this property still remains as a big hurdle for their practical employment.

Challenges and perspectives

Nanostructured inorganic oxide glasses such as QDEGs or PNEGs have unique strengths, offering high resistance against external factors such as moisture, oxygen, and heat. These properties give them long-term stability, which conventional colloidal-based QDs or PNCs cannot beat, and is crucial for practical display applications. Along with the stability, their relatively easy fabrication process and encapsulation-free characteristics can significantly reduce production costs. Overall, nanostructured glasses are good potential candidates for use in displays, replacing conventional RG-LEDs or cQD-based white light sources.

However, to enter the commercial market, several challenges need to be properly addressed, including their relatively low PLQY under 450 nm excitation, low luminous efficacy, and cadmium or lead-free QDs (or PNCs). Although extensive studies are still required to solve those problems, there is much room yet to be explored. Considering their high potential and very early stage of investigation, nanostructured glasses will remain as strong competitors to cQDs or cPNCs for several decades.

Currently, QDs on glass are being considered to replace QD enhancement films in premium displays, to reduce display panel thickness as well as production cost. A new OLED display using QDs as green and red color filters (QD-OLED) is set to be released by Samsung Display in late 2021, and an OLED using QDs or PNCs as an emission layer (QD-LED) as well as microLED displays using QDs as color converters are also being extensively investigated for next generation high-end display devices. As the demand for QD-based displays increases due to their wide color gamut, interest in their robustness, long-term reliability. and reduced production cost will continue to expand commercial opportunities for nanostructured glasses.

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ASTM Committee C08 on Refractories—

An overview of the definitive standard tests for refractories*

By William L. Headrick Jr. and Kate Chalfin

In this review of current standard tests from "ASTM Committee C08 on Refractories"[1]—which includes ruggedness test, interlaboratory study, and precision and bias overview—both published information and opinions of producers and end-users are presented.

Over 12,000 ASTM standards operate globally. Defined and set by ASTM committee members, they improve the lives of millions every day.

ASTM standards enhance performance and help everyone have confidence in the things they buy and use—from the toy in a child's hand to the aircraft overhead.

Working across borders, disciplines, and industries, ASTM uses the expertise of over 30,000 members to create consensus and improve performance in manufacturing and materials, products and processes, and systems and services.

Relationships with its members and customers helps ASTM to understand commercial needs and consumer priorities, and with standards across over 145 committees, the work done through ASTM touches every part of everyday life: helping our world work better.[2]

Refractory raw material producers, producers, and users rely on ASTM standards as the definitive standards for comparing refractory materials in the United States and internationally. The standards are well written, easily followed, and lead to repeatable results. However, problems can occur in the use of standards. In many cases, the referenced standard is outdated, and the user needs to access and follow the most current standard. In other cases, the standard is referenced yet not followed. Sometimes, the standard is followed to the letter, but results are not used correctly for a variety of reasons, including

1) A lack of understanding of the ruggedness test that was used

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to determine what factors are critical to be controlled to obtain valid results.

2) The interlaboratory study has not been completed so results from test to test and especially from laboratory to laboratory are suspect.

3) The standard is correctly followed, all factors are correctly controlled, and reporting is correct. Yet the results are not used correctly due to a lack of understanding of precision within the laboratory and between laboratories as compared to bias.

An overview of ruggedness test, interlaboratory study, and precision and bias should assist in eliminating the before stated difficulties and make the results of standards more useful. A review of most used standard methods of test for evaluating performance and data sheet values for users of refractories should assist test users and results users more fully understand the significance of the results. Both published information and opinions of producers and end-users are presented as hearsay evidence should allow users to determine the tests needed to obtain pertinent results.

Developing a test method

ASTM has identified a procedure to develop new and revised test methods. ASTM requires all test methods to have precision and bias statements that are based on interlaboratory test methods. Although there exists a wide range of statistical procedures, there is a small group of generally accepted techniques that are very beneficial to follow. ASTM E 1488 "Standard guide for statistical procedures to use in developing and applying test methods" is designed to provide a brief overview of the procedures and suggest an appropriate sequence of carrying out the procedures. Figure 1 illustrates the recommended procedure for developing a standard test.

This procedure is generally followed as closely as possible to develop good repeatable test procedures. Other standard organizations do not always follow similar procedures which in part may lead to poor test results and understanding. It is important that test users and test interpreters understand these steps

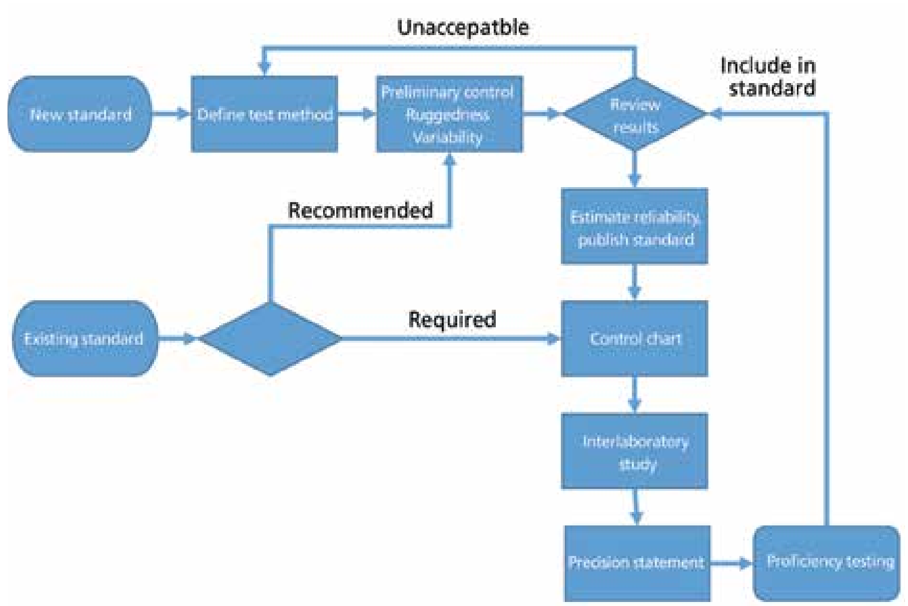

Figure 1. Sequence of steps in developing and applying test methods.

and the implications, which are covered in more detail in the following sections.[3]

Ruggedness test

The purpose of a ruggedness test is to identify those factors that strongly influence the measurements provided by a specific test method and to estimate how closely those factors need to be controlled.

Because there usually are many environmental factors that might be considered in a ruggedness test, it is customary to use a "screening" type of experiment design that concentrates on examining many first order effects and generally assumes that second order effects such as interactions and curvature are relatively negligible. Often in evaluating the ruggedness of a test method, if there is an indication that the results of a test method are highly dependent on the levels of the environmental factors, there is a sufficient indication that certain levels of environmental factors must be included in the specifications for the test method, or even that the test method itself will need further revision.[4]

Interlaboratory study

Interlaboratory testing of a method is carried out by a chosen group of laboratories that are available and willing to undertake the test work. The coordinator of the program must ensure that every participating laboratory has appropriate facilities and personnel and performs the method exactly as written. If this goal is achieved, the statistics developed during the interlaboratory study will be adequate for determining if the method can produce satisfactory precision in actual use. If the program includes certified reference materials, the test data also provide information concerning the accuracy of the method. The statistics provide a general guide to the expected performance of the method in the laboratories of those who will use it.[5]

Precision and bias

The primary purpose of including results of various studies, including an interlaboratory study, are to provide estimates of precision and bias.[3]

Precision is a measure of the variability among test results conducted on the same material in the same laboratory by the same person (repeatability) and between laboratories (reproducibility). Usually, the repeatability is smaller than the reproducibility.

Bias refers to the difference between a population mean of the measurements or test results and an accepted reference or true value. Bias is measured for very few refractory related tests as the results of the test are only defined by the test. That is, there is no standard reference value for most refractory materials or properties.[3]

Repeatability index (r) is the statistic given in the method that estimates the expected range of results reported in the same laboratory on different days, a range that is not exceeded in more than 5% of such comparisons.

Reproducibility index (R) is the statistic that estimates the expected range of differences in results reported from two laboratories, a range that is not exceeded in more than 5 % of such comparisons. Use R to predict how well your results should agree with those from another laboratory.

To use R, first obtain a result from the test method, then add R to, and subtract R from, this result to form a concentration confidence interval. Such an interval has a 95% probability of including a result obtainable by the method should another laboratory analyze the same sample. For example, a result of 46.57% was obtained. If R for the method at about 45% is 0.543, the 95% confidence interval for the result (that is, one expected to include the result obtained in another laboratory 19 times out of 20) extends from 46.03 to 47.11%.[5] Most of the R values for refractories are much larger than this example.

Standard methods of test

Review of most commonly used test standards in the refractories industry. There is no specific order to the review. The author has listed the standards in the order of most used, primarily for technical data sheets and specifications, and most questioned results. The author apologizes if a standard is not covered. Precision statements were simplified by converting values on the standard to percentages and rounding. Do not use this document as definitive precision values. The standard gives much more detail on the precision statement.

C16-03(2012) Standard Test Method for Load Testing Refractory Shapes at High Temperatures

The ability to withstand load at high temperature is a measure of the high-temperature service potential of the material.

Precision

Average percent deformation

Dense 70% alumina brick—
% Deformation +/–29% in laboratory; +/–20% between laboratories

This test may have been the first refractory standard developed by ASTM C08. It is still a valid test and could be used for service limit, but it may not be used very often as it is not often requested by end users or shown on data sheets.

C133-97(2015) Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories

The cold strength of a refractory material is an indication of its suitability for use in refractory construction.

Precision

Cold crushing strength (CCS)

Dense brick—CCS +/–12% in laboratory; +/–45% between laboratories

Dense castable—CCS +/–7% in laboratory; +/–23% between laboratories

Modulus of rupture (MOR)

Dense brick—MOR +/–10% in laboratory; +/–40% between laboratories

Dense castable—MOR +/–9% in laboratory; +/–20% between laboratories

This test is the most controversial. Many users do not follow the standard to the letter, leading to results varying by more calculated precision. Just changing from cardboard to the prescribed cellulose fiber wall board can lead to increase of measured value by 50%. (By the way, the standard does not specify the density of the cellulose fiber board, density of the fiber board changes the values.) The standard allows for specimen sizes that are different than those for which the precision was calculated. It is easy to show by statistical methods that larger specimens lead to lower results with higher reliability as this test result is dominated by the distribution of the largest flaws in the specimen. There is also controversy over whether MOR or CCS is the better method. The author prefers diametral compression (splitting tensile) test, but a standard has not been completed for it by C08, see ASTM C496-11 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens by committee C09.61 for concrete.

ASTM C583-15 Standard Test Method for Modulus of Rupture of Refractory Materials at Elevated Temperatures

This test method covers determination of the high-temperature modulus of rupture of refractory brick or monolithic refractories in an oxidizing atmosphere and under action of a force or stress that is increased at a constant rate.

Precision

Modulus of rupture (MOR)

Alumina Brick—MOR +/–22% in laboratory; +/–36% between laboratories

This test is thought to be indicative of service strength. The author is not sure how strong a refractory needs to be at temperature, as it is theorized and seen that stronger materials generally have worse thermal shock and sometimes shorter lifetimes. Most requirements for elevated temperature MOR seem a bit excessive. A correlation study between elevated temperature MOR and service life would be interesting.

C830-00(2016) Standard Test Methods for Apparent Porosity, Liquid Absorption, Apparent Specific Gravity, and Bulk Density of Refractory Shapes by Vacuum Pressure

Apparent porosity, water absorption, apparent specific gravity, and bulk density are primary properties of refractory shapes. These properties are widely used in the evaluation and comparison of product quality and as part of the criteria for selection and use of refractory products in a variety of industrial applications.

Precision

Apparent porosity (P)— +/–3% in laboratory; +/–4% between laboratories

Bulk bensity (B)— +/–0.5% in laboratory; +/–0.6% between laboratories

This test is noncontroversial. Gives great results and is easy to complete with a minimum of expensive equipment. Vacuum or boiling water; vacuum is preferred for castables.

C704/C704M-15 Standard Test Method for Abrasion Resistance of Refractory Materials at Room Temperature

This test method measures the relative abrasion resistance of various refractory samples under standard conditions at room *temperature. The abrasion resistance of a refractory material provides an indication of its suitability for service in abrasion or erosive environments.*

Precision

High alumina brick (A)– +/–26% in laboratory; +/–47% between laboratories

Conventional castable (A)– +/–55% in laboratory; +/–78% between laboratories

Do not talk to American Petroleum Institute (API) about this method! Modifications for API have made this method much better, but more work needs to be done before API can reliably use it as a specification. This standard may be the most edited and worked on standard in C08.

C201-93(2013) Standard Test Method for Thermal Conductivity of Refractories

The thermal conductivity (*k*-values) determined are "mean temperature" measurements rather than "at temperature" measurements.

or

C1113/C1113M-09(2013) Standard Test Method for Thermal Conductivity of Refractories by Hot Wire (Platinum Resistance Thermometer Technique)

The *k*-values determined are "at temperature" measurements rather than "mean temperature" measurements. Typically values by hot wire are 10–20% higher than values obtained by C201.

The thermal conductivity *k*-values determined at one or more temperatures can be used for ranking products in relative order of their thermal conductivities. Estimates of heat flow, interface temperatures, and cold face temperatures of single, and multicomponent linings can be calculated using *k*-values obtained over a wide temperature range.

Precision

Hot plate

Mean thermal conductivity (*k*)– +/–3.4% in laboratory; +/–9% between laboratories

Hot wire

Thermal conductivity (*k*)– +/–?% in laboratory; +/–?% between laboratories

Both methods work well. Equipment is expensive in either case. It is important to keep in mind that hot plate measures mean thermal conductivity while hot wire measures thermal conductivity at temperature. The author has had better luck estimating cold face temperature of refractory structures using hot wire results. But, what about when a specification states that thermal conductivity is not exceed a maximum, but does not define the test method? Hot plate give the lower value.

C1171-16 Standard Test Method for Quantitatively Measuring the Effect of Thermal Shock and Thermal Cycling on Refractories

This test method indicates the ability of a refractory product to withstand the stress generated by sudden changes in temperature.

Precision

MOR lost– +/–59% in laboratory; +/–65% between laboratories

Sonic velocity lost (V)– +/–17% in laboratory; +/–23% between laboratories

Do not get me started. I can vary the results on this test in so many ways and follow the standard to the letter. No wonder the precision is so high. There should be a better way!

C1445-13 Standard Test Method for Measuring Consistency of Castable Refractory Using a Flow Table

This test method covers the procedure for determining the consistency of castable refractory mixes by the flow table method.

Precision

Percent flow (F)– +/–25% in laboratory; +/–40% between laboratories

This standard is a great internal quality control test. It quickly shows if major batching problems occurred. Also, you need C230/C230M-14 Standard Specification for Flow Table for Use in Tests of Hydraulic Cement, which describes the flow table and how to keep it in calibration. The easiest way to keep the flow table in calibration is to occasionally replace the cam and lifting shaft.

Conclusion

Refractory raw material producers, producers, and users rely on ASTM standards as the definitive standards for comparing refractory materials in the United States and internationally. Hopefully, this overview has increased understanding of why precision and bias statements after ruggedness testing makes ASTM tests the optimum standard tests. The author hopes that this document will help refractory producers educate end users on data sheet values and specifications that rely on values that cannot be statistically measured according ASTM Standard Test Methods. Of most importance, one should always remember that laboratory testing is only indicative of service. If the primary mode of failure in service is thermal shock look for materials with a high thermal shock resistance, not a high cold crushing strength or bulk density. It seems like end users always want stronger refractories, but how many failures are due to exceeding the strength of a refractory (okay, impact damage, maybe).

About the authors

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[1]ASTM International, "Committee C08 on Refractories, Committee Scope," [Online]. Available: http://www.astm.org/COMMIT/SCOPES/C08.htm. [Accessed 25 October 2016].

[2]ASTM Intrnational, "About ASTM International," [Online]. Available: http://www.astm.org/ABOUT/overview.html. [Accessed 25 October 2016].

[3]"E1488-08 Standard Guide for Statistical Procedures to Use in Developing and Applying Test Methods," ASTM International.

[4]"E 1169-07 Standard Practice for Conducting Ruggedness Tests," ASTM International.

[5]"E 1601-98 Standard Practice for Conducting an Interlaboratory Study to Evaluate the Performance of an Analytical Method," ASTM International, 2003.

Credits: SmartMat@2020

The 5th International Conference on Smart Materials and Nanotechnology (SmartMat@2020) took place Dec. 1–4, 2020, at the Nongnooch Pattaya Garden & Resort in Thailand.

Twelve co-hosts and four sponsors supported the conference, which was attended by over 605 participants from around the world. Rattikorn Yimnirun, professor at Vidyasirimedhi Institute of Science and Technology (Wangchan, Thailand) and dean of the School of Energy Science and Engineering, chaired the conference committee. He also is chair of the ACerS Thailand Chapter, which served as the main host of the conference.

A poster session featuring 259 posters took place during the conference.

The conference was organized in a hybrid format to allow international participants to attend via an online platform and domestic participants to attend the conference onsite. The i-STEM team professionally managed both the online meeting via Zoom and the onsite meeting at Nongnooch Tradition Center.

After registration at Nongnooch Tradition Center, the welcome reception of SmartMat@2020 took place at Thai village. Participants at the welcome reception met old and new friends and exchanged ideas about recent smart materials and state-of-the-art technology.

Attendees were treated to a banquet and performance at Nongnooch Pattaya Garden & Resort.

On the second and third day of SmartMat@2020, the atmosphere was full of knowledge and academics. There were three plenary speakers, seven keynote speakers, 20 invited speakers, and 16 international journals represented across the eight parallel sessions and four special seminars. ACerS president Dana Goski and past-president Tatsuki Ohji welcomed delegates in recorded messages to the opening plenary session. A poster session featured 259 posters. Special academic round table seminars and committee meetings for ACerS Thailand Chapter and IEEE Magnetic Society Thailand Chapter also took place. Social activities gave participants the opportunity to gain new colleagues and to build academic strength in Thailand.

The organizing committee thanks the i-STEM organizers for their great teamwork and hard work to make this great meeting happen.

Participants' feedback was positive and can be seen by checking the hashtag #SmartMat2020 #iSTEM #Nongnooch-Garden on Facebook.

We look forward to seeing everyone at SmartMat@2024 in Thailand.

Social activities gave participants the opportunity to gain new colleagues and to build academic strength in Thailand.

MS&T20
MATERIALS SCIENCE & TECHNOLOGY

BUILDING COMMUNITY IN THE TIME OF COVID-19:

ACerS 122nd Annual Meeting at MS&T20 offers engagement for hundreds of materials scientists

Credit: ACerS

Speakers share their thoughts on how to broaden participation in the materials science and engineering profession during the town hall cohosted by ACerS, AIST, and TMS on Nov. 4, 2020, during MS&T20.

Planning a virtual conference for a couple hundred attendees is challenging. But how do you convert a conference that typically welcomes several thousand people when held in-person to a successful virtual event? That was the challenge staff and organizers faced this year when planning how to safely hold ACerS 122nd Annual Meeting at the 2020 Materials Science & Technology (MS&T20) meeting.

When quarantines and travel restrictions began taking effect in the United States this March, ACerS, the Association for Iron and Steel Technology (AIST), and The Minerals, Metals & Materials Society (TMS) discussed what would become of this year's MS&T. In July, the societies formally announced the unwanted but necessary decision to cancel the in-person conference. However, a month later, the pivot to MS&T20 Virtual was confirmed.

ACerS traditionally holds its Annual Meeting activities at MS&T. But to simplify MS&T this year, ACerS held its Annual Business and Division meetings a month before MS&T, during the week of October 5. MS&T Virtual then took place last week from November 2–6. Over 1,200 people from 40 countries attended MS&T20 Virtual, which included over 800 presentations.

Below are highlights from ACerS 122nd Annual Meeting at MS&T20.

Diversity, inclusion, equity take center stage

On Wednesday, Nov. 4, the three societies cohosted a town hall on broadening participation in the materials science and engineering profession.

ACerS president-elect Elizabeth Dickey monitored the session, which kicked off with presentations by National Society of Black Engineers executive director Karl Reid and University of California, San Diego professor of mechanical and aerospace engineering Olivia Graeve before transitioning into a panel discussion that answered questions from the audience. The recording of the town hall is available at https://www.youtube.com/watch?v=UqalWgtk7Dw.

New Division award: Anna O. Shepard

This year, the Art, Archaeology and Conservation Science Division debuted the Anna O. Shepard Award, which recognizes individuals who have made outstanding contributions to materials science applied to art, archaeology, architecture, or cultural heritage. The inaugural presentation of this award went to Ronald Bishop, research archaeologist and curator at the Smithsonian's National Museum of Natural History and a long-term research associate at the NIST National Center for Neutron Research. He talked about ceramic compositional analysis from an Americanist archaeological perspective.

This year's Rustum Roy lecture by Penn State professor James Adair also was particularly noteworthy. He presented a talk titled "Early retrospectives from the time of COVID," a topic of high interest to all.

Students at MS&T20: Speaking contests and humanitarian pitch

Each year there are several events organized specifically for student and Material Advantage members at MS&T. Though some of the rules for certain competitions were modified for the virtual format this year, students still enjoyed a robust program of engagement.

The Material Advantage Student Speaking Contest took place via prerecorded videos that were uploaded to the virtual MS&T platform. This year's winner was Jerry Howard of the University of Utah, who presented on improving materials for pulp capping using sodium metasilicate glass.

Participants in the second annual Humanitarian Pitch Competition also uploaded videos of their presentations. This year's winner was the team H2Flow from Colorado School of Mines, who presented on developing water filters out of concrete, almond leaves, and sand.

Because of the virtual format, the Annual Awards Banquet regrettably could not be held in person this year. Instead, ACerS compiled a special 2020 Virtual Awards Celebration video honoring all of this year's awardees, which is available at https://www.youtube.com/watch?v=7L9sRTTNVeI.

ACerS 123rd Annual Meeting at MS&T21 will take place Oct. 17–21, 2021, in Columbus, Ohio.

VIRTUAL MEETING

ELECTRONIC MATERIALS AND APPLICATIONS (EMA 2021) JAN. 19–22, 2021

ceramics.org/ema2021

Organized by the ACerS Electronics and Basic Science Divisions

Electronic Materials and Applications 2021 (EMA 2021) is an international conference focused on electroceramic materials and their applications in electronic, electrochemical, electromechanical, magnetic, dielectric, biological and optical components, devices, and systems. Jointly programmed by the Electronics Division and Basic Science Division of The American Ceramic Society, EMA 2021 will be a virtual event on the same planned dates, **Jan. 19–22, 2021**.

EMA 2021 is designed for scientists, engineers, technologists, and students interested in basic science, engineering, and applications of electroceramic materials. Participants from across the world in academia, industry, and national laboratories exchange information and ideas on the latest developments in theory, experimental investigation, and applications of electroceramic materials.

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

EMA 2021 PLENARY SPEAKERS

TUESDAY, JANUARY 19

Louca

Despina Louca

Maxine S. and Jesse W. Beams Chair in Physics and professor of physics, University of Virginia, USA

Title: *Electronic band tuning under pressure in $MoTe_2$ topological semimetal*

WEDNESDAY, JANUARY 20

Wang

Haiyan Wang

Basil R. Turner Professor of Engineering, School of Materials Engineering and School of Electrical and Computer Engineering, Purdue University, USA

Title: *Field induced mass transport phenomena in flash sintered high temperature ceramics and their unique properties*

FIVE REASONS TO ATTEND EMA 2021 VIRTUAL

- **It is safe**! Technology has made it possible to learn about the latest electronic materials research in a safe environment.
- **It is affordable.** You will not have to spend money on airfare, hotel, tips, and meals. The registration rate is a fraction of the cost of an in-person meeting.
- **Networking opportunities.** You can still network with industry professionals online.
- **Watch what you missed.** The entire conference will be recorded, so if you miss part of EMA 2021 Virtual, you will be able to go back and watch all presentations until **March 31, 2021**.
- **More employees can attend.** With an affordable registration rate and no travel costs, you can afford to pay for more employees to attend.

OFFICIAL NEWS SOURCES

American Ceramic Society bulletin — emerging ceramics & glass technology

CeramicTechToday — FROM THE AMERICAN CERAMIC SOCIETY

EMA 2021 SCHEDULE OF EVENTS

TUESDAY, JANUARY 19

Welcome message and remarks from ACerS president
Plenary session 1 – Despina Louca, University of Virginia
Coffee break with symposium discussion rooms
Concurrent technical sessions
Lunch break and sponsor showcase
Concurrent technical sessions
Coffee break
Concurrent technical sessions

WEDNESDAY, JANUARY 20

Plenary session 2 – Haiyan Wang, Purdue University
Coffee break with symposium discussion rooms
Concurrent technical sessions
Lunch break, career panel, sponsor showcase
Concurrent technical sessions
Coffee break
Concurrent technical sessions.

THURSDAY, JANUARY 21

Concurrent technical sessions
Coffee break with symposium discussion rooms
Lunch break and sponsor showcase
Concurrent technical sessions
Coffee break
Concurrent technical sessions
Student presentation and poster award ceremony

FRIDAY, JANUARY 22

Concurrent technical sessions
Coffee break with symposium discussion rooms
Concurrent technical sessions
Lunch break and sponsor showcase
Concurrent technical sessions
Failure: The Greatest Teacher

VIRTUAL MEETING

45TH INTERNATIONAL CONFERENCE AND EXPOSITION ON ADVANCED CERAMICS AND COMPOSITES

FEB. 8–12, 2021

ceramics.org/icacc2021

Organized by the Engineering Ceramics Division of The American Ceramic Society

We are pleased to announce that the 45th International Conference & Exposition on Advanced Ceramics & Composites (ICACC) will be held from **Feb. 8–12, 2021,** as a virtual meeting. This conference has a strong history of being the preeminent international meeting on advanced structural and functional ceramics, composites, and other emerging ceramic materials and technologies. On behalf of The American Ceramic Society, the Engineering Ceramics Division has organized this esteemed event since 1977. Due to the high quality of technical presentations and unique networking opportunities, this event has achieved tremendous worldwide interest and has attracted active participation from ceramic researchers and developers from the global technical community thanks to the dedication and support of our membership.

This year the technical program will reflect the growth and success of ICACC by featuring 18 symposia, five focused sessions, one special focused session, and the 10th Global Young Investigator Forum. (The planned honorary symposium was postponed to 2022.) These technical sessions, consisting of both oral and poster presentations, will provide an open forum for scientists, researchers, and engineers from around the world to present and exchange findings on recent advances on various aspects related to ceramic science and technology. The technical program reflects critical areas of interest within ceramics and advanced composites, with a particular emphasis on current trends in research, development, engineering, and application of advanced ceramics.

Award and Plenary Speakers

JAMES L. MUELLER AWARD

Munir

Zuhair A. Munir, Distinguished Professor, Emeritus, Department of Materials Science and Engineering, and Dean, Emeritus, College of Engineering, University of California, Davis, USA

Title: *Electric field effects in the processing of materials*

BRIDGE BUILDING AWARD

Ferraris

Monica Ferraris, professor of science and technology of materials, Politecnico di Torino, Italy

Title: *Joining and integration: Building bridges between materials*

PLENARY SPEAKER

Greer

JULIA R. GREER, Ruben and Donna Mettler Professor of Materials Science, Mechanics, Medical Engineering, California Institute of Technology, USA

Title: *Materials by design: Three-dimensional (3D) nano-architected meta-materials*

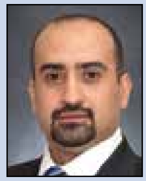
PLENARY SPEAKER

Sasaki

Kazunari Sasaki, senior vice president and Distinguished Professor, Kyushu University, Japan

Title: *Ceramics for fuel cells and hydrogen energy*

GLOBAL YOUNG INVESTIGATOR AWARD

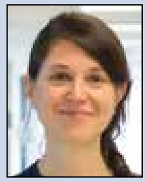


Almansour

Amjad Almansour, aerospace ceramic materials research engineer in the Materials and Structures Division, NASA Glenn Research Center, USA

Title: *Understanding the durability of SiC based ceramic matrix composites (CMCs) for gas turbine engine hot section components*

ENGINEERING CERAMICS DIVISION JUBILEE GLOBAL DIVERSITY AWARD



Hemmer

Eva Hemmer, assistant professor, Department of Materials Chemistry, University of Ottawa, Canada

Title: *Rare-earth-based opto-magnetic nanoparticles – Current trends and challenges*

Krogstad

Jessica A. Krogstad, assistant professor, Department of Materials Science and Engineering, University of Illinois, Urbana-Champaign, USA

Title: *Dynamic, radiation tolerant ceramics: Understanding defect mobility and microstructural evolution in ceramics subject to ion irradiation*

Inada

Miki Inada, associate professor in the Center of Advanced Instrumental Analysis at Kyushu University, Japan

Title: *Microwave effect on the synthesis of metal oxide particles by hydrothermal method*

Schedule of Events

VISIT

CERAMICS.ORG/ICACC2021

FOR THE COMPLETE SCHEDULE

Calendar of events

January 2021

19–22 Electronic Materials and Applications (EMA2021) – VIRTUAL EVENT ONLY; www.ceramics.org/ema2021

February 2021

8–12 45th International Conference and Expo on Advanced Ceramics and Composites (ICACC2021) – VIRTUAL EVENT ONLY; www.ceramics.org/icacc2021

March 2021

9 IMFORMED: Mineral Recycling Forum 2021 – VIRTUAL EVENT ONLY; http://imformed.com/get-informed/forums/mineral-recycling-forum-2021

15–17 China Refractory Minerals Forum 2021 – VIRTUAL EVENT ONLY; http://imformed.com/get-informed/forums/china-refractory-minerals-forum-2020

24–25 56th Annual St. Louis Section/Refractory Ceramics Division Symposium on Refractories – Hilton St. Louis Airport Hotel, St. Louis, Mo. www.ceramics.org

24–29 ➨ 2nd Global Forum on Smart Additive Manufacturing, Design and Evaluation (SmartMADE) – Osaka University, Nakanoshima Center, Japan; http://www.jwri.osaka-u.ac.jp/~conf/Smart-MADE2021

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

April 2021

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

May 2021

1–4 6th Ceramics Expo – Cleveland, Ohio; https://ceramics.org/event/6th-ceramics-expo

3–7 6th International Conference on Competitive Materials and Technology Processes (ic-cmtp6) – Hunguest Hotel Palota, Miskolc-Lillafüred, Hungary; www.ic-cmtp6.eu

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

17–20 China Ceramitec 2021 – Messe München, Germany; https://www.ceramitec.com/en

23–28 14th Pacific Rim Conference on Ceramic and Glass Technology (PACRIM 14) – Hyatt Regency Vancouver, Vancouver, British Columbia, Canada; www.ceramics.org/PACRIM14

June 2021

7–9 ACerS 2021 Structural Clay Products Division & Southwest Section Meeting in conjunction with the National Brick Research Center Meeting – Omni Austin Hotel Downtown, Austin, Texas; www.ceramics.org

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

July 2021

18–23 Materials Challenges in Alternative & Renewable Energy 2021 (MCARE 2021) combined with the 4th Annual Energy Harvesting Society Meeting (EHS 2021) – Hyatt Regency Bellevue Bellevue, Wash.; www.ceramics.org

September 2021

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

October 2021

12-15 ➨ International Research Conference on Structure and thermo-dynamics of Oxides/carbides/nitrides/borides at High Temperature (STOHT) – Arizona State University, Ariz.; https://mccormacklab.engineering.ucdavis.edu/events/structure-and-thermodynamics-oxidescarbidesnitridesborides-high-temperatures-stoht2020

17–21 ACerS 123rd Annual Meeting with Materials Science & Technology 2021 – Greater Columbus Convention Center, Columbus, Ohio; www.ceramics.org

January 2022

18–21 Electronic Materials and Applications 2022 (EMA 2022) – DoubleTree by Hilton Orlando at Sea World Conference Hotel, Orlando, Fla; www.ceramics.org

23–28 46th International Conference and Expo on Advanced Ceramics and Composites (ICACC2022) – Hilton Daytona Beach Oceanfront Resort, Daytona Beach, Fla.; www.ceramics.org

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

Entries in **BLUE** denote ACerS events.

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

denotes virtual meeting

classified advertising

Career Opportunities

TWO POSTDOCTORAL POSITIONS AVAILABLE FOR GLASS RESEARCH

CeRTEV, São Carlos, Brazil

Applications for postdoctoral fellowships are invited for conducting fundamental research at the Center for Research, Technology and Education in Vitreous Materials (CeRTEV) in São Carlos, Brazil; http://www.certev.ufscar.br. The period of the fellowship is two years, starting in **April–June 2021**, renewable for two additional years upon mutual consent.

CeRTEV is an 11-year (started in 2013) joint effort of the Federal University at São Carlos (UFSCar), the University of São Paulo (USP), and the State University of São Paulo (UNESP), to research the area of Functional Glasses and Glass-Ceramics.

The postdoctoral research will be focused on fundamental investigations of ion-conducting glasses by molecular dynamics (MD) simulations, NMR, and impedance spectroscopy of structural links to kinetic processes (diffusion, viscous flow, relaxation, phase separation, crystallization) in glass and glass-ceramic science. Projects in the development and use of glass and glass-ceramics solid electrolytes in Li^+/Na^+ batteries as well as the assembly and characterization of all-solid-state batteries will also be welcome. The researcher is expected to conduct the post-doc activities in one of the joint CeRTEV laboratories and supervised by one of our Principal Investigators in close collaboration with the other CeRTEV researchers and students.

Applicants should have a Ph.D. degree in physics, chemistry, materials science, or engineering, previous experience with computer simulations, or Raman spectroscopy or NMR, or electrical and electrochemical characterization of solid electrolytes and devices and have a genuine interest in conducting interdisciplinary research in an international environment. Previous experience in glass science, solid state physics or chemistry is advantageous. The language requirements are **English, Spanish, or Portuguese**. The monthly fellowships (non-taxable) include ca. R$ 7.300,-plus 15% professional expenses (e.g., for travel and conference participation), which is far enough for a comfortable living style. Travel expenses from and to their home countries will also be covered.

Please send your application including CV, list of publications, a 2-page research proposal, and the names and email addresses of two senior references by **Jan. 30, 2021** to the following persons: MD simulations and NMR – Prof. Hellmut Eckert (eckert@ifsc.usp.br), ion conducting glasses, solid electrolytes, and all-solid-state batteries – Prof. Ana Candida Martins Rodrigues (acmr@ufscar.br)

Please always copy Laurie Leal: certevlamav@gmail.com

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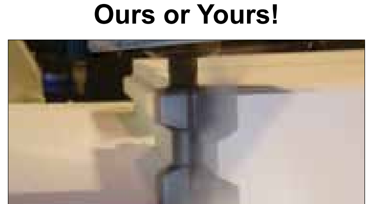

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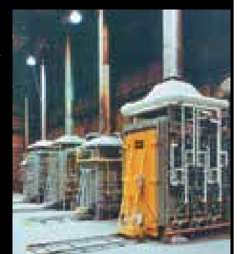

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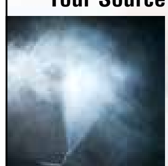

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deciphering the discipline

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

Matthew Wong
Guest columnist

MicroLEDs enable the future of displays

Since the commercialization of smartphones and wearable electronic devices, we are surrounded with various display applications in our daily lives. According to a healthcare survey,[1] the average daily screen time in the United States has increased from about 8.4 hours in 2018 to roughly 10 hours in 2019, and it is expected to exceed 13.5 hours in 2020. (This anticipated time is probably further increased due to the impacts of the COVID–19 pandemic.)

In recent years, emerging display applications started filtering onto the market as well, such as near-eye displays for virtual reality and augmented reality and head-up displays in automotive applications. But are current display technologies allowing these novel devices to reach their full potential?

Full-color displays are composed of red, green, and blue pixels. The three colors typically are generated using either backlit color filters in liquid-crystal displays (LCDs) or organic materials in organic-light-emitting diode (OLED) displays. However, LCDs and OLED displays have fundamental issues that limit next-generation display technologies in terms of resolution, brightness, and power consumption, among other elements.

Micro-light-emitting diodes (microLEDs) are considered as a promising candidate for future display applications. MicroLEDs are inorganic LEDs with device dimensions less than 100×100 μm^2, and the displays can be formed by harnessing color-conversion materials or using microLEDs with three emission colors.[2] These microLEDs exhibit benefits from both LCDs and OLED displays, such as high brightness (LCDs) and excellent contrast ratio (OLED).

Because microLEDs are a relatively young display technology—there is less than 20 years of research and development on these devices compared to more than 40 years for LCDs and OLED displays—there are several ongoing challenges and obstacles for mass production of microLED displays. For example, maximizing energy efficiency.

Ideally, because of their similarities, microLEDs should adopt the highly energy efficient nature of traditional LEDs for illumination applications. LEDs made from gallium nitride (GaN) and aluminum gallium indium phosphide (AlGaInP) inorganic semiconductor materials are known to be the most energy efficient emitters, and they are used for almost all solid-state lighting applications.

Unfortunately, researchers have found that the maximum efficiency decreases as the device dimensions shrink, a finding attributed to plasma damage at the device sidewalls. The reduction in the peak efficiency is especially evident for microLED displays made from GaN and AlGaInP.[3]

In my research group at the University of California, Santa Barbara, we recovered microLED efficiency by sidewall passivation using atomic-layer deposition (ALD) of dielectric materials, including silicon dioxide and aluminum oxide, which was the first demonstration that the efficiency of microLEDs can be regained partially by proper sidewall treatments.[4] Sidewall passivation is a common technique used to suppress surface defects and plasma damage in semiconductors, and it is typically done using plasma-enhanced chemical vapor deposition. We achieved peak efficiency that is independent of device dimensions from 100×100 μm^2 to 10×10 μm^2. Sidewall passivation using ALD also enhanced other optoelectrical performances of GaN and AlGaInP microLEDs, including emission homogeneity, light output power, and the ideality factor.

Despite the short development lifespan of microLED displays, researchers have demonstrated remarkable prototypes, and multiple products are already commercially available. As many academic research groups and companies continue actively investigating microLED displays from a variety of perspectives, the realization of microLED displays and all the compelling display applications are anticipated to gain acceptance in the market relatively soon.

References

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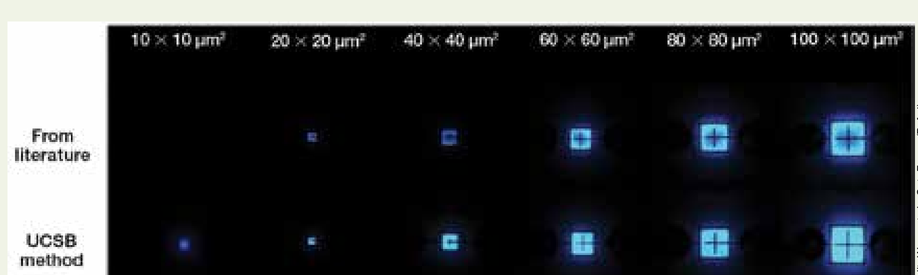

Figure 1. Electroluminescence images of microLEDs without (top) and with (bottom) ALD sidewall passivation at 1 A/cm^2 applied current density.

Credit: Wong et al., *Opt. Expres* (Ref. 4)


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