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Spring 2018

Department of Materials Science and Engineering

DEPARTMENT NUMBERS

- ***30 tenured/tenure-track faculty***
- ***170 graduate students***
- ***385 undergraduate students***
- ***76 research associates/ postdoctoral scholars***
- ***$16,318,449 annual research expenditures***

From left to right: Dr. Shashank Priya, Dr. John Mauro, and Dr. Jon-Paul Maria stand on the steps in the Steidle Building atrium.

THREE NEW FACULTY JOIN THE DEPARTMENT

The department has gained three new faculty during the 2017-18 academic year and they have already made a significant impact in the department and University. Dr. John Mauro started in the fall semester. Drs. Jon-Paul Maria and Shashank Priya joined the MatSE faculty in January and are both Penn State alumni.

Dr. John Mauro comes to the department from Corning where he made significant contributions to the glass industry during his eighteen-year tenure. One of his groundbreaking glass discoveries is the co-invention of three iterations of Corning's Gorilla Glass. Along with a trove of international ties, he brings with him the ability to create an environment that melds the experimental and modeling aspects of discovery, paired with a creative process that helps produce groundbreaking products like Gorilla Glass. Mauro wants to help advance the glass research group by embracing both experimental and modeling aspects of glass chemistry and physics, including both fundamental science and engineering. Mauro will also be hosting the Ceramic and Glass Industry Foundation's (CGIF) 20th University Conference on Glass and Summer School in August 2018.

Dr. Jon-Paul Maria '98, an expert in new material discovery, comes to the department from North Carolina State University where he spent fifteen years serving in the Department of Materials Science and Engineering. Maria's research focuses on processing science issues associated with synthesizing integrated systems for intelligent microwave communication, telemetry, and radar systems. Specifically, his team designs and fabricates microwave circuit components using novel materials, processing conditions, and integration approaches. A specific focus of this work is to replace expensive or difficult to manufacture materials with inexpensive alternatives that do not compromise performance. This requires that they fundamentally understand the materials science of processing as in many cases they are dealing with system components that have narrow windows of stability.

Dr. Shashank Priya '03, a new associate vice president for research in Penn State's Office of the Vice President for Research, comes to us from Virginia Tech where he was the Robert E. Hord Jr. Professor of Mechanical Engineering and associate director for research and scholarship in the Institute for Critical Technology and Applied Science (ICTAS). Priya has extensive experience working with large faculty teams and initiating international collaborations. Through these experiences, he's gained a rich understanding of various models for creating national and global partnerships and exploring new growth opportunities and will continue to do so at Penn State. Priya's research is focused on developing bio-inspired materials, understanding the complex nature of properties in these materials, and, once this understanding has been achieved, utilizing them to invent unique applications.

DEPARTMENT LIFE

FACULTY, STUDENT, & ALUMNI NEWS

RESEARCH UPDATES

PennState College of Earth and Mineral Sciences

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A NOTE FROM THE DEPARTMENT HEAD

The year started with much excitement. A sprinkler pipe in our beautiful rotunda in the very recently renovated Steidle Building froze and burst during an especially severe cold snap over the holiday break. The resulting flood impacted many offices throughout Steidle although (thankfully!) the laboratories were spared. The University responded exceptionally quickly and repairs have been on-going in the months since then. I am happy to report that all but two spaces that are directly under the rotunda are fully mended and we expect all repairs to be complete by this summer.

Much more positively, we welcomed Drs. Jon-Paul Maria and Shashank Priya to the MatSE faculty in January. They join Dr. John Mauro, who came to the department at the start of the fall 2017 semester from Corning. Dr. Maria comes to us from North Carolina State University and is an expert in new material discovery, engineering the properties of materials, and developing new advances in materials synthesis and characterization. Dr. Priya, who is an associate vice president for research at Penn State, comes to us from Virginia Tech and his research is focused on multifunctional materials, energy, and bio-inspired material systems. I am proud to note that both Jon-Paul and Shashank are returning MatSE alumni and bring the total number of tenured or tenure-track faculty in the department to thirty!

The department continues to benefit from the generous donations of our amazing alumni. These donations have been substantially augmented by Penn State's attractive 2:1 and 1:1 matching programs for new gifts that are in effect through June 30, 2018. Please find more information at greaterpennstate.psu.edu under the Open Doors tab, Matching Programs.

As always, I look forward to hearing from alumni and friends of MatSE at sbs5563@psu.edu and 814-863-3117. Do not hesitate to drop me a line to share your story or to let me know when you will be in State College; I will be happy to arrange for you to tour the impressive Millennium Science Complex or the newly renovated Steidle Building.

Happy spring everyone!

Susan B. Sinnott

Susan B. Sinnott
Department head and professor of materials science and engineering
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STEIDLE EARNS AWARDS AND LEED CERTIFICATION

Steidle Building, our department home and one of the most iconic buildings on the campus, has earned Leadership in Energy and Environmental Design (LEED) Silver certification from the U.S. Green Building Council based on the recent renovations. The improvements that helped secure this new status include implementation of energy-efficient systems, structural improvements, and use of recycled materials.

In March, Steidle Building added another honor to its arsenal after the Master Builders' Association (MBA) of Western Pennsylvania awarded it a 2017 Building Excellence Award in the category of Renovation Construction over $10 million.

LEADERS CHANGING THE WORLD

FACULTY AWARDS

ZI-KUI LIU NAMED DISTINGUISHED FACULTY

Dr. Zi-Kui Liu was one of fifteen professors named distinguished faculty in 2018. Professor Liu's research interests focus on the modeling and design of a wide range of materials chemistry and processing through integrating first-principles calculations, statistic mechanics, thermodynamic/kinetic modeling, and critically designed experiments for structural and functional applications.

ROMAN ENGEL-HERBERT RECEIVES PAUL F. ROBERTSON AWARD FOR EMS RESEARCH BREAKTHROUGH OF THE YEAR

Associate Professor Roman Engel-Herbert has been selected to receive the 2018 Paul F. Robertson Award for EMS Research Breakthrough of the Year. The award was created in 2012 with support from a generous gift by EMS alumnus Paul F. Robertson. The award is given for singular research or teaching achievements communicated in one or a small series of articles, reports, or presentations. Roman was selected for his research in the area of transparency conductors. He will be recognized at the Wilson Awards Banquet on April 15, 2018.

BEESE RECEIVES THE 2018 TMS AIME ROBERT LANSING HARDY AWARD

Assistant Professor Allison Beese was honored with the 2018 Minerals, Metals & Materials Society (TMS) AIME Robert Lansing Hardy Award for exceptional promise in the field of mechanics of metallic materials and, in particular, the advancement of mechanical metallurgy understanding in additive manufacturing.

This award recognizes a young person, under the age of 35, in the broad fields of metallurgy or materials science for their exceptional promise of a successful career.

QING WANG RECIEVED FACULTY SCHOLAR MEDAL

Professor Qing Wang was one of six Penn State faculty to recieve the 2018 Faculty Scholar Medals for Outstanding Achievement, which recognizes scholarly or creative excellence represented by a single contribution or a series of contributions around a coherent theme.

Wang was selected for his outstanding scholarly contributions to the development of novel functional polymers and polymer nanocomposites with dramatically enhanced electrical, dielectric and transport properties. He has developed a completely new class of polymer dielectric materials for high-temperature applications.

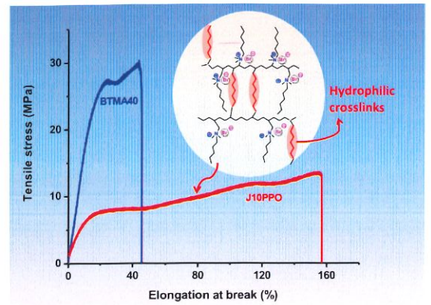
INVENTING TOMORROW: FOCUS ON MATERIALS RESEARCH

SCALABLE ANION MEMBRANES

Michael Hickner's research group has been developing a new anion membrane technology with applications to fuel cells, electrolyzers, flow batteries, and other energy conversion devices, and also serves as critical materials for the purification of water in electrodialysis systems.

In a project funded by the National Science Foundation's Designing Materials to Revolutionize and Engineer our Future (DMREF) program, the Hickner group has teamed with researchers from New York University (NYU), Rensselaer Polytechnic Institute (RPI), and University of Tennessee (UT) to design, synthesize, and test new materials for use in alkaline fuel cells and discover a set of rules for best practices in the development of future materials for fuel cell applications. Computational scientists at NYU and UT are informing the synthesis of new materials at RPI, and the Penn State team endeavors to improve the conductivity and stability of these materials.

In a project funded by the Department of Energy, Hickner's team is partnering with the 3M Company and the National Renewable Energy Laboratory to design commercially scalable membranes. As part of the DOE's Advanced Research Projects Agency-Energy (ARPA-E) IONICS program, the team has surveyed more than thirty possible synthetic pathways and material designs and downselected promising candidates based on their performance and potential to be synthesized at large scale. Through this work a number of patents have been secured on new membrane designs.



Mechanically tough, cross-linked anion exchange membranes were achieved by introducing a hydrophilic and flexible Jeffamine polypropylene glycol-block-poly cross-linker into the cationic macromolecular network.

The team reports in *Macromolecules* that mechanically tough, cross-linked anion exchange membranes were achieved by introducing a hydrophilic and flexible Jeffamine cross-linker into the cationic macromolecular network, which demonstrated outstanding strength and flexibility.

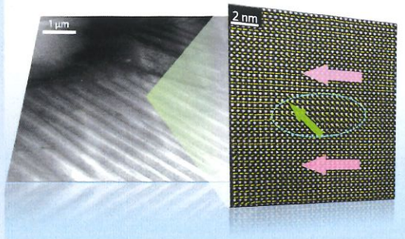
Liang Zhu, Tawanda J. Zimudzi, Ying Wang, Xuedi Yu, Jing Pan, Juanjuan Han, Douglas I. Kushner, Lin Zhuang, and Michael A. Hickner,"Mechanically Robust Anion Exchange Membranes via Long Hydrophilic Cross-Linkers,"Macromolecules, 2017, 50 (6), pp 2329–2337. DOI: 10.1021/acs.macromol.6b01381.

DESIGNING A NEW MATERIAL FOR IMPROVED ULTRASOUND

Development of a theoretical basis for ultrahigh piezoelectricity in ferroelectric materials led to a new material with twice the piezo response of any existing commercial ferroelectric ceramics, according to an international team of researchers from Penn State, China, and Australia.

Adding small amounts of a carefully selected rare earth material, samarium, to a high-performance piezoelectric ceramic called lead magnesium niobate-lead titanate (PMN-PT) dramatically increases its piezo performance, the researchers reported in *Nature Materials*. This materials-by-design strategy will be useful in designing materials for other applications as well, the team believes.

"This is not the typical way to develop new materials," said the team's co-corresponding author, Donald W. Hamer Professor of Materials Science and Engineering Long-Qing Chen. "The majority of existing useful materials are discovered by trial-and-error experiments. But here we designed and synthesized a new piezoelectric ceramic guided by theory and simulations."



A long-range ferroelectric domain with nanoscale structure heterogeneity (4-8 nm) is evidenced by high-resolution TEM. Image: Fei Li/Penn State.

Fei Li, Dabin Lin, Zibin Chen, Zhenxiang Cheng, Jianli Wang, ChunChun Li, Zhuo Xu, Qianwei Huang, Xiaozhou Liao, Long-Qing Chen, Thomas R. Shrout, Shujun Zhang, "Ultrahigh piezoelectricity in ferroelectric ceramics by design,"Nature Materials volume 17, pages 349–354 (2018), DOI:10.1038/s41563-018-0034-4.

NEW PROPERTIES FOR ADDITIVELY MANUFACTURED METALS

Professors Allison Beese and Zi-Kui Liu have teamed up to work toward the design of additively manufactured, functionally graded metallic materials. In this work, the goal is to fabricate components in which the elemental composition, and therefore properties, change spatially within a complex 3-D component. Properties they hope to be able to spatially tailor within components include mechanical, thermal, and magnetic.

To additively manufacture functionally graded materials, a laser heat source is used to create a melt pool in a previous layer of a 3-D component. Powder feedstock material is deposited into the melt pool, and as the deposition system moves on to deposit the 2-D layer, the melt pool cools and fuses to the layer below. By incorporating multiple feeders of powder feedstock in the system, the ratio of each of the metals or metal alloys deposited at a given location can be deliberately changed. However, this mixture of metals or alloys may lead to issues with the formation of intermetallic phases that need to be avoided for a successful, crack-free gradient, meaning that linearly grading from one alloy to another may not work, and instead, different compositional pathways (free of intermetallics) need to be identified.

In the fabrication of these functionally graded materials (e.g., with terminal alloys of Ti-6Al-4V, Invar, Inconel 625, stainless steel 304L), Beese's group performs the experimental characterization of the components, identifying composition, phases, and mechanical properties as a function of location. Liu's group performs thermodynamic and kinetic calculations to determine the phases that are predicted to form as a function of composition. The experimental findings are used to improve the thermodynamic databases used for calculations and to guide additional kinetic modeling. Together, the aim is to be able to use the experimentally validated computational approaches to design pathways that allow for the successful fabrication of components with spatially tailored properties, through the spatial tailoring of chemistry.

Lourdes D. Bobbio, Richard A. Otis, John Paul Borgonia, R. Peter Dillon, Andrew A. Shapiro, Zi-Kui Liu, Allison M. Beese, "Additive manufacturing of a functionally graded material from Ti-6Al-4V to Invar: Experimental characterization and thermodynamic calculations,"Acta Materialia Volume 127, 1 April 2017, Pages 133-142, https://doi.org/10.1016/j.actamat.2016.12.070.

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The Department of Materials Science and Engineering bi-yearly newsletter

ALUMNI SPOTLIGHT: MARK DOUGLAS WAUGH, '97 B.S. MATERIALS SCIENCE AND ENGINEERING, CERAMICS OPTION

Since starting his twenty-year career at Murata Electronics North America, Mark Waugh has come a long way from his Dover, Pennsylvania, roots where, as a high school student, he contemplated aerospace engineering. Fast forward to Waugh's time as an undergraduate at Penn State, when after receiving guidance from his highly respected thesis adviser, Professor Clive Randall, Waugh decided instead to pursue a degree in materials science and engineering. "Professor Randall believed in me and was a strong supporter," Waugh said. "He answered my numerous and never-ending questions and taught me the skills of analytical thinking, writing, organization, and time and project management."

After graduation, Waugh immediately started his career at Murata Electronics as a primary engineer, supervising a cleanroom that manufactured ceramic capacitors for military and underwater sea cable applications. In 2004, he followed Murata from State College to Smyrna, Georgia, where he entered technical marketing as a business development engineer. Nine years later, Waugh was offered an opportunity to move to Kyoto, Japan, to work in Murata's Technology Planning Department. While there, Waugh created the basis of Murata's Core Technology Book, used today by global teams to engage in collaborative discussions with new partners. While there, Waugh, an avid road cyclist, also participated in Japan's Cycling Shimanami Kaido—one of the country's largest cycling events.

Today, Waugh works out of Murata's Georgia facility and helms strategic marketing efforts for Murata's healthcare strategy in the United States. In this role, Waugh leads the charge in developing partner relationships with hospitals, clinicians, universities, start-up companies, incubators, collaborators, and other related organizations. A special partnership, spearheaded by Waugh, is the one between Murata and the Cleveland Clinic. Waugh led Murata's strategic investment into Prevent Biometrics, a Cleveland Clinic spinoff that seeks to advance concussion safety in sports.

When not working, traveling, or dealing with Atlanta traffic, Waugh and his wife, Sharon, play man-on-man defense with their 18-month-old identical twin girls, Emma and Lily. And on football weekends, he proudly displays his Penn State pride by wearing his blue and white. "Having an engineering degree from Penn State has served me well and is always held in high regard," Waugh said.

And Waugh's parting words of wisdom? "One can have great ideas, be at the top of your game, but if unable to communicate effectively to internal and external stakeholders, a project can get sidelined or fail. Today more than ever, finely tuned communication skills are essential to success."