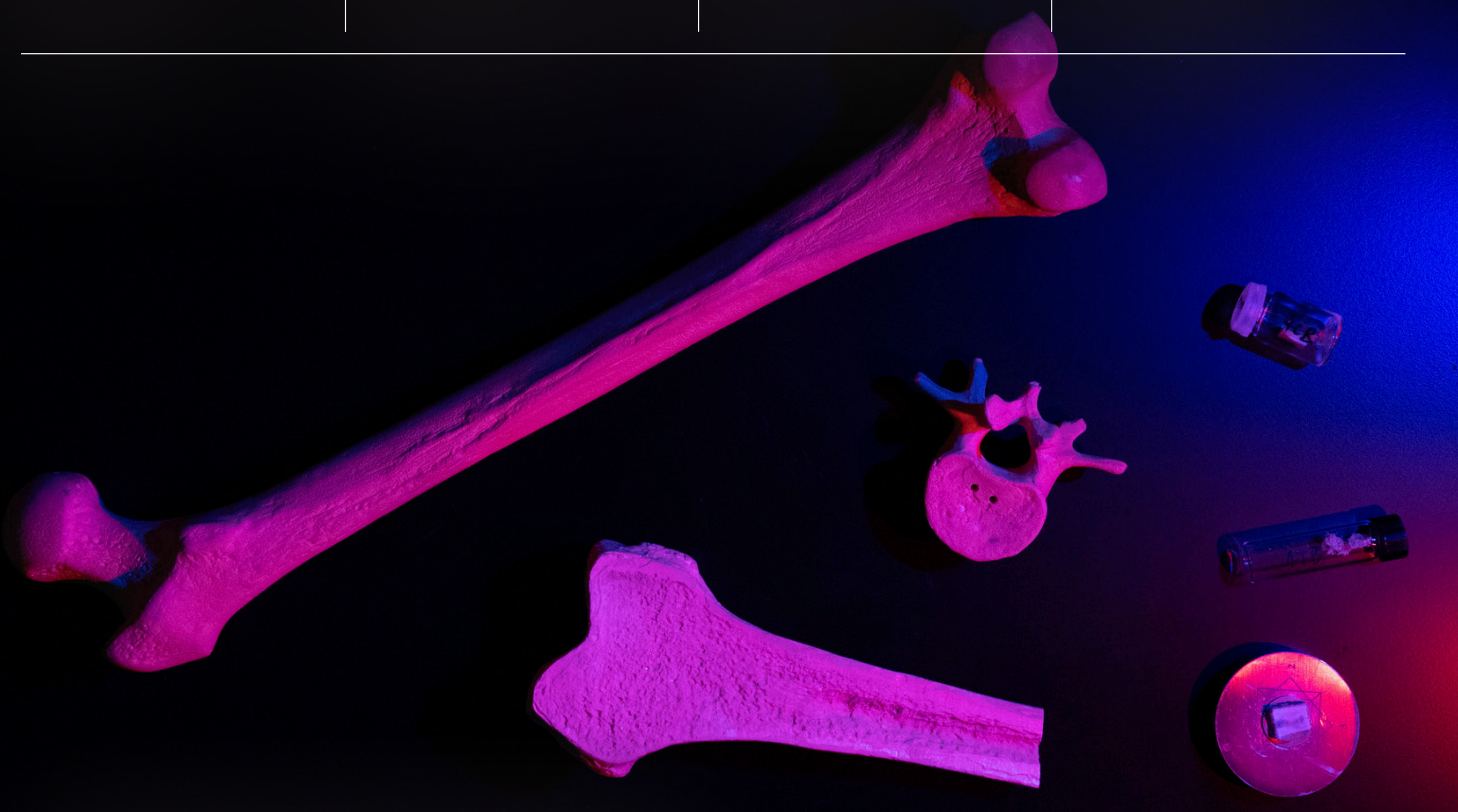
CornellEngineering
Materials Science and Engineering

MSE

Newsletter
Fall 2020



FRACTURED BONES, HELPING THEM HEAL

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DEAR ALUMNI AND FRIENDS OF THE DEPARTMENT

GREETINGS FROM PROFESSOR R. BRUCE VAN DOVER, FORMER MSE CHAIR

I would like to thank Materials Science and Engineering students, alumni, faculty and staff for allowing me to serve as the department chair for these past 5 years. During my tenure as chair, MSE has graduated many BS , M.Eng, M.S. and Ph.D. students. Not only has MSE grown in alumni we have also gained new faculty members, adding new breadth to our research and course offerings. Hundreds of innovative papers were written, and research flourishes in MSE in research centers, laboratories and interdisciplinary collaborations across the university and the world.

Research at MSE continues to push the boundaries of material structure, leading to new fundamental understanding and new materials applications; I invite you to read about some highlights on page 6-13. As always the implications of our research are broad and wide reaching. Our faculty have moved forward research in quantum simulations, biomaterials and cancer research, semiconductors, energy storage, and crystal growth.

I invite you to read about some awards and honors earned by our students on Page 24. Congratulations to Jin Suntivich, who has been granted tenure and promoted to the rank of associate professor, and to Professor Lara Estroff, who was promoted to the rank of full professor. Professor Ulrich Wiesner toured France as a CNRS Institute of Chemistry Ambassador and Professor Andrej Singer received an NSF Early Career award.

Our students, undergraduate and graduate, continue to surpass all goals set for them. Students John Eom and Alicia Cintora have developed a simple yet powerful photovoltaic lesson module for incorporation into the national high school engineering curriculum. Two graduate and two undergraduate students have received prestigious NSF fellowships.

Our alumni are an integral part of our community as well. On Pages 18-19 we profile, Brigadier General William Edwards, '96 Ph.D., who not only is a high-level researcher at HP leading an R&D product design team, but who also serves as an officer in the Oregon National Guard.

I would also like to use this opportunity to once again congratulate our 2019 Distinguished Alumni Awardee, Dr. Yonn Rasmussen '89 Ph.D. She is vice president of Xerox Corporation. Under her purview is the engineering and manufacturing of digital printers. Yonn also exemplifies Cornell's culture of service by serving not only on the MSE advisory board, but also on the Alumnae Engagement Committee of the President's Council of Cornell Women as well as representing MSE alumni, and all alumni, as a member of the Cornell Board of Trustees. Please learn more about Yonn and her professional and service works on page 20-21.

I was delighted that so many alumni were able to join us at our virtual reunion this year. We'll certainly look into keeping this option available in the future, in addition to our yearly on-campus celebration. Please stay connected with us: hearing from our recent and established alumni helps us continue to evolve our program to better serve our current students.

But even as the department has flourished, we have also endured strain. This year we have faced challenges due to COVID-19, including an abrupt move to remote learning. I would like to thank our entire community for handling this situation better than anyone could have hoped. In 2019, MSE mourned the loss of Emeritus Professor Stephen L. Sass. Plans are in the works for a symposium in remembrance of all that Professor Sass contributed to research and academics in the department. Please see page 5 for more information.

As I look back over my time as chair of Materials Science and Engineering, I am very proud of where we are. Moreover, I am eager to see where Prof. Lara Estroff's leadership, as incoming Chair, will take us. Lara is a committed researcher and educator, and since joining MSE in 2005 she has been dedicated to seeing the growth and diversification of our department. Lara has served as our Director of Graduate Studies since 2015 and her commitment to our students and their success is unparalleled.

Thank you to all of the MSE Community for allowing me to serve as the Chair and best wishes to all.

Sincerely,

R. Bruce van Dover
MSE Department Chair

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ABOUT THE COVER

When Erik Taylor joined the Eve L. Donnelly Lab, Materials Science and Engineering, he had lots of first-hand experience with broken bones and how they heal. He had broken nine bones. He didn't know that he would later conduct research on bones and how to help them heal. Photo courtesy of Dave Burbank

WELCOME FROM PROFESSOR LARA ESTROFF, MSE CHAIR

Thank you, Bruce not only for your warm welcome, but also for your years of service. I look forward to continuing to grow the vibrant department you have advanced over these past 5 years. I would also like to extend my thanks to my colleagues for affording me this opportunity to further develop the department to which we are all committed. I am honored to be the first female chair of MSE at Cornell, and I look forward to working with all of you in the years ahead.

We find ourselves at an uncertain, and yet exciting, time in higher education. We are pushing ourselves and our students to teach and to learn in ways we had never imagined. Together, we have faced lab shutdowns and reactivations, and explored creative ways in which to continue doing the research that is the backbone of our department. As I look forward, I know that as a result of these challenges and opportunities, we will emerge stronger as a community and more nimble as a department.

Our department is built upon a triumvirate of faculty, students, and staff. In the coming years, my goals are to empower and support all of them to excel and lead in the greater materials research and education arenas. In research, Cornell MSE continues to focus on driving fundamental science with real-world impact within a highly collaborative and interdisciplinary environment. We have multiple faculty leading research centers and multi-PI collaborative efforts across campus, several of which are highlighted throughout this Newsletter. In education, we are continuing to develop and evolve our undergraduate program as well as attracting some of the best PhD, MS, and MEng students to our graduate programs. Lastly, but in no way least, we strive to foster an equitable, diverse, and inclusive community. Amidst the turmoil gripping our country, I have been heartened to see our students, faculty, staff, and alumni come together to support each other and push us to be the best version of ourselves that we can be. MSE is a small department, however this allows us to form deep connections among our faculty, staff, students and alumni. These connections, just like our research collaborations, give us strength to come together to realize real change in our community and make our potential impacts widespread.

Please stay connected, opportunities to support the growth of MSE are listed on our website and page 22. We are so proud of all of our alumni, and without you, we would not be recognized as one of the top materials science and engineering programs in the world, or advance beyond where we are.
Thank you for this opportunity and I look forward to seeing where MSE goes with our combined efforts.

Warm regards,

Lara Estroff

MEET THE MATERIALS SCIENCE AND ENGINEERING ADVISORY BOARD

Comprised of 9 highly reputable industry and academic leaders, the Materials Science and Engineering Advisory Board serves a critical role in providing the department with counsel concerning curriculum, industry trends and new programmatic directions. The committee meets annually with department faculty and students to review and discuss the strategic direction of the program.

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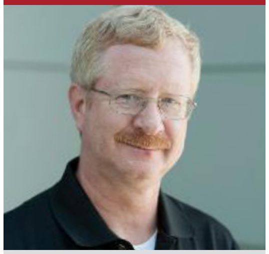

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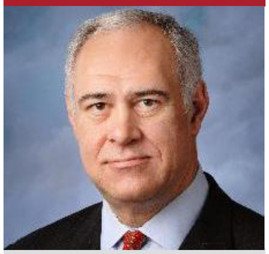

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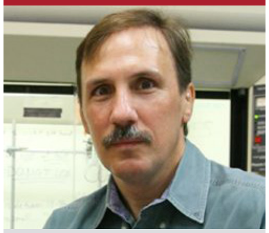

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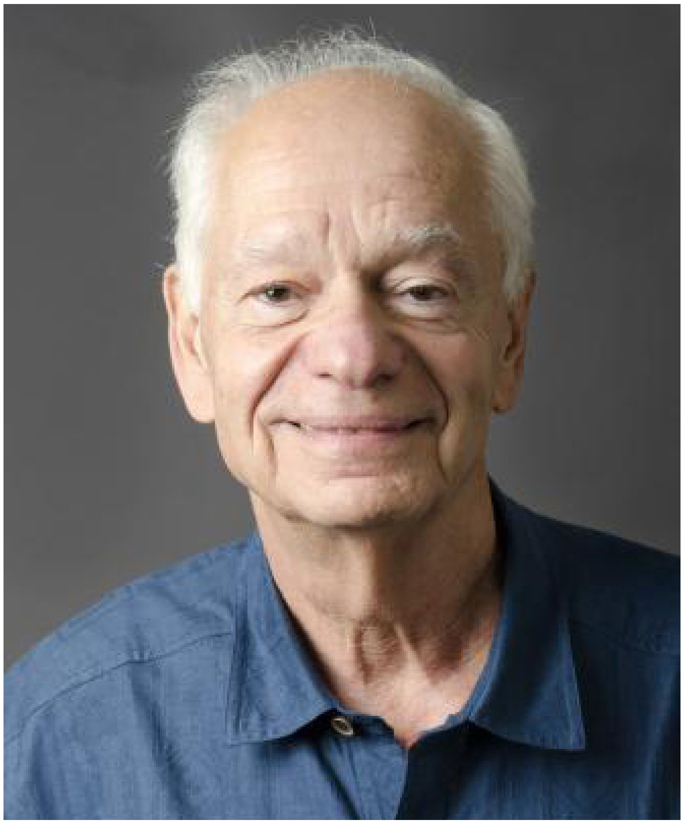


PROFESSOR STEPHEN LOUIS SASS,

who pioneered fundamental studies of crystalline interfaces, died in Ithaca, New York on August 15, 2019. He was 79.

Steve was born on March 11, 1940 in Bronx, NY. He received a Bachelor's degree in Chemical Engineering from the City College of New York in 1961 and then carried out graduate studies in the Department of Materials Science at Northwestern University, earning his Ph.D. in 1966. He spent the following year as a postdoctoral researcher at Technische Hogeschool, in Delft, The Netherlands as a Fulbright Scholar. In 1967, he joined Cornell University as an Assistant Professor, advancing to full Professor in 1979. He was elevated to Emeritus status in 2008.

Professor Sass was a leader in using transmission electron microscopy to investigate the structure of metals and ceramics at the atomic level. Steve published more than 130 articles in the refereed literature, which were cited thousands of times worldwide. His careful studies of crystalline interfaces were particularly influential. He worked collaboratively with many of the faculty across the university, and was a Fellow of ASM International, the professional organization of materials scientists and engineers.

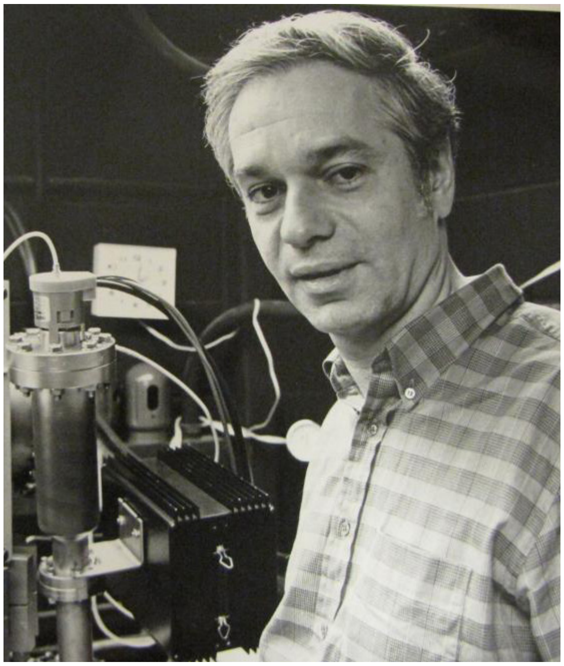
Steve was an accomplished author, penning the book "The Substance of Civilization: Materials and Human History from the Stone Age to the Age of Silicon." In addition, he was a New York Times Op-Ed contributor with two articles published; “Scarcity, Mother of Invention” in August 2006 and “Can China Innovate without Dissent?” in January 2014.

Steve received many distinguished awards including the Stephen H. Weiss Presidential Fellowship in 2002, recognizing sustained and distinguished contributions of faculty members to undergraduate teaching, and was the first recipient of the Northwestern University Distinguished Achievement Award for Alumni of Materials Science and Engineering in 2012.

He served as the Director of Undergraduate Studies in Materials Science and Engineering from 1988-1998 where he began publicizing the excitement of materials science in high schools across the country, and was instrumental in increasing undergraduate enrollment. He also developed a rigorous undergraduate research program which was a significant factor in recruiting women to the field of materials science and opened doors for more women to participate in research. Steve took great pride in this and alumni of the program considered it a life-changing experience.

Beyond his many scientific achievements, Steve's legacy includes legions of undergrad and graduate students, many of whom remain in the field and are now professors themselves. He was extremely open-minded and had an infectious enthusiasm for science that sparked conversations and friendships around the world.

Steve is survived by his wife of 53 years, Karen, his two sons Adam and Erik and two grandchildren,Carol and Levi. Steve and Karen were very active in the Friends of the Library, Ithaca Chamber Orchestra, and were avid travelers and music lovers.



MSE WELCOMES JAMES HWANG

James Hwang '73 M.S. '76 Ph.D. has joined the faculty of Cornell's Department of Materials Science and Engineering (MSE). After earning his doctorate from Cornell in 1976, Hwang worked in industry for twelve years, including stints with IBM, Bell Labs, GE, and GAIN. He then joined the faculty at Lehigh University in 1988 and has been there for thirty years.

"I am happy to be back at Cornell after so many years away," says Hwang. "I was invited to campus in May of 2018 to receive an MSE Distinguished Alumni award. And while I was here, Department Chair Bruce van Dover asked if I would like to spend my sabbatical year from Lehigh at Cornell as a visiting professor. And that discussion evolved into 'why not just stay here at Cornell as research faculty?'"

Hwang's research career has been a productive one, with more than 400 published papers and eight U.S. patents to his name. He has received an outstanding Achievement Award from the Chinese Institute of Engineers and he is a Life Fellow of the Institute of Electrical and Electronic Engineers (IEEE). In scanning a list of Hwang's publications, it becomes clear that his research interests have been varied over the course of his career thus far.

"I switch fields quite often," says Hwang. "I take a sabbatical leave every seven years and I use those leaves to explore new areas and get new ideas. And when I follow that urge to do something new, my goal is to have a real impact on the field."

The field Hwang is hoping to have a major impact on now that he is at Cornell is millimeter-wave integrated circuits for use in communications and radar. The frequencies Hwang is talking about are 110 GHz and higher. If his research is successful, Hwang foresees antennas capable of handling greater bandwidth and therefore allowing a greater telecommunications rate. "Conventional wisdom is that we will need more and more base stations to be able to implement 6G communications," says Hwang. "But when I saw the work Debdeep Jena and Grace Xing are doing here on aluminum nitride and gallium nitride, I saw chance for collaboration."

"This is a paradigm shift," says Hwang. "I have been inspired by Professors Jena and Xing---I want to move into the circuits level. I think we can do 6G differently and efficiently using an array of antennas."

In addition to the presence of Xing and Jena, Hwang was also drawn to the fact that at Cornell he would be a research professor with no formal teaching responsibilities. "I enjoy one-on-one mentoring and I will still be able to do that with students in the lab," says Hwang, "but I will be able to direct most of my effort and energy into the research instead of preparing lessons and lectures."

When he is not working on the hardware to power the 6G network, Hwang likes to ski. "It was quite a shock for me to arrive at Cornell in 1970," says Hwang. "I had never been here but even from Taiwan I had heard of its reputation for excellence and for natural beauty. But I didn't know it was cold here. I showed up in January and there was a lot of snow." Rather than transferring to a warmer place, Hwang learned to ski and he has been doing it ever since, all around the world.

James Hwang

DOE FUNDING WILL HELP RESEARCHERS CREATE NEW QUANTUM STATES OF MATTER

Andrej Singer, assistant professor of materials science and engineering and David Croll Sesquicentennial Faculty Fellow, will lead a three-year project funded by the Department of Energy's Office of Science that will attempt to create new quantum states of matter.

The award is sponsored by the DOE's Office of Basic Energy Sciences, under its "Research at the Frontiers of X-Ray Free Electron Laser, Ultrafast Chemistry and Materials Sciences" program. The Singer group's project was one of 10 chosen for funding totaling $30 million.

The group's proposal is titled "Engineering Interfaces and Defects in Heterostructures for Controlling the Properties of Non-Thermal Phases in Quantum Materials." The objective of this research is to chemically and structurally control quantum states and their lifetimes following exposure to ultra-short laser bursts.

Investigators include Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry; Kyle Shen, professor of physics; Nicole Benedek, assistant professor of materials science and engineering; and John Harter, Ph.D. '13, assistant professor of materials at the University of California, Santa Barbara. The group will receive about $2.73 million from the DOE for its research.

"We are incredibly excited and look forward to developing new ways of controlling quantum materials," said Singer, who arrived at Cornell in fall 2017.

"Short light bursts can, for a brief time—a few trillionths of a second—induce extremely useful properties, including superconductivity," he said. "Imagine making that property live longer, so we could use it in applications—this is precisely what we will work on. Our work could revolutionize how we design and build our future electronics."

Harnessing emergent properties in quantum materials could lead to a range of advances, from energy harvesting and storage to next-generation electronics and magnetic devices. These unique properties are often short-lived, however; the Singer group's research will focus on magnetic properties, metal-to-insulator transitions and possible light-induced superconductivity.

"Quantum materials are inherently complex," Singer said. "Barely noticeable microscopic rearrangements can entirely change the functionality. X-ray free-electron lasers are vital for identifying the relevant puzzle pieces required for engineering artificial quantum materials."

The goal of all 10 funded projects is to help speed discovery of new materials and chemical processes through better step-by-step observation and control of matter's behavior at atomic and molecular scales.

"Discoveries in materials science and chemistry have long been critical drivers of technological innovation and economic growth," U.S. Secretary of Energy Rick Perry said in a statement. "These projects will keep American scientists on the cutting edge of one of today's most promising and potentially productive areas of research."

by Tom Fleischman

Andrej Singer

CORNELL, AIR FORCE TO STUDY ‘DISRUPTIVE MATERIAL’ IN NEW CENTER

The AFRL Cornell Center for Epitaxial Solutions leadership team holds a plaque commemorating the opening of the center in March at Cornell. From left: associate professors Mike Thompson and Farhan Rana, and professors Debdeep Jena, David Muller and Huili Grace Xing.

A new center established by Cornell and the Air Force Research Laboratory (AFRL) aims to discover the atomic secrets of beta-gallium oxide, a promising new material that has piqued the interest of engineers for its potential to allow electronic devices to handle dramatically more power.

Sixteen members of the AFRL joined researchers at Cornell March 7 during a daylong kickoff event for the AFRL-Cornell Center for Epitaxial Solutions (ACCESS). The center is made possible by a three-year, $3 million grant from AFRL with additional funds from Cornell and an option for a two-year extension.

“The way beta-gallium oxide atoms are arranged is really unique; it’s the only semiconductor material that shows this structure,” said Mike Thompson, associate professor of materials science and engineering and director of the center. “It’s shown potential to be a key disruptive material for high-powered electronics.”

Silicon has long been the go-to semiconductor material for electronic devices, but with the emergence of electric vehicles, renewable energy sources and 5G communications networks comes a need for a materialthat can handle higher voltages, higher power densities and higher frequencies. And if beta-gallium oxide proves to have the performance that is predicted, it will enable a wide range of new devices and applications.

"It's a new frontier in terms of just how hard you can drive a device and understanding where our current models break down for devices we use today," said Gregg Jessen, AFRL fellow and principal electronics engineer, adding that applications could include compact power supplies for new types of radar systems, communications technologies and sensors.

"Cornell has a long history of being experts in compound semiconductors and has expertise where we don't, so our skill sets complement each other," added Jessen.

Some of the earliest research on beta-gallium oxide's value as a semiconductor has been conducted by Huili Grace Xing and Debdeep (DJ) Jena, both professors of materials science and engineering and of electrical and computer engineering. Recent samples of the material synthesized by their research group produced some unanticipated results, according to David Muller, professor of applied and engineering physics who analyzed the samples' atomic structures with his state-of-the-art microscope.

"Like people, what makes a material interesting is its defects, and we've already seen some exciting defect structures in the materials Grace and DJ have grown," said Muller, who is also a member of the center's technical team. Discoveries have included new materials and atomic structures when the beta-gallium oxide is mixed with other elements such as tin or aluminum.

The research will continue under the center, where engineers will focus on developing growth and processing methodologies for high-quality beta-gallium oxide, as well as developing a fundamental understanding of the material's properties.

Rounding out the technical team is Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry, who will focus on synthesis of the material, and Farhan Rana, professor of electrical and computer engineering, who will focus on understanding atomic defects through optical probes.

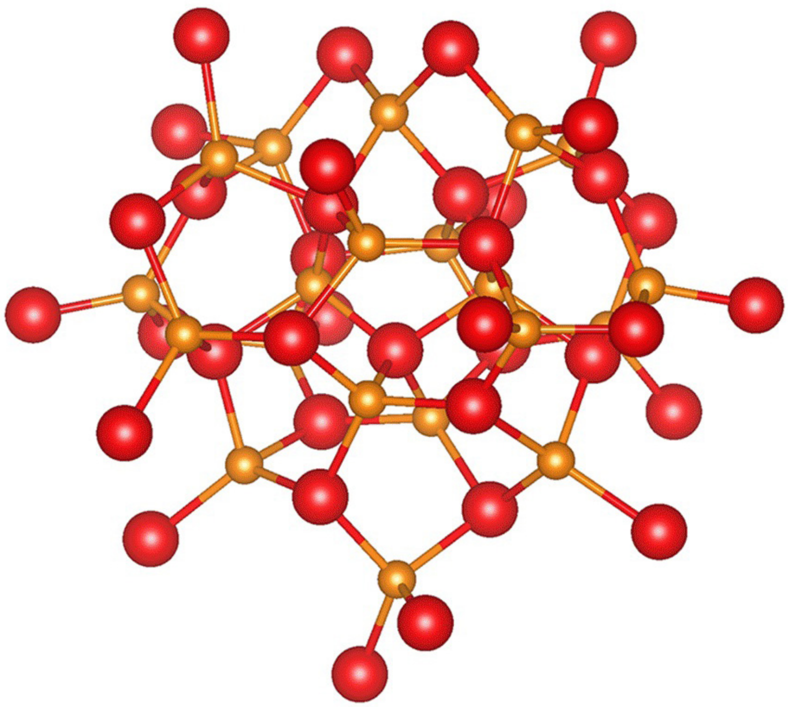
The center also includes an exchange program between Cornell and the AFRL in Dayton, Ohio, AFRL researchers visiting Cornell will be able to access facilities associated with the center, including the Cornell NanoScale Science and Technology Facility; the Cornell Center for Materials Research; the Platform forthe Accelerated Rea lization, Analysis and Discovery of Interface Materials; and the Cornell High Energy Synchrotron Source.

Meanwhile, Cornell students involved in the center will spend a year in Dayton, where they will have the opportunity to apply their education to new research challenges at the AFRL.

"The value of these types of centers is immeasurable to the College of Engineering for a number of reasons," said David Erickson, S.C. Thomas Sze Director of the Sibley School. "They allow us to develop deep partnerships to give our students real-world experience, to marshal our resources to meet national needs, and allow us to dedicate our science to solve important problems."

by Syl Kacapyr

TINY PARTICLES CAN SWITCH BACK AND FORTH BETWEEN PHASES



Three years ago, when Richard Robinson, associate professor of materials science and engineering, was on sabbatical at Hebrew University in Israel, he asked a graduate student to send him some nanoparticles of a specific size.

"When they got to me, I measured them with the spectrometer and I said, 'Wait, you sent me the smaller particles instead of the bigger ones.' And he said, 'No, I sent you the bigger ones,'" recalls Robinson, of his conversation with his advisee Curtis Williamson, a doctoral student in chemical and biomolecular engineering. "We realized they must have changed while they were in flight. And that unleashed a cascade of questions and experiments that led us to this new finding."

They deduced that the particles had transformed during their trip from Ithaca to Jerusalem. This realization led to the discovery of inorganic isomerization, in which inorganic materials are able switch between discrete states almost instantaneously—faster than the speed of sound. The finding bridges the gap between what's known about phase changes in organic molecules, such as those that make eyesight possible, and in bulk materials, like the transition of graphite into diamonds.

Their find was surprising because it implied that inorganic materials could transform like organic molecules, said Robinson, co-author of the paper, "Chemically Reversible Isomerization of Inorganic Clusters," which published Feb. 15 in *Science*.

"We found that if you shrink inorganic material small enough, it can easily jump back and forth between two discrete phases, initiated by small amounts of alcohol or moisture on the surface," Robinson said. "On the flight there must have been moisture in the cargo bin, and the samples switched their phase."

Williamson is the paper's first author. Senior authors are Robinson; Tobias Hanrath, associate professor at the

Smith School of Chemical and Biomolecular Engineering; and Uri Banin, professor of chemistry at Hebrew University. Douglas Nevers, Ph.D. '18, Andrew Nelson, doctoral student in materials science and engineering, and Ido Hadar of Hebrew University also contributed.

"We bridged the two worlds between big materials that change more slowly, and small, organic materials that can flip back and forth coherently, between two states," Robinson said. "It's surprising that we saw an instantaneous transformation from one state to another in an inorganic material, and it's surprising that it is initiated with a simple surface reaction."

Isomerization—the transformation of a molecule into another molecule with the same atoms, just in a different arrangement—is common in nature. Often it's sparked by the addition of energy, as when light causes a molecule in the retina to switch, enabling vision; or how olive oil, when heated too high, isomerizes into the unhealthy form known as a trans-fat. Bulk materials such as graphite can also change phases, but they require a lot more energy than at the molecular level and the change occurs more gradually, with the change spreading across the substance rather than an instantaneous transformation.

In the past, larger nanoparticles were found to change phases in a way that was closer to how bulk materials change than to molecules. But when the Cornell team looked at even smaller clusters of atoms at the Cornell High Energy Synchrotron Source (CHESS), they observed the quick change between discrete states for the first time.

We now finally see that there's a new regime where you can coherently flip from one state to another instantaneously," Hanrath said. "If you make them small enough, the inorganic materials can flip back and forth very easily. It's a revelation."

Robinson said the researchers would not have been able to precisely determine atoms' positions without CHESS, where they performed total-scattering experiments in which they examined all the X-ray scatterings of the cluster, enabling them to pinpoint the locations of the atoms.

They were also aided by a new technique they developed to create magic-sized clusters—so-called because they have the "perfect" number of atoms and no more individual atoms can be added, making them extremely stable.

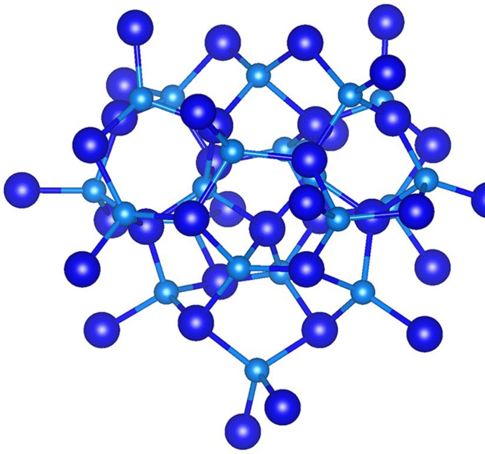
"We were able to come up with a very pure magic-sized cluster," Robinson said. "Because of that, when it reacts with the alcohol or water you see a very pure transformation" from one discrete state to another.

Though further research is needed, possible future applications include using these particles as switches in computing or as sensors, Robinson said. The discovery could also have uses relating to quantum computing or as a seed for the generation of larger nanoparticles.

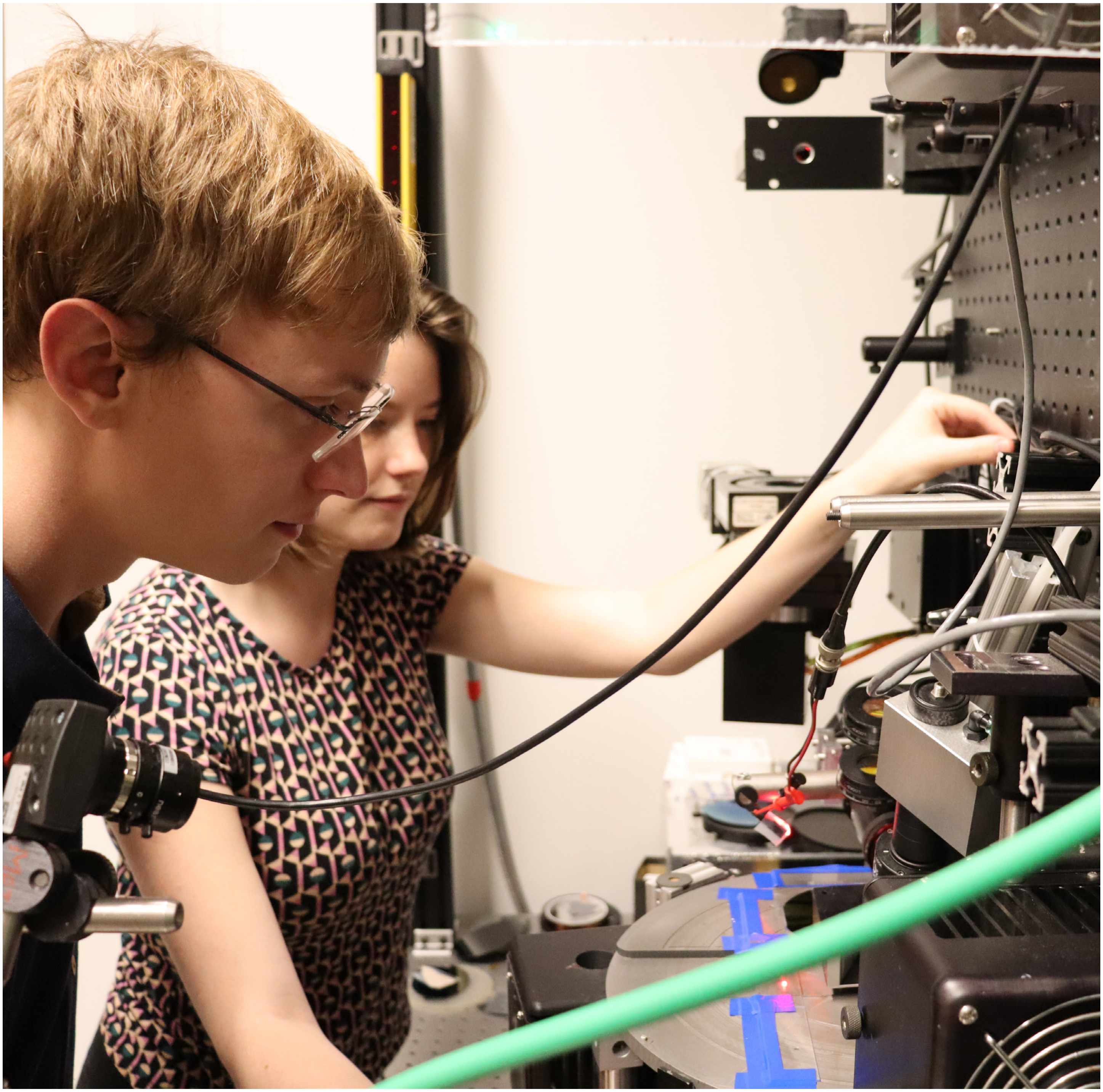
The work was supported by the National Science Foundation and made use of the Cornell Center for Materials Research Shared Facilities and CHESS, which both receive funding from the NSF. The researchers also received funding from the European Research Council, Hebrew University and the U.S. Fulbright Scholar Program.

by Melanie Lefkowitz

Richard Robinson



INNOVATIVE AI SYSTEM COULD HELP MAKE FUEL CELLS MORE EFFICIENT



Duncan Sutherland and Aine Connelly

An artificial intelligence system developed by a Cornell-led team has identified a promising material for creating more efficient fuel cells—a potential breakthrough in both materials science and machine learning.

The system, which relies on a collective of algorithmic bots each performing a distinct task, sifts through hundreds to thousands of combinations of elements to create a map of phases—arrangements of atoms in relation to each other that humans can then use to determine which might work as a new material.

"This problem forced us to develop a whole new approach that really pushes the frontier of AI to derive physically meaningful solutions," said Carla Gomes, professor of computer science and director of the Institute for Computational Sustainability, and first author of "CRYSTAL: A Multi-Agent System for Automated Mapping of Materials' Crystal Structures," published in June in *Materials Research Society Communications*.

Researchers seeking to improve fuel cells for cars are searching for a catalyst that would allow them to replace hydrogen, which is difficult to store, with methanol, which could be far more efficient.

But because no known materials are efficient catalysts for methanol oxidation, a new material is needed, said co-author John Gregoire, Ph.D. '09, a staff scientist at the California Institute of Technology.

"If a viable catalyst exists, it's going to need to be discovered by combining elements of the periodic table, and the number of combinations is so vast that it can't be done with traditional experimentation," said Gregoire, formerly a postdoctoral researcher in the lab of co-author R. Bruce van Dover, the Walter S. Carpenter, Jr., Professor of Engineering.

Researchers also need to understand the crystal structure, or phase, of the material, since solids may have multiple phase structures and each one behaves differently as a catalyst.

"Humans can solve the phase map for simple composition systems containing two elements," Gregoire said, "but whenever there are more than two elements, it's too much information for humans to process, and we need AI to assist."

Existing machine learning approaches, however, weren't well-suited for the strict constraints of scientific discovery, in which solutions must not only be plausible but obey the laws of physics and chemistry, Gomes said.

To meet the challenge, Gomes and colleagues developed a system called CRYSTAL for crystal phase mapping, in which multiple bots each take on a different part of the problem, from predicting the phase structures of various combinations to making sure those predictions obey the rules of thermodynamics.

Machine learning systems typically learn how to solve problems using a large amount of annotated training data—for example, an algorithm to distinguish dogs from cats would be trained by a dataset of images labeled either "dog" or "cat." Labeled data isn't available in this case, so CRYSTAL also needed to be able to draw inferences from unlabeled data—a process known as unsupervised learning.

"For a single monolithic system, this would be overwhelming," Gomes said. "But if we do this in a very agile way, bringing together a multi-agent system to reason collectively, we can find solutions quickly and satisfy all the constraints."

Gomes said CRYSTAL was inspired partly by the IBM Watson supercomputer, which used a community of AI agents coming up with different possible solutions to beat human champions at "Jeopardy!"

Using CRYSTAL, researchers were able to identify a unique catalyst, composed of three elements crystallized into a certain structure, that is effective for methanol oxidation and could be incorporated into methanol-based fuel cells.

"This is an important discovery that challenges our understanding of catalysis, and an important research direction toward designing the next generation of catalysts," Gregoire said.

Co-authors include doctoral students Junwen Bai, Johan Björck, Sebastian Ament and Brendan Rappazzo, M.Eng. '18; Yexiang Xue, Ph.D. '18, now an assistant professor in the Computer Science department of Purdue University; postdoctoral researcher Shufeng Kong; and Richard Bernstein, a programmer/analyst at the Institute for Computational Sustainability. Santosh K. Suram of Caltech, now at the Toyota Research Institute, also contributed.

The research was supported by the National Science Foundation, the Army Research Office, the Air Force Office of Scientific Research, the Toyota Research Institute and the U.S. Department of Education. For materials characterization, the researchers made use of the Cornell High Energy Synchrotron Source.

by Melanie Lefkowitz

FRACTURED BONES, HELPING THEM HEAL

When Erik Taylor joined the Eve L. Donnelly Lab, Materials Science and Engineering, he had lots of first-hand experience with broken bones and how they heal. He had broken nine bones. He didn't know that he would later conduct research on bones and how to help them heal.

Neither did he know this during his internship in Zurich, Switzerland, when he was mechanically testing ceramics, constructed from synthetically-produced nacre, also known as mother-of-pearl, the material found in seashells.

In the course of his first-year of graduate school at Cornell University, one of his professors said, "A Ph.D. is one of the last opportunities to do something completely different." This resonated with Taylor. Shortly thereafter he would be exploring bone at the small, micro, and nano scale in the Donnelly lab.

HOW BONES CHANGE WITH DISEASE

The Donnelly Lab looks at chemical or compositional changes in the bone, resulting from disease and drug treatment, working specifically on the chemical characterization of bone that has suffered from atypical fractures in patients with osteoporosis. They also work on bone fractures in patients with diabetes.

Taylor first worked on basic science research, validating the standards of measures the Donnelly Lab uses. He says, "I was using chemistry and basic physics to confirm, in synthetic systems, that what our lab is looking at in bone tissue actually has legitimate physical meaning. Are the techniques that we use for synthetic systems valid when we use them for living bone tissue?" Successfully, his findings confirmed that their techniques are valid when applied to bone tissue, validating their usage in the lab.

Taylor, then, began translational research that aligns closely with the Donnelly Lab. In a collaboration with scientists from University of California, Davis and University of Missouri, Kansas City, Taylor evaluated the effectiveness of various drug treatments for osteoporosis in rats. "Bone is a dynamic, living tissue. It is constantly being created and reabsorbed. In patients with osteoporosis, however, new bone is being formed a lot less quickly than bone is being reabsorbed," explains Taylor. "So the bones become smaller, weaker, and more brittle."

SEARCHING FOR BETTER TREATMENT FOR OSTEOPOROSIS

Typically, there are two different treatments for osteoporosis. One of the treatments, the most common, is to take bisphosphonates. These drugs act to stop bone from being reabsorbed. The other treatment, which is to inject parathyroid hormone (PTH), stimulates the formation of new bone. Both of these treatments have their downsides. Taking bisphosphonates long-term leads to old and brittle bones. On the other hand, PTH can only be administered in limited durations because of a potential increased risk of developing osteosarcoma, a rare and deadly cancer

The differential mechanisms of these anti-resorptives allows them to be combined, potentially overcoming each treatment's downside and producing better results than monotherapies (using only one or the other) alone. Therefore, Taylor and his collaborators were excited to see what happened when the two treatments were administered sequentially. They treated rats with osteoporosis with a regime that began with a round of bisphosphonates to prevent further bone loss, then a round of PTH to stimulate new, healthy bone, and finished with another round of bisphosphonates in order to lock in the newly created bone. They compared the bones of these rats with those that had been treated with only bisphosphonates, only PTH, or rats that did not receive any treatment

What they found in their experiment supported their hypothesis. The rats with the dual-drug treatment had stronger, more robust bone structures than any of the other groups. Taylor and the Donnelly group went one step further, using their expertise in characterizing micro- and nano- scale composition of bone to identify additional elements that contributed to stronger, healthier bone.

"Most of the improvement in the bone was in the collagen," Taylor says. "The rats that underwent the new drug treatment had collagen that was less cross-linked than the other treatment groups. Less cross-linkage is generally a sign that the bone is less brittle."

The early success of these experiments shows great promise for developing a successful, cost-effective treatment for osteoporosis in humans. "PTH injections are about $900 a month, whereas bisphosphonates are only $10. Combining these treatments would make sure bone health is maintained while treatment costs stay affordable," Taylor says.

PATIENTS WITH ATYPICAL FEMORAL FRACTURES

Taylor also works on a project that further showcases the Donnelly Lab's specialty in characterizing bone at microscopic levels. He looks at bone tissue in patients that have experienced an atypical femoral fracture, which puts the patient at a much higher risk of mortality than individuals who experience regular fractures. The patients most susceptible to atypical fractures are post-menopausal women with osteoporosis who underwent long-term treatment with bisphosphonates. The question that Taylor and the Donnelly Lab are attempting to answer is why these individuals are more prone to these types of fractures.

"We know that very small changes in the composition and distribution of material properties in the bone play a role, along with other factors such as bone geometry, in atypical fractures," says Taylor.

However, atypical fractures are rare in clinical settings, and the Donnelly Lab only studies tissue obtained from real patients. For this reason, Taylor is collaborating with researchers at Villanova University to create computer models of the bone microstructures, inputting experimental data into those models to identify which microstructures appear to be most important in causing fractures.

Taylor says, "From our experimental data, we showed that structures called cement lines deflect cracks that are

"PTH INJECTIONS ARE ABOUT $900 A MONTH, WHEREAS BISPHOSPHONATES ARE ONLY $10. COMBINING THESE TREATMENTS WOULD MAKE SURE BONE HEALTH IS MAINTAINED WHILE TREATMENT COSTS STAY AFFORDABLE." —ERIC TAYLOR

propagated in the bone, helping us to better understand why atypical fractures are occurring. And now, we are able to look at and manipulate those cement lines with computer models. This allows us to figure out exactly how they might be implicated in fracture development." The project aims to increase the Donnelly Lab's expertise in understanding bone at microscopic scales.

BONE CHEMISTRY

Though challenging, Taylor has enjoyed the switch from inorganic and synthetic chemistry to organic materials.

Taylor says, "I always knew I wanted to do something with chemistry. Both of my grandparents were big-time chemists. My grandfather was one of the people who worked on the hydrogen bomb. My grandmother researched the chemistry of photosynthesis. I still do chemistry, too—bone chemistry."

by Colton Poore

MSE PH.D. STUDENTS CREATE LESSON FOR NATIONALLY-DISTRIBUTED H.S. ENGINEERING CURRICULUM

If you happened to be walking through the Engineering Quad at lunchtime on Thursday, January 30 you may have seen a group of high school students holding small devices up to the sun. After a few moments, these same students were calling out numbers and comparing results with other students. If you had stopped to ask someone in the group what they were doing, you might have been surprised by the answer.

John Eom, a Ph.D. student in the Department of Materials Science and Engineering (MSE) and co-creator of the lesson the students were participating in that day, sums it up: “They made berry-powered solar cells.” You read that correctly—the students used crushed berries and just a few other ingredients to create cells for turning light into electricity.

Eom and Alicia Cintora, (who is also an MSE Ph.D. student), first designed and taught the lesson in 2019. They took what they learned last year, altered the plan a bit to cut out some of the downtime, and then taught the new-and-improved version of the lesson this year. The lesson takes two days. On Day One, small groups of students each assemble cells, carefully recording several variables in their assembly process. Then each completed cell is tested to see what voltage it produces. Because the production process for each group's cell varied, the cells also had highly variable outputs.

On Day Two, students shared their results from Day One. "We heard from the teams that got the best results," says Cintora. "And then as a group we altered the procedure to reflect what we learned from Day One. We wanted to get the students thinking about how they could consciously design an experiment."

This lesson grew directly out of an Engaged Cornell grant received by Julie Nucci, who recently retired from positions as an Adjunct Professor of Materials Science and Engineering and Director of Education and Outreach for PARADIM, a National Science Foundation platform that helps users create new interface materials. Cornell is one of several universities involved in PARADIM.

Those high school students you may have seen in the quad that day? They weren't on campus just to visit. The permanent, year-round classroom for their senior year of high school is located in Thurston Hall—on the Engineering Quad. They are part of the New Visions Engineering Program launched three years ago by Nucci and Jim Overhiser, PARADIM K-12 Education Director, in collaboration with the Tompkins-Seneca-Tioga Board of Cooperative Educational Services (TST BOCES), as the K-12 education and outreach program of PARADIM. Their teacher is David Syracuse and the program allows them to explore various engineering careers while having access to some of the facilities and faculty of Cornell Engineering.

Observing the two-day progress of this berry-powered solar cell lesson was Kevin Ng. Ng was in Ithaca visiting from the University of Texas-Austin. He was here for the specific purpose of watching the lesson and then considering it for inclusion in a nationally distributed curriculum called Engineer Your World (EYW). This course, taught as part of the New Visions Program, gives students the

opportunity to receive three engineering credits at UT Austin funded by PARADIM. Engineer Your World is described as "an innovative, student-centered curriculum that engages learners in authentic engineering experiences and inspires them to embrace an engineer's habits of mind."

Nucci had previously learned about the EYW curriculum and noticed the lack of materials science and engineering incorporated in the curriculum. She partnered with Cheryl Farmer, EYW Program Director, in writing the Engaged Cornell proposal that funded the creation of this berry solar cell, MSE-focused lesson for the Engineer Your World Curriculum. The opportunity to raise student awareness of materials science and engineering at the high school level across the country was the driving force behind the grant.

After fabricating their berry-powered solar cells, taking their measurements, and comparing the results, the students now have a better idea of what is required to create a rigorous multi-variable experimental design. And Kevin Ng saw first-hand the students' engagement in what will become the first MSE lesson for the Engineering Your World curriculum, scheduled to debut this fall.

by Chris Dawson

ENGINEERING, LEADERSHIP, PATRIOTISM

WILLIAM EDWARDS, PH.D. '96, FOUND SUCCESS AS AN ENGINEER AND A MEMBER OF THE U.S. NATIONAL GUARD

William Edwards

Whether it's a microscopic droplet of ink exiting a printer nozzle, or securing peace throughout half of the world, William Edwards, Ph.D. '96, is focused on challenges both small and large.

For over 30 years, Edwards has juggled a dual career as an inkjet technology engineer and as a member of the U.S. National Guard, where he is currently transitioning from brigadier general and mobilization assistant to the director of operations for the U.S. Indo-Pacific Command to his new role as commander of NATO Headquarters Sarajevo located in Bosnia and Herzegovina.

"It's definitely a time management challenge," said Edwards of finding success with two professions, "and you have to love what you do, both sides of your career."

Edwards studied materials science and engineering at Cornell as a doctoral student in the laboratory of Professor Dieter Ast, conducting research on integrated circuit materials.

"I can't say enough about the experience I had at Cornell. It was a great time in my life," said Edwards, who attributes his technical knowledge and ability to problem solve to his time at the university. Cornell is also where he met his late wife, Roberta Stinson, Ph.D. '93, who studied fiber science.

As a means to pay for his college education, Edwards joined the U.S. National Guard where he had served as a reserve of the U.S. Armed Forces since he was a senior in high school.

"I had an uncle who was in the Army and I always admired him and his service. There's something patriotic in me that wanted to do something similar. That's what got me into the Guard, but what kept my there is I just love serving. It's something that has defined who I am," said Edwards.

After graduating from Cornell, Edwards moved to Oregon where he took a job with Hewlett-Packard. He is currently a hardware design manager for a team of engineers developing technology and products to support the company's thermal inkjet printers. During his 24 years at the company, he has worked on research and development of integrated circuit chips, printhead technologies, supply development, software and firmware.

"What's been interesting is the number of different applications outside of printing some of that technology is being applied to. HP's 3D-printing technology is based off some of the inkjet technologies that were developed for printers," said Edwards. At Cornell, inkjet technologies have inspired a host of emerging technologies, including organ and tissue engineering. "It's fascinating," added Edwards, who will soon retire from the company to work full-time for the National Guard.

Edwards' current role at the National Guard U.S. Indo-Pacific Command involves advising on all aspects of military deployments, operations, training, and multi-national programs throughout the region, which covers much of the Pacific and Indian Oceans and includes Asia and Australia.

"Fifty-two percent of the planet lives in the region, which includes India. They like to say 'from Hollywood to Bollywood, penguins to polar bears' are our responsibility," said Edwards. "The United States has a number of treaty allies that we work closely with and there's a number of countries that we have some challenging relationships with. What we try to do is ensure a free and open region, free from coercion, free from aggression, and open for all nations," said Edwards.

Though his careers are vastly different, Edwards does see parallels between engineering and the armed forces, especially as it comes to facing challenges.

"Ultimately, engineers are problem solvers and whether those are technical problems, organizational problems, or things in the national security environment, it's about how you break down the elements of those problems and begin to slowly, over time, reduce them and make them into things you can manage," said Edwards.

Leadership is another theme that Edwards has found essential to success is both careers.

"You acquire this leadership skill you continue to develop as you go through your life. There's no book or formula for it, but you have to get to know people and how to motivate and inspire them," said Edwards. "People are different and so you have to work with them to get the best out of their skill sets so that they can achieve what they want. You've got to have an authentic and real interest in the people you're working with."

Edwards' advice to young engineers is to keep an open mind and be accepting of life's surprises.

"You're going to start in one part of your career field or education and you may find yourself in a position that you never would have imagined, doing something that may seem like you're entirely unqualified for," said Edwards, "but I wouldn't underestimate your ability to adapt and even excel in an environment that you never would have seen yourself in before."

Edwards added: "You learn things about yourself when you stretch outside of your comfort zone and ultimately, that is part of life."

by Syl Kacapyr

DISTINGUISHED ALUMNI AWARD

R. Bruce van Dover (left) with Yonn Rasmussen '89 Ph.D. receiving her award

If you were to draw a circle centered on Gaithersburg, M.D. and having a radius equivalent to a six-hour drive from that center, you would see the entirety of places Yonn Rasmussen and her parents were willing to consider for college. Let's call it "Yonn's Circle." Admittedly, that circle would contain some stellar schools—Princeton, the University of Pennsylvania, Carnegie-Mellon, the University of Virginia, and Columbia, just to name a few.

But for a high school senior interested in math, science, engineering, law, and cultural anthropology, two places bubbled up to the top of the list: Columbia University in New York City and Cornell, in Ithaca. "When I was little I was a very verbal child," says Rasmussen during a recent phone interview. "My parents thought 'oh, she's probably going to be a lawyer,' but in high school I applied for and won a scholarship from the Society of Women Engineers (SWE).

"It was given in the form of two classes at the University of Maryland."

The classes Rasmussen took were Engineering 101 and an engineering career exploration class that allowed students to get a taste of what each of the engineering disciplines was about. "Because of those two classes, I knew I wanted to major in engineering," says Rasmussen. "But I was also always interested in the intersection between technology and the humanities, so I knew I wanted to go to a school that was a true university rather than a technical institute. I guess you could say I wasn't a typical geek," says Rasmussen with a chuckle.

Rasmussen and her parents visited Columbia, and her parents were intimidated by New York City. Then they came to Ithaca and loved the campus. The decision was made; Rasmussen came to Cornell. It should be no surprise that she joined SWE at Cornell right away. The connection has lasted to this day, with Rasmussen coming back to campus for SWE events over the years whenever she is able.

Once at Cornell, Rasmussen was unsure about what engineering discipline to major in. Before affiliating with a department, she shopped around to find the best match for her interests. "I decided on Materials Science and Engineering, partly because of a conversation I had with Professor Ruoff," says Rasmussen. (Arthur Ruoff was a longtime faculty member in the Department of Materials Science and Engineering and served as department chair for ten years.) "He sat down and we talked and I was so impressed that the department chair actually took the time to talk with me. By the end of the conversation he asked me when I was going to be the department chair. That made such a huge impression on me."

Rasmussen liked that the study of materials brought in so many of the subjects she was interested in: physics, chemistry, chemical engineering, and physical chemistry. She was also excited by the prospect of getting into a lab and doing research as an undergraduate. As a junior she took part in the co-op program and worked at General Electric's (GE) Corporate Research Center in Schenectady, NY. "The co-op program always seemed like such a great opportunity," says Rasmussen. "I felt like everyone should do it. I got to work on a nickel-based super alloy used in jet turbine engine blades—we were trying to design a material to have certain specific properties such as corrosion- and fatigue resistance. It helped me see that I loved the application side of materials science and engineering as much as the theoretical side. It also helped me see how much I cared about the commercialization of technology."

Fully taking advantage of the breadth of what Cornell had to offer, in addition to classes within her major as an undergrad, Rasmussen took several classes and seminars in social anthropology and psychology "I was often the only engineering student in those classes," she says. "I really liked seeing the tools used by other cultures and how technology influenced the development of different societies."

"At first, I thought I would just get a job after graduation," says Rasmussen. "But some of my co-op supervisors at GE talked to me about going straight into a doctoral program." Rasmussen went through some job interviews as a senior and even received several attractive offers, but in the end she took the advice offered by her GE supervisors and went on for a Ph.D. at Cornell in Materials Science and Engineering. Under Professor Barry Carter, Rasmussen explored the structure property relationship of materials through the study of the microstructure of ceramic grain boundaries and metal/ceramic phase boundaries using high resolution electron microscopy.

Rasmussen took her Ph.D. and went right to work for the Xerox Corporation. "I started out doing research and technology development in photoreceptors, but I was always interested in how to get products to market," says Rasmussen. "Xerox has been great for me because over time I have had opportunities to lead organizations with engineering as well as global manufacturing capabilities, productizing technologies into the marketplace." Rasmussen has had a very successful career thus far with Xerox and has more than twenty five patents. She has risen to the rank of Vice President of the Xerographic Component Systems Group, where she is responsible for technology, product development, and worldwide manufacturing operations in the U.S., the Netherlands, Canada, and Brazil.

More recently she has been developing large scale printed electronics manufacturing capabilities to deliver printed addressable memory. She is enthusiastic about this burgeoning field of printed electronics and how it has the potential to revolutionize how we live through its application to smart objects in the new world of the Internet of Things.

In a recent wide-ranging discussion of her career and what she has learned from it, Rasmussen makes it clear that she is still that same person that was interested in both engineering and the humanities back in high school. There is discussion of technology, but also much talk of sustainability, ethics, organizational dynamics, and the value of self-reflection. "No matter what you decide to do for a living," says Rasmussen, "you are confronted by choices. You have to be conscious and thoughtful about your decisions. You should always be asking yourself if your decisions are aligned with your values. I am lucky to be in a position where my values and my job coincide. I hope to make the world a better, more sustainable place."

Rasmussen also stresses the importance of her humanities studies to her career. "It is essential to understand organizational dynamics and how to navigate through the big picture. A person can be very smart and technologically skilled and still not understand the high-level dynamics." Even today, years after graduating, it is obvious how grateful Rasmussen is to Cornell. "I learned so much more than engineering at Cornell. There is an intellectual breadth here that is hard to match anywhere else."

One value held dear by Rasmussen is the importance of giving back. She is the Xerox Executive Liaison for Cornell with a focus on recruiting Cornell graduates to work for Xerox. She is on the advisory board of the Department of Materials Science and Engineering at Cornell. She participates in student mentoring sessions hosted by the Cornell chapter of SWE, and mentors Cornell students through the Cornell sponsored Externship and FRESH program. And she is the Chair of the Mentoring Committee of the President's Council of Cornell Women.

Over the years, the circumference of "Yonn's Circle" has grown to encompass the world. But at the center of that circle are still the things that were most important to her as a bright 18-year old: family, the intersection between engineering and humanities, and Cornell.

by Chris Dawson

MATERIALS SCIENCE AND ENGINEERING AWARDS DINNER

The 2019 Materials Science and Engineering Awards Dinner was held on Saturday, May 4, downtown at The Hotel Ithaca . The annual event honors one or more distinguished alumni of the department and recognizes over a dozen students who have earned various awards throughout the year. Students also presented research posters and had the opportunity to network with corporate collaborators.

AWARDS DINNER


PEPSICO
LEAN GREEN DRINKS COOLER
Drishti Masand

MSE AWARDS

TEACHING ASSISTANT EXCELLENCE PRIZES
Duncan Sutherland
Ryan Page (not pictured)

MASTER OF ENGINEERING PROJECT IMPACT AWARD
Viola Zhang

MASTER OF SCIENCE OUTSTANDING RESEARCH AWARD
Hengyu Zhou

SENIOR THESIS POSTER AWARDS
Louis Wang
Marina Chang


DOCTOR OF PHILOSOPHY OUTSTANDING RESEARCH AWARD
Curtis Williamson

MASTER OF ENGINEERING PROJECT INNOVATION AWARD
Mukund Ayalasomayajula

SENIOR LAB AWARD
Chandreyee Mukherjee
Sarah McDonald
Bari Cohen
Addison Honeycutt

MSE UNDERGRADUATE RESEARCH AWARD
Helen Kuo

MSE UNDERGRADUATE LEADERSHIP AWARD
Sara Gorske

JAMES L. GREGG PRIZE
Kathie Lin

Presenters in order of appearance: Lara Estroff, Alex Deyhim, Shefford Baker, Kit Umbach, Grace Xing, and Richard Robinson.

REUNION WEEKEND 2019

Beautiful weather provided for great conversations reminiscing on the Engineering Quad and throughout Bard Hall during the reception for Reunion Weekend, Friday June 7, 2019. The Department of Materials Science and Engineering event was well attended by alumni, faculty and guests.

GIVING OPPORTUNITIES

We are grateful to the many alumni and friends of the department for their generous support of its programs over the last 50 years. Your generosity allows us to sustain and enhance our programs reputation as a top-tier materials science and engineering department. Please consider a gift that will help the department accomplish its goals.

MODERNIZE & UPGRADE THE INSTRUCTIONAL LABORATORIES

Modernizing the instructional laboratories is a high priority for sustaining the department's reputation for excellence in educating students. The instructional labs are used by undergraduates from across the College of Engineering, in addition to the MSE junior and senior lab teams. Gifts in support of the MSE instructional labs can be earmarked to either of the following two funds: A current-use fund which will support immediate needs and upgrades; and endowment, which will support continuous improvement of the laboratory infrastructure.

ATTRACT TALENTED FACULTY

As MSE hires the next generation of faculty, gifts in support of this priority can be earmarked to either of the following funds: A current-use fund to support salary and research startup costs for hiring a new faculty member in materials science and engineering; or to establish a named faculty endowment.

ENHANCE THE GRADUATE EXPERIENCE

Attracting talented graduate students to the department is a key goal in our pursuit of excellence in research. Your gift will allow MSE to meet its goal of providing competitive graduate fellowships to every first-year graduate student enrolled in the Materials Science and Engineering program.

PROGRAM SUPPORT

- A research fund to support undergraduate students
- Teaching Assistant Awards in recognition of the top graduate teaching assistants

FOR MORE INFORMATION ON THESE OR ANY OTHER GIVING OPPORTUNITIES, CONTACT

Paige Onstad,
Alumni Affairs and Development
po86@cornell.edu

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Materials Science and Engineering