CornellEngineering

Materials Science and Engineering

MSE

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NSF GRANT ACCELERATES MATERIALS DISCOVERY

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ALUMNI AND FRIENDS OF THE DEPARTMENT

PROFESSOR LARA ESTROFF, MSE CHAIR

Greetings Alumni, Colleagues, and Friends, Summer is in full swing in Ithaca – the first of the sweet corn is available at farm stands, Cayuga Lake is full of boaters, the streets of Collegetown are under construction, and afternoon thunderstorms rumble through the valleys. As we emerge from the COVID-19 restrictions and fully reopen campus in anticipation of an in-person, at-density Fall 2021 semester, I am delighted to share with you a few of the highlights and accomplishments of our students, faculty, and alumni over the past semester. In May, we celebrated our graduates in the class of 2021. Please join me in welcoming them as our newest alumni! Our faculty and students were recognized with multiple awards and the NSF-funded materials innovation platform, PARADIM, was renewed for another five years, ensuring continued leadership in the design and synthesis of new inorganic materials for electronic applications. In this issue of the newsletter, we also share recent examples of our continued research excellence, some spotlights of our wonderful students, and the story of one alumnus' contribution to the fight against COVID. As our community continues to strive to provide a supportive, open, and inclusive environment, I am proud to introduce our new initiative, MSE JEDI (Justice, Equity, Diversity, and Inclusion). The MSE JEDI is jointly led by our students and our newly appointed JEDI faculty liaison, Prof. Julia Dschemuhadse. A group of committed students, faculty, and staff have been meeting regularly since January and have developed an ambitious agenda to be implemented in the coming months and years.

We are excited to announce several new hires including Prof. Judy Cha, who will be joining us from Yale University in July 2022, Prof. Mostafa Hassani, who started as an Assistant Professor in July, 2021 and is jointly appointed in MAE and MSE, and Prof. Hari Nair, who started as an Assistant Research Professor in January 2021. These new faculty bring research expertise to the department in areas ranging from topological and 2D nanomaterials to solid-state additive manufacturing of structural materials to novel oxide materials for optoelectronic devices. In department leadership, we welcome Prof. Eve Donnelly as our new Director of Graduate Studies and thank Prof. Jin Suntivich for his service as DGS during the last two years, which were some of the most challenging any of us will face in our academic careers!

Finally, I would like to draw your attention to an event we are planning to celebrate and remember the life and work of Prof. Steve Sass next spring. We are looking to connect with alumni of Prof. Sass' laboratory and others who would like to join us in this event. 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. Please stay connected with us, opportunities to support the growth of MSE are listed on our website. I look forward to hearing from you!

Warm regards,

Lara Estroff, Department Chair

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MSE Welcomes Judy Cha

Judy Cha, Ph.D. '09, has been hired as a professor in Cornell's Department of Materials Science and Engineering, bringing to her alma mater an expertise in nanoscale materials that will be key to enhancing the university's NEXT Nano initiative.

By Syl Kacapyr

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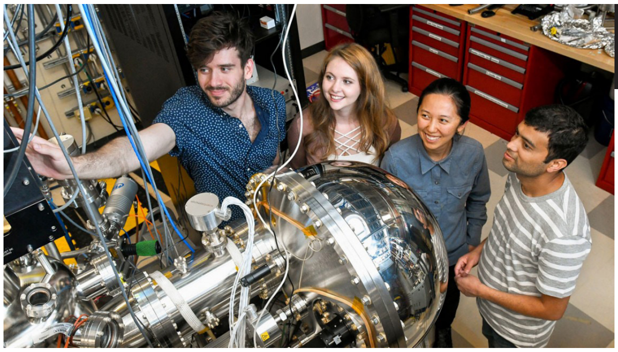

COVER

$22.5M NSF Grant Accelerates Materials Discovery

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By David Nutt

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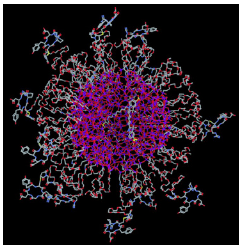

Cornell Start-up Raises $44M to Advance 'C-Dots' Biotech

Elucida Oncology, is a biotechnology company based on C Dots – ultra-small nanoparticles developed at Cornell that show promise in identifying and fighting cancer.

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ALUMNI PROFILE

Greg Galvin, M.S. '82, Ph.D. '84, MBA '93

Entrepreneur Greg Galvin, didn't factor the pandemic into his business plans for the year. And he didn't plan on quickly pivoting his biotechnology company to provide a quick, accurate COVID-19 test.

By Syl Kacapyr

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ABOUT THE COVER

Doctoral students from Cornell, Stanford and Harvard universities participate in PARADIM's weeklong summer school program

MEET THE MATERIALS SCIENCE AND ENGINEERING ADVISORY BOARD

Comprised of 13 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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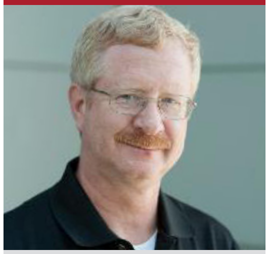

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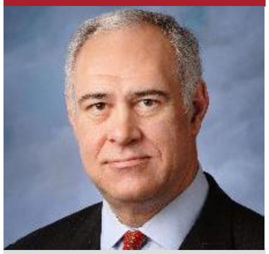

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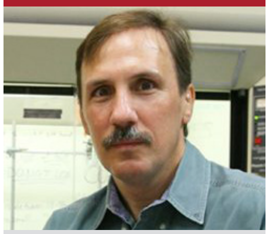

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Northwestern University

Nancy Stoffel

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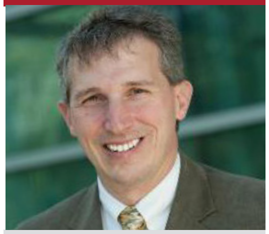
GE Global Research

Rich Vaia



Technology Director of the Functional Materials Division
U.S. Air Force Research Laboratory

Karen Winey

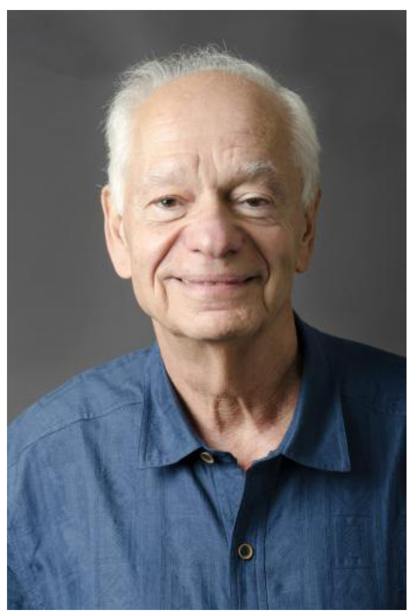
TowerBrook Foundation Faculty Fellow and Professor Materials Science and Engineering
University of Pennsylvania

JEDI - JUSTICE, EQUALITY, DIVERSITY AND INCLUSION

In February, the Department of Materials Science and Engineering held the inaugural meeting of its Justice, Equity, Diversity, and Inclusion initiative (JEDI). JEDI works to advance the department's values of respect, acceptance, fairness, and accountability, and build a community in which the diversity and intersectionality of our members' identities are recognized, accommodated, and celebrated. The initiative represents a joint effort among faculty, students, and staff, and hosts meetings every two weeks that are open to the entire departmental community. Our current efforts are multipronged: we are evaluating and making transparent our department's metrics on student experience, recruitment, and retention; we are spearheading the effort to compose a departmental values statement; we are planning and coordinating recruitment and outreach activities to broaden access to graduate school in general and to Cornell's programs in particular; and we are working to educate ourselves and our community to tackle the challenge of making our communities—small and large—more diverse and inclusive, more just and equitable.

PROFESSOR STEPHEN (STEVE) SASS MEMORIAL SYMPOSIUM

Steve's academic career combined inspiring teaching and cutting-edge research into crystalline interfaces, nanoscale fabrication of new materials, as well as innovative crystallographic characterization and transmission electron microscopy methods. Come join us to celebrate his life and career achievements.



If any of Professor Sass's research group alumni would like to be involved in helping plan the event, contact Marty Murtagh;
mjm43@cornell.edu.
Anyone interested in being on a mailing list to receive more information contact Kyle Page;
kmp265@cornell.edu.

When:
Friday, 10 June, Reunion Weekend 2022
Venue:
Cornell University, Johnson Museum

ALUMNI RETURN TO CORNELL AS KEY FACULTY IN UNIVERSITY INITIATIVES

Judy Cha, Ph.D. '09, has been hired as a professor in Cornell's Department of Materials Science and Engineering, bringing to her alma mater an expertise in nanoscale materials that will be key to enhancing the university's NEXT Nano initiative – an interdisciplinary program designed to advance nanoscale science and microsystems engineering.

Cha is currently the Carol and Douglas Melamed Associate Professor of Mechanical Engineering and Materials Science at Yale University and will join the Cornell faculty in 2022. Her husband, Alex Kwan, Ph.D. '09, associate professor of psychiatry and neuroscience in the Yale School of Medicine, will join Cornell's Nancy E. and Peter C. Meinig School of Biomedical Engineering.

Both alumni are important additions to the College of Engineering, which is growing its roster of interdisciplinary faculty who contribute to university-level centers and initiatives. Cha is a particularly strategic fit, with research interests including atomic understanding of material formation and the design of new materials with applications for quantum computing and information processing.

"Judy is a deep thinker who tackles big questions in materials science," said Lara Estroff, chair of the Department of Materials Science and Engineering. "Her fearless approach combines advanced synthesis with cutting-edge characterization techniques, spanning fields from materials science to physics to electrical and computer engineering. She is already building collaborations across these departments at Cornell."

Cha's research group specializes in the synthesis and characterization of a class of materials known as chalcogenides, which include sulfides, tellurides and selenides. Their work to create two-dimensional, layered topological nanomaterials has a range of novel applications, including quantum computing, biological imaging and renewable energy.

"I'm really excited to work with other faculty members at Cornell to advance in situ transmission electron microscopy experiments, correlating changes in electrical properties as the nanoscale materials undergo phase transitions at cryogenic temperatures," Cha said. "The collaborative environment and long-established research centers at Cornell enable big projects to be undertaken."

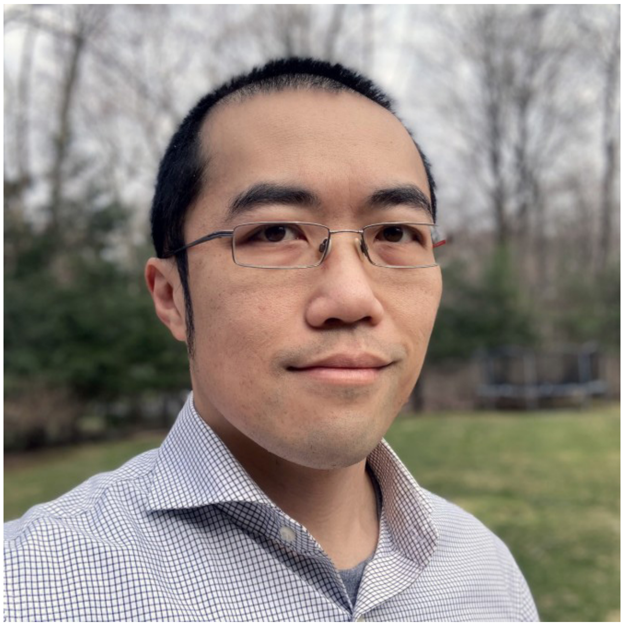
Cha's homecoming will reunite the professor with her doctoral adviser, David Muller, the Samuel B. Eckert Professor of Engineering and task force member of NEXT Nano.

"I think my group fits nicely with the efforts defined in the NEXT Nano initiative, as we can provide nanoscale topological materials for other groups for sophisticated measurements," Cha said. "My primary research focus is on nanowires of topological materials and, currently, I'm looking at a class of topological metals that can rival copper for quantum computing and low-resistance interconnection applications."

Cha is the recipient of the Moore Foundation EPiQS Materials Synthesis Award, the Nano Research Young Innovator Award in Nano Energy, and the National Science Foundation CAREER Award, among other accolades.

Kwan to build on legacy of Watt Webb

Kwan's research focuses on the medial frontal cortex of the brain. Specifically, his research group uses cellular-resolution optical imaging tools to record neural



activity in mice, with applications in understanding psychiatric drugs and the mechanisms underlying mental disorders.

The optical tools used by Kwan can be traced back to his days as a Cornell doctoral student in the laboratory of Watt Webb, the late applied physicist whose imaging techniques revolutionized how scientists observe biological dynamics deep within living tissue. It was in Webb's lab that Kwan developed nonlinear optical microscopes like the ones he uses today to observe the inner workings of the brain.

"Watt Webb was a special scientist because he always had this sense of wonder – every discovery, big or small, was an exciting moment," Kwan said. "I try to do the same for my lab, and I believe there is no better place for the students to learn how to do science than at Cornell."

Kwan's research focus will be of particular value to the Cornell Neurotech initiative, which aims to develop technologies for revealing how individual brain cell's activity in complex neural circuits underlies behavior. He also is expected to develop strong collaborations with Weill Cornell Medicine's Department of Psychiatry, according to Marjolein van der Meulen, James M. and Marsha McCormick Director of the Meinig School of Biomedical Engineering.

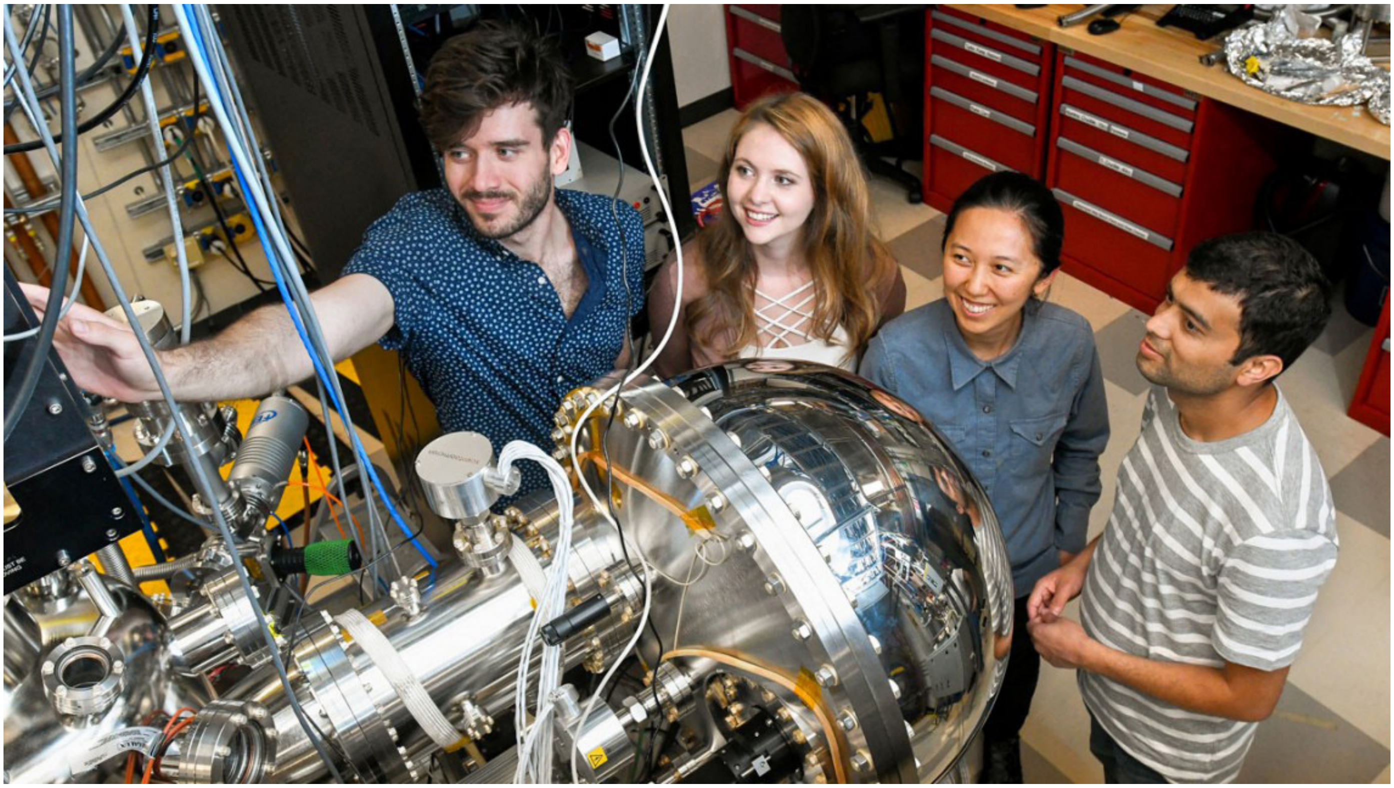
"We are excited to have Alex join us as his neural circuit focus is unique and strengthens our neuroscience community within the school and across campus," van der Meulen said. "He also adds to our strong imaging and instrumentation effort, bringing expertise in optogenetics, the stimulation and suppression of activity with light."

Kwan's research is supported by multiple grants from the National Institutes of Mental Health and the Simons Foundation. He will join the Cornell faculty in 2022.

"I look forward to forming new collaborations at Cornell," Kwan said. "It's exciting that even though my lab is still preparing for the move, we have already started talking with people at Cornell about new microscopy techniques that can overcome imaging limitations."

by Syl Kacapyr

$22.5M NSF GRANT ACCELERATES MATERIALS DISCOVERY



Doctoral students from Cornell, Stanford and Harvard universities participate in PARADIM's weeklong summer school program.

Cornell's Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM) has received a second award of $22.5 million from the National Science Foundation (NSF) to fund another five years, enabling scientists, engineers and entrepreneurs nationwide to design and create new inorganic materials for use in electronics.

PARADIM, launched in 2016, is one of four material innovation platforms that emerged from the NSF's response to the National Materials Genome Initiative, which set out to discover, develop, manufacture and deploy advanced materials twice as quickly, and at a fraction of the cost, as conventional methods.

"PARADIM is creating a new model for materials research," said Charles Ying, the NSF program officer overseeing PARADIM. "Users throughout the country and scientists at Cornell University and Johns Hopkin University not only benefit from the state-of-the-art and often unique instruments, but also share technical know-how and data for a common goal of speedy design and creation of novel materials."

In its first five years of operation, PARADIM has hosted more than 170 unique users from 41 universities and national labs, providing them with the state-of-the-art facilities, equipment and expertise to make breakthrough discoveries in electronic materials, which reverberate far beyond the lab.

"What's special to PARADIM is that it's not just a place where you send your ideas for new materials and we make them," said Lena Kourkoutis, associate professor in applied and engineering physics, and PARADIM co-director. "The users come to the facility and become part of the discovery process from idea to realization. They are being trained in approaches of making materials-by-design, and that has broader impact in the long run. We see this because we have a number of junior faculty who come to us, bring their students and jump-start their career."

Research at PARADIM has resulted in 140 journal publications to date. Among the platform's most notable discoveries are a new ultrawide bandgap semiconductor, rutile GeO_2, in thin film form; a new type of topological insulator; and a form of galfenol that is the world's highest performance magnetostrictive material – a material consisting of tiny ferromagnets that can change its shape during magnetization – free of rare earth elements.

"The methods and collaborative environment that we make available to our users enable them to discover materials more quickly," said PARADIM co-director Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry in the Department of Materials Science and Engineering. "But it's not serendipitous discovery of better materials. It's what we would call materials-by-design. It's using the latest equipment and methods – to theorize, synthesize and characterize – in order to accelerate the discovery process."

PARADIM is also developing new tools and techniques, such as combining growth and characterization for interface materials. The platform helped a group led by David Muller, the Samuel B. Eckert Professor of Engineering, set a world record in 2018 for the highest resolution microscope, and recently topped that achievement by a factor of two by developing a next-generation electron microscope pixel array detector prototype.

"From its outset, PARADIM set itself the ambitious goal of creating an eco-system where any U.S. scientist can create and characterize virtually any inorganic electronic material of interest. The NSF renewal confirms that PARADIM has not just met this goal, but has in the process defined a world-class model for creating novel materials by design," said Lynden Archer, Joseph Silber Dean of Engineering.

In addition to being a national user facility, PARADIM is actively involved with fostering the next generation of materials scientists and technologists. Forty-seven students have participated in its Research Experiences for Undergraduates program, in which students work on projects supporting PARADIM's mission, and the platform offers a popular weeklong summer school program including lectures and hands-on learning, which has so far trained 230 people, many of whom returned as PARADIM users.

With the new NSF award, PARADIM will be offering two-year traineeships to seven incoming doctoral students in physics, applied physics and material science at Cornell and an additional four traineeships at Johns Hopkins University, which provides PARADIM's bulk-crystal growth facility.

PARADIM is also partnering with the Kavli Institute at Cornell for Nanoscale Science to initiate a new summer and sabbatical program to encourage greater diversity.

The funding renewal is allowing PARADIM to strategically invest in creating new capabilities in magnetic textures and quantum materials, which will help meet the growing interest for quantum technologies in storage and computation.

To that end, PARADIM has expanded its faculty team with the addition of Jie Shan, professor of applied and engineering physics in the College of Engineering and director of PARADIM's thin film facility, and Tomás Arias, professor of physics and a Stephen H. Weiss Presidential Fellow, director of PARADIM's theory user facility.

PARADIM is also investing in data, specifically artificial intelligence and machine learning, as a means to make and analyze samples faster. Data, after all, supports one of the key tenets of PARADIM: the open sharing of information and knowledge.

"The platform is free of charge to users from across the nation," Schlom said. "What the nation gets from it is the data. When users come and use the equipment, our equipment stores all of the synthesis conditions, the images of diffraction, whether it's electron diffraction, or X-ray diffraction. Normally if it's your own lab, only a small fraction of that data ever goes into a paper. And the rest of it is dark, it's lost. So part of our vision is to make all data, on successful as well as unsuccessful samples, available to the public. And that has some social aspects to it also."

by David Nutt

PARADIM enables scientists, engineers and entrepreneurs nationwide to design and create new inorganic materials for use in electronics.

CORNELL STARTUP RAISES $44M TO ADVANCE 'C DOTS' BIOTECH

Elucida Oncology, a biotechnology company based on C Dots – ultra-small nanoparticles developed at Cornell that show promise in identifying and fighting cancer – recently secured $44 million in financing, in addition to $28 million raised in 2018.

C Dots, originally called Cornell dots, were created more than 15 years ago in the lab of Uli Wiesner, the Spencer T. Olin Professor of Engineering in the Department of Materials Science and Engineering. Wiesner has been working to put C Dots to use in the fight against cancer ever since.

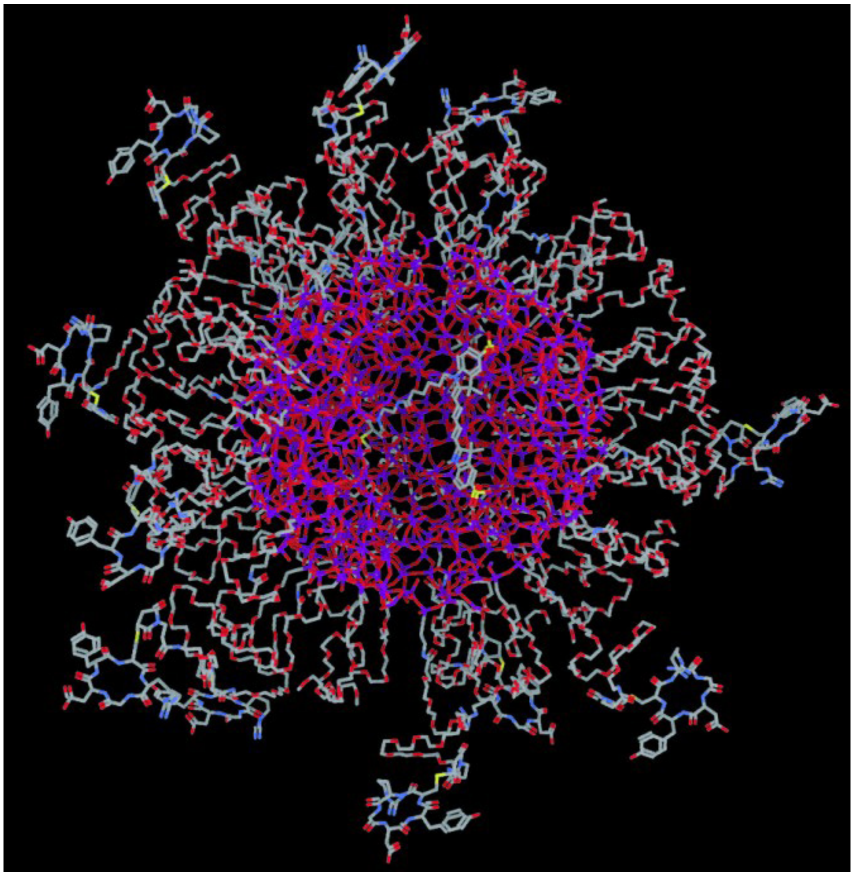
As a result of their size, C Dots proved safe and effective for use in human beings as both an imaging and a diagnostic tool in early clinical studies. The new funding will help the company gain regulatory approval as a targeted cancer therapeutic, and to expand its management team and its laboratory capabilities.

"This vote of support from investors means a lot to me," Wiesner said. "Given C Dots' broad applicability, I have been pushing efforts in health care-focused startups since 2005 to commercialize this technology. At the beginning it was a reagent company. Then we started a company focusing on diagnostics, and now we have a company emphasizing therapeutics."

This evolution shows the flexibility and the value of the C Dot platform, he said.

Elucida was founded in 2014 and co-founders include Wiesner, Kai Ma, Ph.D. '15, and Dr. Michelle Bradbury, director of intraoperative imaging at Memorial Sloan Kettering Cancer Center and professor of radiology at Weill Cornell Medicine.

In the C Dots, each silica-based nanoparticle has an embedded fluorescent molecule in the interior for optical detection, as well as several organic ligands and functional groups on the surface. This makes the C Dot platform more flexible: Specific ligands prevent attack from the body's defenses, while targeting groups cause the C Dot to specifically bind with tumor cells when they come into contact.



A rendering of the molecular structure of a Cornell dot, which is smaller than 10 nanometers.

In this configuration, C Dots are currently being tested as a diagnostic tool in ongoing clinical trials at Memorial Sloan Kettering and Weill Cornell Medicine. When they are injected into a person with cancer, the glowing C Dots attach to cancer cells and can be seen by the surgeon with the use of a fluorescent camera.

In order to gain regulatory approval as a targeted cancer therapeutic, the company will need to complete ongoing toxicology studies and file an Investigational New Drug application with the Food and Drug Administration, according to Geno Germano, CEO and president of Elucida. The latest round of funding will support these moves.

"We have an excellent technology, an incredible team at Elucida, and a world-class board to help us navigate the highly complex landscape around cancer therapeutics," Wiesner said.

Elucida is planning to start clinical trials this summer; by the spring of 2022, the company expects to have the first data from those trials.

"If this trial validates our therapeutic approach the way we think and hope it will," Wiesner said, "our C Dot nanoparticle platform will give us a whole battery of disease-fighting products."

by Chris Dawson

ENGINEERS SHOW NEW CONTROL OF PHONONS USING LASER PULSES

Cornell engineers used precisely timed laser pulses to control changeable properties in a quantum material, pioneering a method that may have wide applications across a class of materials with immense technological interest.

Postdoctoral researcher Oleg Gorobtsov is co-lead author of "Femtosecond Control of Phonon Dynamic Near a Magnetic Order Critical Point," published May 17 in Nature Communications. Gorobtsov works in the lab of senior author Andrej Singer, assistant professor of materials science and engineering in the College of Engineering.

The engineers used femtosecond laser pulses aimed at specific points in a thin metal film with magnetic order to control the material's transient phonon state – the vibrational motion in which the material's atoms oscillate. The technique gives physicists another tool in the quest to control quantum materials at their natural time and length scales, Gorobtsov said.

"Technology is moving into the direction of ever-faster switching between different states of a material," he said. "Lasers currently offer speeds as fast as one millionth of one billionth (a quadrillionth) of a second. During this switching, detrimental or beneficial non-equilibrium atomic vibrations, or phonons, often arise."

This method of using multiple photoexcitations to initiate and then either extinguish or control these transitional vibrational states in a material with magnetic order shows qualitatively how phonon dynamics can be controlled using laser pulses.

The work was carried out at the Linac Coherent Light Source at the SLAC National Accelerator Laboratory in Palo Alto, California. Gorobtsov and Singer ran the experiment at the SLAC facility because its X-ray equipment gave them the ability to precisely measure the material's changes in transitional states.

"Obviously, when these materials are used in real devices, we cannot put a state-of-the-art X-ray source inside to measure the material response," Gorobtsov said. "However, the unique information from an X-ray free electron laser lets us build a fundamental quantitative model of ultrafast transitions in this material."

Having this quantitative model will enable researchers to predict the behavior of elemental chromium, the paradigmatic quantum material used in this study, as well as that of many related materials.

This experiment grew out of an earlier study Singer ran, in which he showed that a single laser pulse could initiate a transitional vibrational state in a quantum material.

"We saw that a laser pulse induces an extraordinarily strong response," Singer said, "and that led us to believe that multiple pulses would offer a unique opportunity to control the magnetic quantum material. Dr. Gorobtsov's experiment shows that our hypothesis was correct."

Gorobtsov and Singer see possible applications in the field of spintronics – the study of an electron's intrinsic spin, its magnetic moment and its charge in solid-state devices. Being able to induce, control and extinguish changes in spin states with precision would have implications in energy harvesting and storage, and in data storage and transfer.

"It is hard to imagine the full range of applications," Singer said, "but the new fundamental understanding holds promise for new advances in ultrafast science and technology."

by Chris Dawson

COLLABORATION SPARKS NEW MODEL FOR CERAMIC CONDUCTIVITY

As insulators, metal oxides – also known as ceramics – may not seem like obvious candidates for electrical conductivity. While electrons zip back and forth in regular metals, their movement in ceramic materials is sluggish and difficult to detect.

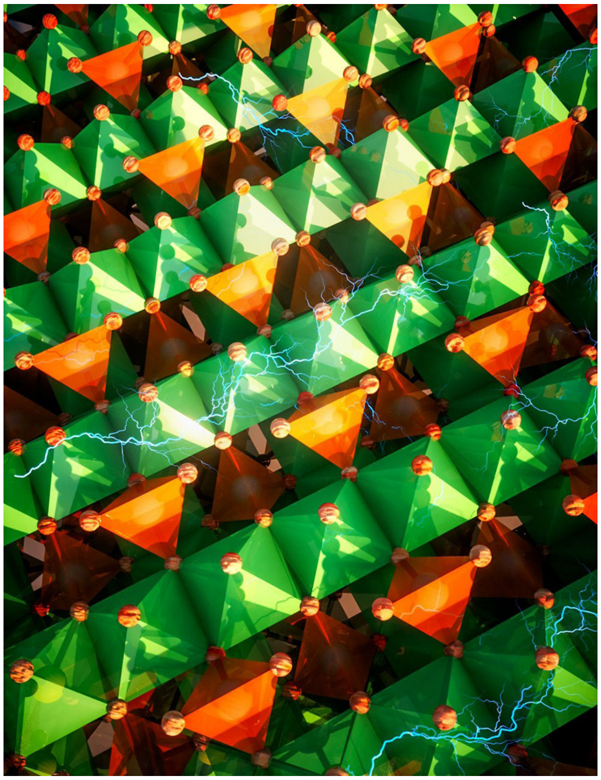
But ceramics do contain a large range of conductivities. This behavior was laid out in 1961 in the "small polaron hopping model," which described the movement of polarons – essentially electrons coupled to a lattice distortion – from one end of a material to the other.

An interdisciplinary collaboration led by Richard Robinson, associate professor of materials science and engineering in the College of Engineering, has shown just how outdated and inaccurate that model is, especially regarding complex oxide systems. By updating the model to reflect different pathways for conduction, the team hopes its work will help researchers who are custom-tailoring the properties of metal oxides in technologies such as lithium ion batteries, fuel cells and electrocatalysis.

Their paper, "Breakdown of the Small-Polaron Hopping Model in Higher-Order Spinels," published online Oct. 21 in Advanced Materials and was featured on the cover of the Dec. 8 issue. The lead author is doctoral student Anuj Bhargava.

"This is the most commonly-used formula in the field, but it hadn't been touched in 60 years. That's a big deal because, nowadays, metal oxides are used in many applications where the performance is directly impacted by the conductivity – for example, in energy systems like electrical energy storage and generation, electrocatalysis, and in new-generation materials," Robinson said. "Many people are putting a great amount of experimental effort into oxides right now, but they haven't carefully examined how the charge carriers move in the material, and how the composition influences that conductivity.

"If we understood how electrons are conducted and we could customize the composition to have the highest conductivity, we could optimize the energy efficiency of a lot of materials out there," he said.



An interdisciplinary collaboration led by Richard Robinson updated the "small polaron hopping model" to reflect different pathways for conduction in ceramics. Their work will help researchers who are custom-tailoring the properties of metal oxides in technologies such as lithium ion batteries, fuel cells and electrocatalysis.

To get a detailed look at the way electrons move in metal oxides and how their occupation sites can affect the material's conductivity, Robinson turned to Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry. Schlom and his team used the Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM) and the Cornell NanoScale Science and Technology Facility (CNF) to grow and characterize thin crystalline films of manganese-doped iron oxide (MnxFe3-xO4).

Robinson's group then used the Cornell High Energy Synchrotron Source (CHESS) to determine the atomic locations and the charge state of the positively charged ions, called cations, and measured how the material's conductivity changes at different temperatures.

They brought the material to Lena Kourkoutis, associate professor in applied and engineering physics, who used advanced electron microscopy to get an atomically precise view of the crystal's substrate and compositional gradients, and confirmed the team's findings.

Lastly, Robinson's team consulted researchers at Technion – Israel Institute of Technology, who used computational methods to explain how polarons hop differently in materials based on the energy barriers and oxidation states. Their results uncovered the existence of large energetic barriers associated with "switching" conduction paths between the two different cations, and this provided the crucial final piece that was necessary to put a new formula together.

"This new finding gives us insight into something that's been overlooked. Instead of the Edisonian, trial-and-error approach of just making and testing a bunch of new materials, we can now take a more systematic approach to figuring out why the materials behave differently, especially on this really important level, which is electronic conductivity," Robinson said. "The important processes in energy materials involve conductivity, electrons coming in and out of the material. So for any application with metal oxides, conductivity is important."

by David Nutt

NANOSCALE DEFECTS COULD BOOST ENERGY STORAGE MATERIALS

Some imperfections pay big dividends.

A Cornell-led collaboration used X-ray nanoimaging to gain an unprecedented view into solid-state electrolytes, revealing previously undetected crystal defects and dislocations that may now be leveraged to create superior energy storage materials.

The group's paper, "X-ray Nanoimaging of Crystal Defects in Single Grains of Solid-State Electrolyte Li7-3xAlxLa3Zr2O12," published April 29 in Nano Letters, a publication of the American Chemical Society. The paper's lead author is doctoral student Yifei Sun.

For a half-century, materials scientists have been investigating the effects of tiny defects in metals. The evolution of imaging tools has now created opportunities for exploring similar phenomena in other materials, most notably those used for energy storage.

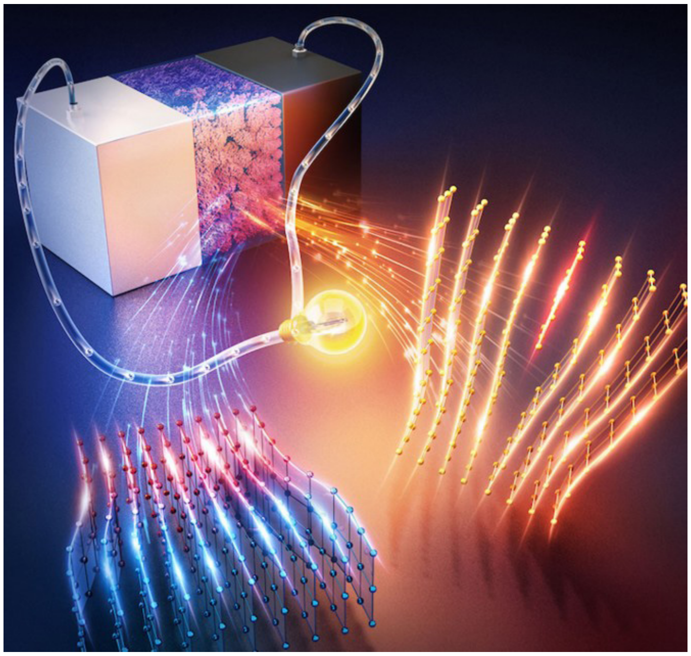
A group led by Andrej Singer, assistant professor and David Croll Sesquicentennial Faculty Fellow in the Department of Materials Science and Engineering, uses synchrotron radiation to uncover atomic-scale defects in battery materials that conventional approaches, such as electron microscopy, have failed to find.

The Singer Group is particularly interested in solid-state electrolytes because they could potentially be used to replace the liquid and polymer electrolytes in lithium-ion batteries. One of the major drawbacks of liquid electrolytes is they are susceptible to the formation of spiky dendrites between the anode and cathode, which short out the battery or, even worse, cause it to explode.

Solid-state electrolytes have the virtue of not being flammable, but they present challenges of their own. They don't conduct lithium ions as strongly or quickly as fluids, and maintaining contact between the anode and cathode can be difficult. Solid-state electrolytes also need to be extremely thin; otherwise, the battery would be too bulky and any gain in capacity would be negated.

The one thing that could make solid-state electrolytes viable? Tiny defects, Singer said.

"These defects might facilitate ionic diffusion, so they might allow the ions to go faster. That's something that's known to happen in metals," he said. "Also like in metals, having defects is better in terms of preventing fracture. So they might make the material less prone to breaking."



Singer's group collaborated with Nikolaos Bouklas, assistant professor in the Sibley School of Mechanical and Aerospace Engineering and a co-author of the paper, who helped them understand how defects and dislocations might impact the mechanical properties of solid-state electrolytes.

The Cornell team then partnered with researchers at Virginia Tech – led by Feng Lin, the paper's co-senior author – who synthesized the sample: a garnet crystal structure, lithium lanthanum zirconium oxide (LLZO), with various concentrations of aluminum added in a process called doping.

Using the Advanced Photon Source at the U.S. Department of Energy's Argonne National Laboratory, they employed a technique called Bragg Coherent Diffractive Imaging in which a pure, columnated X-ray beam is focused – much like a laser pointer – on a single micron-sized grain of LLZO. Electrolytes consist of millions of these grains. The beam created a 3D image that ultimately revealed the material's morphology and atomic displacements.

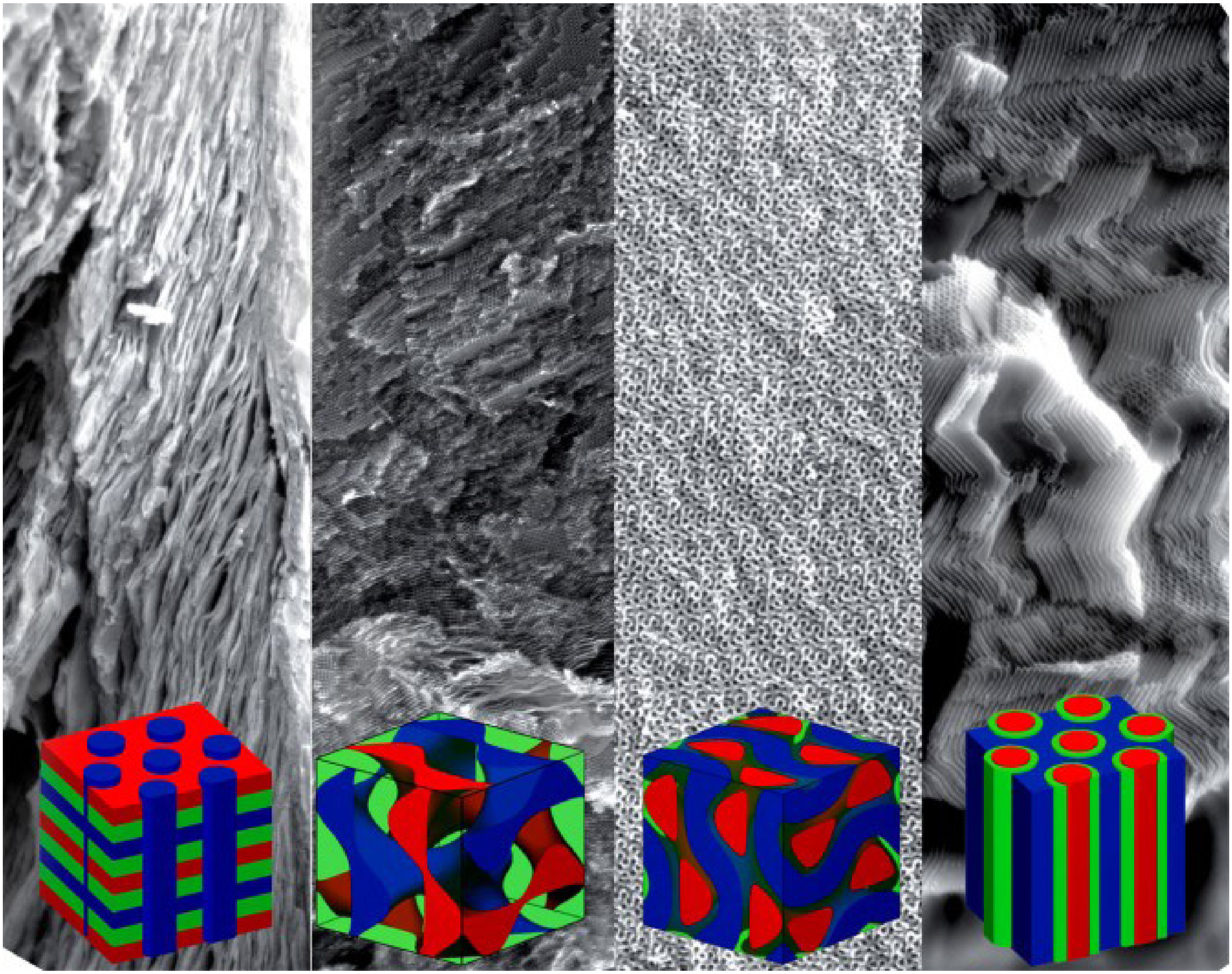
"These electrolytes were assumed to be perfect crystals," Sun said. "But what we find are defects such as dislocations and grain boundaries that haven't been reported before. Without our 3D imaging, which is extremely sensitive to defects, it would be likely impossible to see those dislocations because the dislocation density is so low."

The researchers now plan to conduct a study that measures how the defects impact the performance of solid-state electrolytes in an actual battery.

"Now that we know exactly what we're looking for, we want to find these defects and look at them as we operate the battery," Singer said. "We are still far away from it, but we may be at the beginning of a new development where we can design these defects on purpose to make better energy storage materials."

by David Nutt

SUPERCONDUCTING QUANTUM MATERIAL HAS AN ORGANIC TWIST



These scanning electron microscopy images show the four different superconductor quantum material structures that were directed by the spontaneous self-organization of soft organic block copolymers, along with color schematics of the four structures.

An interdisciplinary team of Cornell researchers has taken its breakthrough discovery – which melded the ability of soft organic materials to spontaneously self-organize with quantum materials to create superconductors with novel porous architectures – and upped the ante by designing a new cohort of these "quantum metamaterials" that can achieve superconductivity at temperatures competitive with state-of-the-art solid-state materials synthesis.

In the process, they've demonstrated the intrinsic superconducting properties are a function of the architecture itself.

The group's paper, "Superconducting Quantum Metamaterials from Convergence of Soft and Hard Condensed Matter Science," published May 16 in Advance Materials. The paper's lead author is Peter Beaucage, Ph.D. '18.

The interdisciplinary team, which brings together researchers in engineering, chemistry and physics, was led by Ulrich Wiesner, the Spencer T. Olin Professor of Engineering.

"When you look at the regular way that superconductors are put onto chips, it's all expensive and nonscalable high-vacuum approaches," Wiesner said. "What we do here is employing low-cost and scalable solution-based processes completely compatible with microelectronics processing. You can basically spin coat these materials onto your chip. You then simply submit them to various heat processing steps, and you get superconductors. And now we know how to get high-quality superconductors."

The collaboration includes co-authors R. Bruce van Dover, the Walter S. Carpenter Jr. Professor of Engineering; and Sol Gruner, the John L. Wetherill Professor of Physics, and Francis DiSalvo, John A. Newman Professor, Emeritus, both in in the College of Arts and Sciences.

The researchers unveiled their initial self-assembled, three-dimensional gyroidal superconductor, created from niobium nitride, in 2016. The gyroid is a complex cubic structure that contains multiple spirals and pores and allows electronic transport in all three orthogonal directions of space. This was an entirely new architecture for superconductors.

The researchers used organic block copolymer self-assembly to structure-direct a niobium oxide sol into a composite with two intertwining gyroidal networks. After heat treatment in air to remove the polymer and generate a mesostructured and porous gyroidal oxide, the oxide was further transformed into a nitride using subsequent heat treatments in ammonia. By heating and cooling the material in stages up to 850 degrees, the team was able to achieve superconductivity.

"It was a big deal to demonstrate the proof of principle because it showed we can use the structure control on the nanoscopic level from these designer macromolecules and marry that with the properties of superconductors," Wiesner said. "We now understand this much, much better."

In the years since their initial findings were published, the researchers discovered that by heat-treating niobium nitride with gases such as argon and carburizing gas, they could achieve high-quality superconducting materials. The niobium nitride becomes more equilibrated, the crystal defects essentially heal, and the quality of the material improves to the point that its transition temperature for superconductivity jumps from the initially achieved 7.9 kelvin to 16 kelvin, comparable to state-of-the-art materials.

By integrating more inorganic sol nanoparticles into the same polymer, the researchers also realized the promise of block copolymers to create other distinct morphologies, or structures, by self-assembly.

While the inorganic lattice parameters of the four structures are very similar, the quantum properties turn out to be different.

"In principle, you think, OK, it's the same material. So it should have the same transition temperature below which it becomes superconducting. Not true," Wiesner said. "The transition temperature is actually a function of the mesostructure, not the intrinsic atomic structure of the niobium nitride. That is what's called metamaterial behavior. If we now imprint those block copolymer mesostructures onto the superconductors, we're actually going to get completely different properties out."

Since the process is more cost-effective and scalable than traditional solid-state approaches, the resulting high-quality metamaterials could find use in a range of known or novel applications, such as quantum information science, or energy conversion and storage, or sensing.

"In the beginning, we were crawling," Wiesner said. "Now, I would argue, we're walking. We see the street and we're gearing up to run."

by David Nutt

INSPIRED BY HIS EDUCATION, ALUMNUS CREATES FAST COVID-19 TEST

Greg Galvin

Entrepreneur Greg Galvin, M.S. '82, Ph.D. '84, MBA '93, didn't factor the pandemic into his business plans for the year. He didn't expect the shutdowns or the equipment shortages. And he didn't plan on quickly pivoting his biotechnology company to provide a quick, accurate COVID-19 test that enabled Cayuga Health System to open one of the first drive-through testing sites in the nation.

Galvin, the 2014 Cornell Entrepreneur of the Year, is founder and CEO of Rheonix, an Ithaca-based company that is ramping up production of a fully automated, same-day test for SARS-CoV-2, the virus that causes COVID-19.

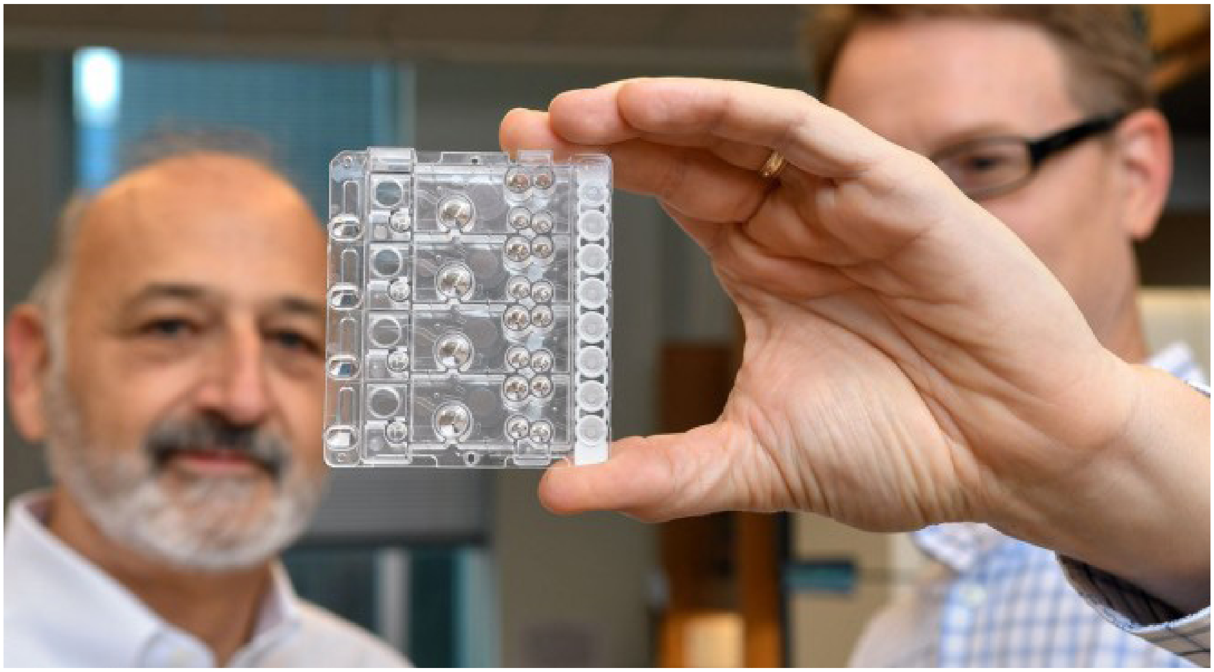
Rheonix's simple-to-use diagnostic system consists of an assay – a biomolecular analyzer that detects genetic material from a person's respiratory sample – and a specialized workstation, which does not require a technician or advanced knowledge to operate. The workstation can process up to 24 assays at once.

Over 12 months from February 2020 Rheonix grew from 50 employees to over 180. Manufacturing lines were duplicated and new highly automated production equipment was added to bring test capacity from 5000 per week to over 100,000 in response to the demand for rapid testing.

During the peak of the pandemic production of the assay and workstation has mostly been at the mercy of a crippled supply chain, Galvin says. But Rheonix has been meeting as much of the demand as possible ever since the Food and Drug Administration (FDA) authorized emergency use of its assay in April 2020.

Rheonix's early entry into the coronavirus testing market came as the company had already been seeking FDA approval of a similar assay for rapid testing of sexually transmitted infections. The technology needed to produce a coronavirus test was so similar that Rheonix had a working prototype just three weeks after the Centers for Disease Control and Prevention published the virus's genetic sequence, in February.

Galvin said it was just a matter of altering the system to detect a different



and the flu are very similar, so distinguishing between the two diseases is clinically important because the treatment protocols are completely different for them," said Galvin.

Although Rheonix is not based on Cornell technology, Galvin says it's still inspired by his Cornell education.

"THE UNIVERSITY IS FOSTERING A LOT MORE ENTREPRENEURIAL ACTIVITY THAN JUST THE NUMBER OF STARTUPS THAT USE CORNELL TECHNOLOGY. WHETHER IT'S CORNELL INTELLECTUAL PROPERTY OR A CORNELL ALUM, IT'S STILL A CORNELL CREATION."

—GREG GALVIN

genetic target – a business move that not only made sense financially, but also served the community.

"The sense of urgency was apparent and the need was personal for everyone at the company," says Galvin, a former member of the Cornell University Board of Trustees. He currently serves on the advisory councils for the College of Engineering and the Department of Materials Science and Engineering.

"But also this ability to develop a product, put it out in our local community and create immediate benefits," he says, "I think it really helped motivate people."

Among the first organizations to receive the test were Cayuga Health System in Ithaca and United Health Services in Binghamton, New York. The assays enabled Cayuga Health to open one of the first drive-through testing stations in the nation. "We've delivered a total of 30 instruments to their lab," Galvin says, "which theoretically puts their capacity at over 13,000 samples per day."

Rheonix is scoring high marks for the accuracy of its rapid testing. Comparative data released by the FDA in September show that, of the 58 molecular assays it compared, Rheonix's scored the fourth highest in its ability to detect a small amount of viral material in a given sample.

"We were very pleased to see the results," Galvin says. "We knew our test was very sensitive, but what really surprised me out of that data was how wide the disparity between the different tests actually is. I really didn't expect the tests to be that different."

While Rheonix ramps up production of its COVID-19 assay, it will also be seeking FDA approval of a newly developed assay that can target four viruses at once: influenza A, influenza B, respiratory syncytial virus and SARS-CoV-2.

"The physical symptoms of COVID

"Rheonix is an example of the much, much greater number of startup businesses that are created by Cornellians that don't necessarily use Cornell intellectual property," says Galvin, a frequent speaker on campus who has created a graduate fellowship to support engineering students. "The university is fostering a lot more entrepreneurial activity than just the number of startups that use Cornell technology. Whether it's Cornell intellectual property or a Cornell alum, it's still a Cornell creation."

by Syl Kacapyr

MEET TASNUVA TABASSUM '17

Tasnuva Tabassum graduated from Cornell with an M.S. in Materials Science and Engineering in 2017. She utilized The Cornell NanoScale Science and Technology Facility (CNF) to work on research funded by Applied Materials, Inc. (AMAT) specializing on thin film studies with Cornell Professor Emeritus Dieter Ast and Professor Bruce van Dover. She has 2 patents with AMAT and has held various roles within the company as Process Engineer, Quality Engineer and Product Line Manager. She has also invited Professor John Hopcroft and Professor Robert Shepherd from Cornell to speak on AI, ML and Robotics in hopes of creating more research partnerships between Cornell and AMAT. More recently, she has moved to Apple as an Operations Program Manager where her primary focus is supply chain strategies for the iPad and bringing disruptive process improvements to the qualification process.

Why did you choose Cornell?

It's funny actually, but growing up in Bangladesh, we were exposed to a lot of American TV. One of the movies I watched as a teen was "The Perfect Score" where a group of high school students attempted to steal SAT questions. One of the students, played by Chris Evans, wanted to study architecture in Cornell. Since I wanted to study architecture back then, that inspired me. I didn't go into architecture or steal SAT questions, but the Cornell part of that dream came true. And of course, looking at rankings, Cornell is one of the best schools in the world for MSE.

How are things going now?

Things are good but it can always get better. If you told 15 year old me that I was working at Apple, I would have been impressed. But today, I want to do so much more than just work at a big company. It's important to take a step back and look at how far you have come, though. The line between being ambitious and never being content is extremely fine.

What inspired you to choose your field of study?

As I mentioned, I wanted to be an architect when I was younger. But slowly I realized I was great at grasping concepts in Physics, Chemistry and Math. And Materials Science Engineering was a good combination of these. It made more sense to go down that route for a better career path and opportunities. That's the mindset I was raised with: "choose a field that gives you a better chance of success."

What hobbies do you have in your spare time?

I am an extrovert. I love connecting with people. I don't see people as tools but I truly believe every conversation helps me in some way or another. In that sense, I love to host game nights for my co-workers, explore different downtowns in California with friends, and cook authentic Bangladeshi food for everyone. I also have a massive sweet tooth so I love French patisserie and baking.

Do you have any advice for current Engineering students?

Your career is not a race against someone else. You will see that your competitors will always keep changing. Today it could be your classmate, tomorrow it will be a coworker. So there's really no point in focusing on winning against a specific person. Your only constants are things you have control over- confidence and skillset. If you keep working on yourself, you will eventually get to where you need to be.

What is next for you?

I want to eventually start my own business. Depending on the nature of my business and the market I am trying to target, I will spend the next few years trying to gather learnings in those fields.

MSE AWARDS

Professor Darrell Schlom was awarded the 2021 James C. McGroddy Prize for New Materials Recipient from the American Physical Society (APS)"For pioneering the atomic-layer-by-layer synthesis of new metastable complex-oxide materials, and the discovery of resulting novel phenomena."

Professor Uli Wiesner has been recognized with a Special Creativity Award by the National Science Foundation (NSF). This will provide him with a two-year extension of his existing NSF single investigator award.

Professor Mike Thompson has been appointed as the Dwight C. Baum Professor in Engineering.

Professor Chris Ober was awarded with a 2020 Research Excellence Award from Cornell Engineering.

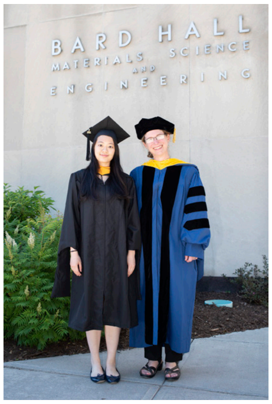
Associate Professor Jin Suntivich was awarded the 2020 James and Mary Tien Award for Teaching Excellence from the College of Engineering.

Maya Martirossyan, a rising fourth year graduate student in Prof. Julia Dschmuhadse's group, received The Dolores Zohrab Liebmann Fellowship which supports graduate students in the humanities, social sciences or natural sciences

Hannah Contreras, Class of 2021, was the recipient of an NSF Fellowship Award.

Konrad Hedderick, a rising fifth year graduate student in Prof. Lara Estroff's group, received an Office of Science Graduate Student Research (SCGSR) Program award from the U.S. Department of Energy.

Jalen Harris, a rising second year student in Prof. Nicole Benedek's lab, received a Computational Science Graduate Fellowship from the Department of Energy.











MSE 2021 Graduation


MSE 2021 Graduation

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

Cornell Engineering
Materials Science and Engineering