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Fall & Winter 2021 Newsletter of the Cornell NanoScale Facility
• Volume 30 • Issue 2 •

CNF

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Cornell NanoScale Facility

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New CNF Staff: Stacy Clementson

Please help us welcome our newest staff member, Stacy, who is taking on the User Program Administration as well as being the face of the CNF "front of house."

Welcome, Stacy!

Photography Credits & NSF Disclaimer

The front and back cover images are from Edward Camacho's latest NanoScribe work with the iconic McGraw Tower. See page 43 for the full story. The inner background image is from Prof. Kyle Shen's work described on page 15. Other photographs in this issue were provided by the author, researcher, CNF staff, or as noted. The director photographs were taken by University Photography. The CNF Annual Meeting screen captures were taken by Melanie-Claire Mallison. The NanoMeter is formatted by Melanie-Claire. She welcomes your comments and corrections at mallison@cnf.cornell.edu

The material in this newsletter is based upon work supported by the National Science Foundation (NSF) under Grant No. NNCI-2025233. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

CNF Cornell NanoScale Science and Technology Facility · National Nanotechnology Coordinated Infrastructure · Cornell University · New York State of Opportunity. Empire State Development · NSF

VIRTUAL CNF SHORT COURSE

Technology & Characterization at the Nanoscale

January 19 - 21, 2022

Registration deadline January 10, 2022

https://cornellcnf.link/tcn

This intensive 3-day VIRTUAL short course offered by the Cornell NanoScale Science & Technology Facility, combines lectures and lab demonstrations designed to impart a broad understanding of the science and technology required to undertake research in nanoscience. The CNF TCN is an ideal way for faculty, students, post docs and staff members to rapidly come up to speed in many of the technologies that users of the CNF need to employ.

Members of the high-tech business community will also find it an effective way to learn best practices for success in a nanofab environment.

Attendance is open to the general scientific community, but class size is limited.

CNF Cornell NanoScale Science and Technology Facility

Directors' Column;
Welcome to the 2021 Winter Edition of the CNF NanoMeter!

2021 CNF Annual Meeting Report

For the second year since the start of the COVID-19 pandemic, the Cornell NanoScale Science and Technology Facility (CNF) held its annual meeting virtually — this year on Thursday, September 9th. We are thankful for the registration and participation of over 163 people. The annual meeting presented an opportunity to showcase excellence in research demonstrated by users and research groups utilizing the plethora of resources offered at the CNF. It was great to review where we were a year ago, how far we have progressed despite continued challenges presented by COVID, and where we are headed!

This year's themes for the user meeting focused on quantum information devices, life sciences, and Artificial Intelligence (AI). Our morning plenary speaker was Professor Debdeep Jena (DJ) from the Cornell Electrical & Computer Engineering and Materials Science & Engineering Departments. DJ spoke on his research of novel materials and devices for quantum computation and communication. Our afternoon plenary speaker was Professor George Malliaras from the University of Cambridge and noted former CNF Director. George's talk highlighted technology for bioelectric medicine and the challenges to establish stable and efficient interfaces between electronics and the human body. Invited presentations from our CNF users provided highlights to their accomplishments over the last year.

The proceedings and videos of the meeting can be found on our website, https://cornellcnf.link/cnfam21

While we had intended to have a live, hybrid meeting, given the realities of the pandemic, the planning team decided to host the meeting virtually and postpone the Poster Session and Corporate Soiree.

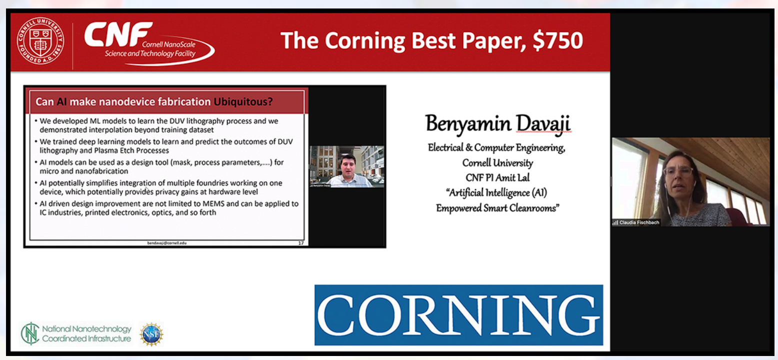
We recently learned we will be hosting the 2022 National Nanotechnology Coordinated Infrastructure (NNCI) Annual Conference in October and plan to combine this with our CNF 45th Anniversary Celebration and Annual Meeting.

Keep an eye on https://cornellcnf.link/annualmeeting for updates and information on next year's very special combined celebration!

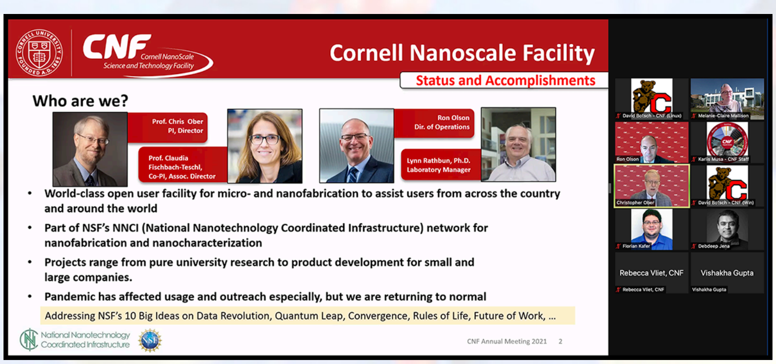
Congratulations to Our 2021 CNF Annual Meeting Award Winners!

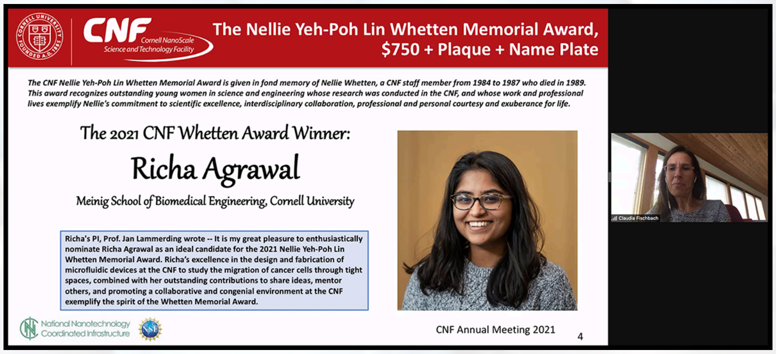
Each year our Corporate Sponsors provide funding that enable us to recognize our student users for their amazing research.

This year the Corning Best Paper Award winner was Benyamin Davaji. Ben presented his work developing an infrastructure to use process and metrology data to train Artificial Intelligence (AI) and Machine Learning (ML) models to learn the fabrication processes and predict outcomes.



Rachel Miller received the CNF Best Paper Award with her paper titled "Elucidating the Chemical Crypsis Mechanism in Puff Adder by Determining Microscale and Nanoscale Structure-Function Relationships via Two-Photon Polymerization 3-D Printing."





Our 2021 CNF Nellie Yeh-Poh Lin Whetten Memorial Award Winner was Richa Agrawa. Richa was recognized by the CNF staff as an outstanding young woman in science and engineering, whose work and professional life exemplify Nellie's commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy, and exuberance for life. (See page 8 for Richa's profile.)

Finally, we thank everyone who attended our meeting and all our amazing corporate sponsors!

CNF Activities

Recently, CNF has participated in workshops intended to explore future strategic capabilities important to facility users such as those who work in CNF. We co-organized, with the University of Minnesota, the first workshop on Quantum Engineering Infrastructure, April 13 to 15. The workshop highlighted the needs of researchers working on the five categories of quantum devices. Scientists from across the USA took part in this exciting event and shared their vision for the future of quantum science. From this workshop, CNF and other sites will be planning tool and skill acquisitions for this nationally important and rapidly growing field. Sites like CNF are already being used to construct qubit devices and this workshop aided us in our thinking about how to best serve the quantum community. In addition, the CNF will continue to work with the University of Minnesota, which is the lead site in the Global Quantum Leap Accelnet Program.

More recently on September 29, CNF took part in a workshop sponsored by the NNCI Research Community on the Internet of Nanothings (IoNT) led by NNCI site, UPenn. NNCI has created several research communities to consider the future of nanoscience ranging from the life sciences to quantum science. The IoNT workshop brought in representatives of companies exploring precision and smart agriculture, autonomous vehicles, energy efficiency and sustainability, environmental and infrastructure monitoring, and human body networks and infrastructure. Several NNCI sites, including CNF, described research being carried out in their facilities. Again, these workshops help us focus on the needs of our ever-changing research community and determine the next steps to meet those needs.

In the world of outreach — we were thrilled to take part in two 4-H events and host several very successful virtual tours. See pages 35-35 for more on our outreach efforts, including an interview with Dylan Arouh, Broadcom Science Challenger. Dylan is definitely going places in the nano-world and we are so glad to be along for the ride!

The 2021 CNF REU Program & the 2022 CNF REU Program

The Cornell NanoScale Science & Technology Facility Research Experiences for Undergraduates (CNF REU) Program has been running since 1990! We've worked with over 300 interns in those years. It was heartbreaking for everyone that the 2020 CNF REU Program had to be cancelled, so we were very pleased when the Cornell restrictions were relaxed enough this past spring to give us time to hire four CNF REU interns. See https://cnf.cornell.edu/education/reu for the full story on the 2021 CNF REU Program — and information on the 2022 CNF REU Program!

2022 January Virtual TCN

The CNF's Technology and Characterization at the Nanoscale (TCN) short course provides an excellent opportunity for the scientific community to learn about the field of nanofabrication from in-house experts. In 2022, the January TCN course will be offered virtually, Wednesday-Friday, January 19-21, 2022. Because the CNF TCN will be virtual in January, the registration fee is only $60! Be sure to register soon as the class size is limited! Registration is now open at https://cornellcnf.link/tcn and details are provided back on page 3.

We do hope to host the 2022 June CNF TCN live and in-person, Wednesday-Friday, June 8-10. We'll know more in the spring of 2022.

Lab Closing for New HEPA Filters

After being in Duffield Hall for almost 20 years, some major maintenance and repair is required. Starting on December 15, the CNF cleanroom will be temporarily closed in order to rebuild our main air handler and replace over 450 HEPA filters. The schedule is still fluid, but we anticipate a total shut down for SIX weeks, tentatively from Wednesday. December 15, 2021 thru Tuesday, February 1, 2022.

We understand that this will be a major disruption to your work schedule, but hope that between the annual holiday shutdown and the typically low usage period in late December and early January, these critical repairs will have minimum impact.

Please begin to take this closure into account in the planning of your projects. As we near finalization of the schedule we will keep you informed of any changes.

Get In While New User Orientation is FREE!!

New user orientation fees have been eliminated for the remainder of the year. If you or someone in your research group would like to become a new CNF user, please visit the Getting Started section of the CNF website to initiate the process. Additionally, if you know of someone who may be interested in becoming a new CNF user, please feel free to share this announcement. Time is short! We cannot train new users once we close for repairs, so start the New User process today!

CNF Tools & Capability Updates

In this issue, we include articles by our expert staff about new processes and equipment that we have been working on. You can find out about our new Angstrom load-locked evaporation system in a report from Aaron Windsor; new EDS capabilities on our Hitachi TM3000 from Amrita Banerjee; new capabilities and processes established on our newly installed Plasma-Therm HDP-CVD system and Veeco Savannah Atomic Layer Deposition (ALD) System from Jeremy Clark; and configuration and capabilities of our newly installed AJA Orin 5 sputter deposition system from Tom Pennell. These articles begin on page 36.

CNF Funding, Partnerships, and PPPs

CNF is one of the sixteen sites that make up the National Nanotechnology Coordinated Infrastructure, NNCI, with support provided by the National Science Foundation (NSF) and the NYSTAR/ESD Matching Grant Program from New York State. The support from the National Science Foundation that comes from our membership in NNCI is essential to keeping CNF at the forefront of nanofabrication and enables us to provide a knowledgeable staff to serve the user community. Part of our funding is hinged on a complete report on your CNF-research-related patents, presentations, and publications (PPPs).

For all PPPs, please remember to use the following acknowledgement: This work was performed in part at the Cornell NanoScale Facility, an NNCI member supported by NSF Grant NNCI-2025233.

We'll be contacting you soon to request your PPPs!

Thank you to all the companies, users, and staff who continue to support the Cornell NanoScale Facility — we appreciate you.

"Coming together is a beginning;
Keeping together is progress;
Working together is success."
Edward Everett Hale

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Your comments, feedback, and suggestions regarding CNF are always welcome.

2021 CNF Annual Meeting: Invited Speakers & Student Award Winners

Please join us in thanking again our invited speakers!

Prof. Debdeep Jena, David E. Burr Professor of Engineering, Cornell; Vishakha Gupta, LASSP, Cornell University (CNF PI Dan Ralph); Hil Fung Harry Cheung, AEP, Cornell University (CNF PI Greg Fuchs); Yebin Liu, Physics, Syracuse University (CNF PI Britton Plourde); Wenwen Zhao, Applied and Engineering Physics, Cornell (CNF PI DJ Jena/ Grace Xing); Benyamin Davaji, Electrical & Computer Engineering, Cornell University (CNF PI Amit Lal); Matthew Tan, Biomedical Engineering, Cornell University (CNF PI Claudia Fischbach); Richa Agrawal, Biomedical Engineering, Cornell University (CNF PI Jan Lammerding); Rachel Miller, MAE & MSE, Cornell University (CNF PI Robert Shepherd); Renhao Lu, Meinig School of Biomedical Engineering, Cornell University (CNF PI Esak Lee); Erik Chow, Biomedical Engineering, Cornell (CNF PI Matthew Paszek); Prof. George Malliaras, Prince Philip Prof. of Technology, University of Cambridge.

Please join us in congratulating our student award winners!

The Corning Best Paper Award Winner

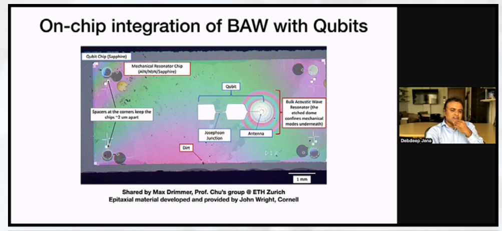
Benyamin Davaji
Electrical & Computer Engineering, Cornell University
CNF PI Amit Lal
"Artificial Intelligence (AI) Empowered Smart Cleanrooms"

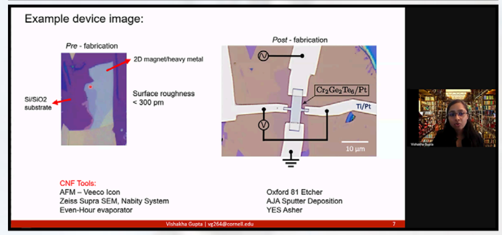
The CNF Best Paper Award Winner

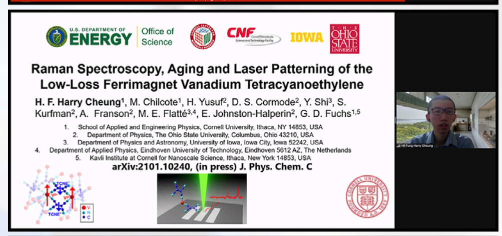
Rachel Miller
MAE & MSE, Cornell University
CNF PI Robert Shepherd
"Elucidating the Chemical Crypsis Mechanism in Puff Adder by Determining Microscale and Nanoscale Structure-Function Relationships via Two-Photon Polymerization 3-D Printing"

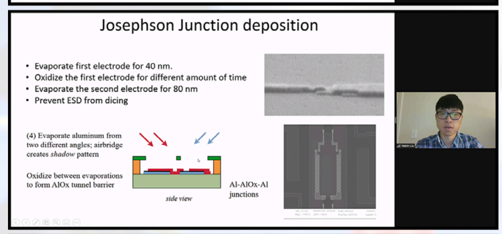
The 2021 CNF Nellie Yeh-Poh Lin Whetten Memorial Award Winner

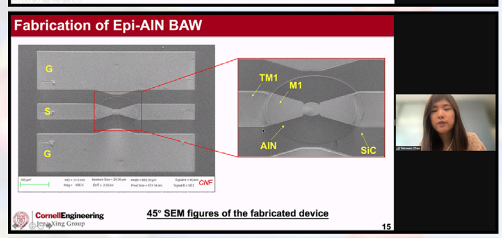
Richa Agrawal
Meinig School of Biomedical Engineering, Cornell University
CNF PI Jan Lammerding
"Assembly and Use of a Microfluidic Device to Study Nuclear Mechanobiology During Confined Migration"

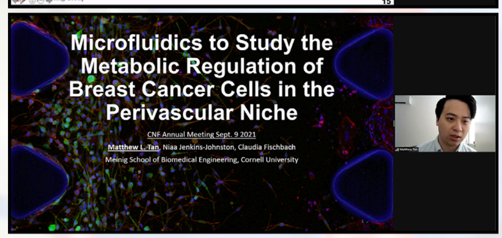


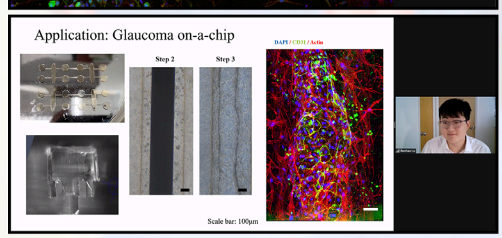


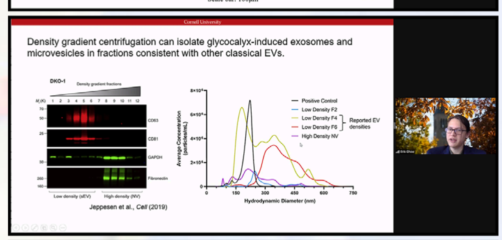


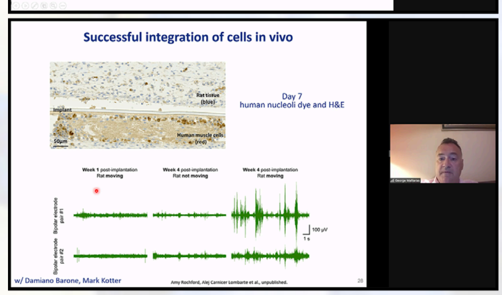












The 2021 CNF Nellie Yeh-Poh Lin Whetten Memorial Award Winner: Richa Agrawal

Richa Agrawal is currently a graduate student in Biochemistry, Cell, and Molecular Biology at Cornell and is the recipient of the 2021 CNF Nellie Yeh-Poh Lin Whetten Memorial Award. This award recognizes young women whose work and professional lives exemplify Nellie's commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy, and exuberance for life.

Richa attended the Ohio State University (OSU) for her undergraduate studies, where she received her bachelor's degree in 2018 in biochemistry with minors in both math and computer science. During her sophomore year, she researched alternatives to traditional synthetic scaffolds for wound-healing by purifying an adhesive from the leaves of the Sundew plant. In her second research experience, she studied the effects of post-translational modifications on the activity of plastin, an actin cytoskeletal remodeling protein that is ectopically expressed in many cancers. These research experiences led to two co-authored publications and several awards and fellowships.

Richa joined the Cornell BMCB program in 2018, and began in Professor Jan Lammerding's research group in 2019. The group is focused on combining molecular biology techniques with engineering principles and fabrication techniques to create new assays and approaches to understand cellular mechanics and function, with a particular emphasis on the nucleus and mechanotransduction.

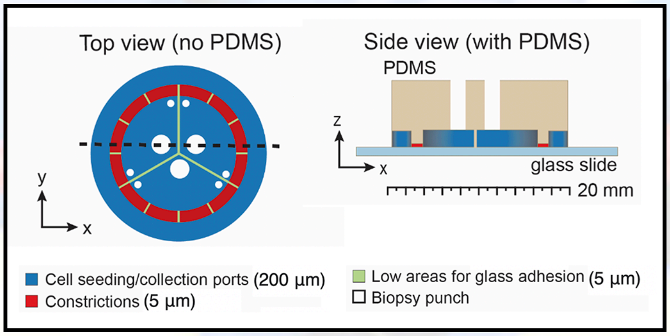


Figure 1: Schematic overview of the PDMS migration device. (A) Top and side view of the device after bonding to glass slide to create a confined environment for cancer cell migration (red area). Figure adapted from manuscript submitted to Methods in Molecular Biology.

Richa's research is focused on understanding how cancer cells spread through the human body, a process that involves cells migrating through spaces within tissues substantially smaller than the size of the cells. Richa was mesmerized by videos of cancer cells squeezing through pores that were less than 10% of their total cross-sectional area, even sometimes rupturing their nucleus and sustaining damage, and yet continuing to migrate. Considering this remarkable ability of some cells to migrate, repair damage, and continue to proliferate, she began to wonder: (1) What is it that enables some cells to tolerate the stress of confined migration, while others are unable or less able to do so? And (2) What are the long-term effects of migration through confined spaces, e.g., does repeated passage through tight spaces affect cell survival or function?

Motivated by these research questions, she developed a polydimethylsiloxane (PDMS) microfluidic device to probe the migratory fitness of cancer cells. In these devices, cells travel through a "field of pillars" with varied spacing, ranging from (1 × 5 µm^2 to 15 × 5 µm^2 in cross section), which closely mimics the intermittent confinement of a tumor microenvironment and interstitial spaces *in vivo*. The cells travel from a seeding port into the confining "field of pillars", and eventually emerge into a collection area, where they can be retrieved for further analysis (Figure 1).

To create these devices, polydimethylsiloxane (PDMS) devices are created from a silicon master mold, which is fabricated using a two-layer approach. The constriction layer is formed by reactive ion etching with HBr to achieve sufficient resolution to resolve the finer features (1 µm × 5 µm), and then the taller seeding and collection ports are fabricated using SU-8 soft lithography (250 µm).

These devices enable the assessment of cellular fitness for confined migration based monitoring the distance traveled through the constriction area over several days, but also enable the collection of large numbers of cells following confined migration. These devices therefore present a high-throughput method for observing the short- and longer-term effects mechanically induced nuclear deformation and rupture have on the tumor cells.

One question of particular interest to Richa is the mechanisms of DNA damage accrued during confined migration and its functional consequences. Preliminary data suggest that some cells stall and longer proliferate after repeated migration through confined pores, whereas others continue to migrate and proliferate. She hypothesizes that some cells are better able to withstand the stress associated with repeated migrations through tight spaces due to an increased ability to prevent and repair DNA damage.

Her current work is focused on further improving the microfluidic migration devices to increase the numbers of cells collected from these experiments to perform sequencing-based techniques and compare differentially expressed genes in both the starting population and cells following confined migration, while conducting image-based analysis to identify specific subpopulations of cells that are particularly well-suited to confined migration. This work will help identify which specific characteristics enable cells to excel at confined migration, with broad relevance to various physiological and pathological processes, such as tumor cell infiltration or cancer metastasis.

Outside of the lab, Richa enjoys backpacking, outdoor sports that do not require coordination, and attempting ambitious baking challenges with varying degrees of success.

Richa would like to express what an honor it is to have received the Whetten Memorial Award, and extends a sincere Thank You to all the CNF staff for their technical help during the fabrication process. She would also like to thank her advisor, Jan Lammerding, for his mentorship, insightful scientific advice, unwavering enthusiasm, and the nomination for the Whetten award.

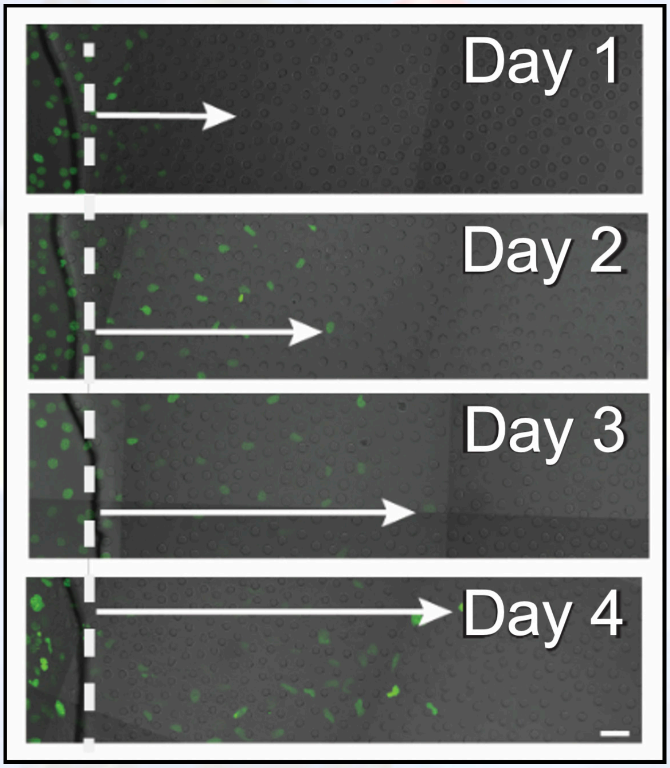


Figure 2: Cell migration in microfluidic device.
Representative image series to show usage of microfluidic devices to determine migratory fitness of cells through control density as a function of distance traveled from seeding port into constriction area (white arrows) over four days. Figure adapted from manuscript submitted to Methods in Molecular Biology.

Nellie Yeh-Poh Lin Whetten; CNF Memorial Award

This award is given in fond memory of Nellie Whetten (above) — a CNF staff member from 1984 to 1987 who died on March 24, 1989. In honor of Nellie's spirit, this award recognizes outstanding young women in science and engineering whose research was conducted in the CNF, and whose work and professional lives exemplify Nellie's commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy and exuberance for life. In the words of her husband, Dr. Timothy Whetten,

"The award should remind us to find out what it is like for people different from us to live and work in the same community. For men, to try to appreciate what it is like to be a woman scientist. For Caucasians, to try to feel what it is to be Asian or Black. For members of racial minorities and women, to try to understand what it is like to be a white male. And finally, the award should stimulate each of us to reach out and encourage women scientists who, like Nellie have the brilliance, stubbornness, and cheerfulness to succeed."

https://cnf.cornell.edu/highlights/whetten — a list of all the CNF Whetten Memorial Award Winners

Superfluid Reacts Strangely Under Pressure Change

By David Nutt
May 25, 2021
Cornell Chronicle

First came the Big Bang. And in the moments afterward? Some physicists believe this so-called inflationary epoch was punctuated by phase transitions in which states of matter underwent significant changes.

One potential model for understanding these transitions is superfluid helium-3. That's because helium-3 remains a liquid down to absolute zero, or minus 459.67°F. At a few thousandths of a degree above absolute zero, it transforms to its superfluid state and flows without resistance. As a superfluid, it is a pure, clean system — like the very stuff that birthed the universe.

A Cornell-led collaboration identified an unusual behavior of superfluid helium-3 when it undergoes a phase transition between two different superfluid states — a transition that theoretically shouldn't happen reliably. If the transition doesn't occur where thermodynamics dictate, then the system is in a "supercooled" state. By varying the pressure of the system while lowering the temperature, the researchers caused the superfluid to transition at even lower limits, enhancing its supercooling. This display of pressure, or path, dependence has never been explored in helium and is entirely unexpected.

"It's kind of strange, because if you look in textbooks, when experiments are conducted, everybody uses constant pressure," said Jeevak Parpia, M.S. '77, Ph.D. '79, professor of physics in the College of Arts and Sciences, who led the Cornell team. "You essentially set the pressure in your system, and then you change the temperature, and things evolve. Whatever happens at a particular point happens because you're changing the temperature. It's so unusual that we see this happen."

The team's paper, "Path-Dependent Supercooling of the 3He Superfluid A-B Transition," published May 25 in Physical Review Letters. The paper's lead author is former postdoctoral researcher Dmytro Lotnyk.

The A to B phase transition is not always easy to predict, because at such a low temperature it isn't governed by the classical laws of physics. On top of that, superfluid helium-3 is something of a mystery. Because it's a clean system, in theory it should remain metastable and not transition to a new phase at all. Yet, it does. Different mechanisms and concepts, such as adjacent phases, have been proposed to explain its surprising phenomena.

Parpia's group has been exploring these phenomena with their longstanding collaborator, John Saunders, professor of physics at Royal Holloway, University of London.

The group fabricated a silicon device 1.1 µm high and 3 mm wide, with a 100 µm-long channel that separated two chambers. They flowed the helium-3 into the channel and flash-heated the system, then observed it cooling as quickly as possible. During a series of experiments, they noticed something puzzling.

When cooled at constant pressure, helium-3 passes through a point where the A phase reliably transitions to the B phase. However, when helium-3 is cooled at a higher pressure and then depressurized after it crosses the transition temperature to superfluidity, the A phase can be supercooled to the B phase at even lower temperatures and lower pressures than before, when constant pressure was applied.

"The complexity of helium-3 probably accounts for its pressure or path dependence," Parpia said.

Parpia believes one possible reason for this trait is that the superfluid is not described by a single set of parameters that account for its energy. Instead, each of its states is described by a set of 18 parameters. To convert from one phase to another, all the terms that are different must change. This effectively requires more energy than is available.

"One thing we want to explore is does this path dependence kind of narrow and go away as we get away from this region? That's one very important question, actually, to answer," Parpia said. "The second thing that we really want to do is to add structure to the channel between the two volumes. If we can do that, then we can engineer, in a prescribed way, new phases."

Co-authors included Erich Mueller, professor of physics (A&S), who provided theoretical support; former postdoctoral researchers Anna Eyal and Abhilash Sebastian; Nik Zhelev, M.S. '13, Ph.D. '16; postdoctoral researcher Yefan Tian; undergraduate research associate Aldo Chavez '22; and research support specialist Eric Smith.

The research was funded by the NSF and the Engineering and Physical Sciences Research Council in the United Kingdom. The researchers made use of the Cornell NanoScale Facility (CNF).

Biomining Rare-Earth Elements; Cornell Engineers are Pioneering a Novel Method for Mining Metals that are Key to Unlocking a Sustainable Future

By Chris Dawson
Cornell Engineering Spotlight

In the search for more sustainable energy technologies, many of the solutions humans are turning to — rechargeable batteries, massive wind turbines, electric cars, LED lighting — rely on what are known as rare-earth elements. There are 17 rare earths on the periodic table, ranging from the lightest, scandium, to the heaviest, lutetium, and they are highly valued for their unique physical and chemical properties that make them useful in sustainable energy technologies.

As is so often the case, solutions to existing problems can create their own, new problems. This is certainly true of our reliance on rare earths to make technologies greener. The industrial processes used to isolate them from their naturally-occurring ores often rely on strong acids or bases that can pollute the environment. Harmful effects of the mining include contaminated soil and water, deforestation and negative health impacts on humans and other animals. These processes also require large amounts of energy.

Our reliance on rare earth elements is not going to end any time soon, so researchers have begun to look for ways to obtain them in less environmentally harmful ways.

A multidisciplinary team at Cornell is on the leading edge of this push to help green technologies get even greener. Between the Department of Biological and Environmental Engineering and the Department of Earth and Atmospheric Sciences — units shared between the College of Engineering (ENG) and College of Agriculture and Life Sciences (CALS) — faculty, postdocs and graduate students have all come together to tackle this problem.

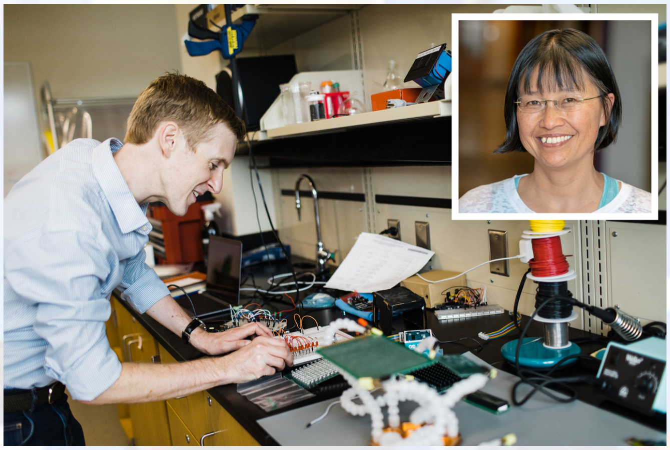


Figure 1: Buz Barstow, assistant professor of biological and environmental engineering. Inset: Mingming Wu.

Led by Buz Barstow, assistant professor of biological and environmental engineering (CALS), the team is looking at ways to "program" microbes to produce organic acids that can leach rare-earth elements from crushed ores or from recycled electronics components. These microbial acids will be far safer than the acids and bases used in existing industrial processes.

Altogether, the processes Barstow and the team of engineers are pioneering can be called "biomining," and if proven scalable, will have a major impact on the sustainability of future electronics as well as on the health of people and the environment.

Alexa Schmitz, postdoctoral associate, and M.Eng. student Don Flood.

'Risky, Cutting-Edge Work'

Postdoctoral researcher Alexa Schmitz joined Barstow's effort when, as a Cornell grad student earning her doctorate in plant pathology and plant-microbe biology, she was in a biofuels seminar presented by Barstow. But in the discussion afterward, he also talked about bioleaching and its potential in the mining and recovery of rare earths.

"It felt like risky, cutting-edge work," says Schmitz, "but at the same time I thought 'Yes. This can definitely work.'" Schmitz was finishing her Ph.D. and looking for a postdoctoral position, and Barstow was looking for help on his biomining project after receiving an Academic Venture Fund seed grant from the Cornell Atkinson Center for Sustainability.

Schmitz got to work right away with a bacterium called Gluconobacter oxydans. It had already been shown to have potential as a bioleaching microbe through initial work done at the U.S. Department of Energy's Idaho National Laboratory. Schmitz used a method developed by Barstow called Knockout Sudoku to selectively inactivate one gene at a time and then build a collection of several thousand variants of G. oxydans. Each of these variants will be tested as a bioleaching agent for rare earths, and then those that perform best will be further developed.

As she gathers data, Schmitz — who is continuing the work with help from the Cornell Atkinson Small Grants Program — says she will be compiling a roster of genes that could be key to the development of an efficient and sustainable system to extract rare earths.

Mutant Bacteria

Monazite is one of the ores known to contain rare earths in sufficient quantities to be worth mining. Schmitz can't just throw a chunk of monazite and some bacteria into a beaker and wait to see what happens. Rather, the initial screening for genes that may be related to leaching of rare earths will happen in microplates that can be read spectroscopically.

Schmitz explains, "Once we know which genes are most important for bioleaching, we will target those genes — and genetic elements controlling those genes — for mutagenesis. This can be done in combination, targeting several genes at once, and the resulting modified strains are screened for changes in bioleaching."

Mutagenesis is a process whereby the genetic information of an organism changes by mutation. That mutation can be spontaneous or it can be controlled in a laboratory. Schmitz and Barstow will force mutations on the genes that are most involved in bioleaching and then measure how effective the mutated organism is at gathering available rare earths. Their hope is that with a high-throughput method for evolving G. oxydans, they will be able to engineer an organism that can leach rare earths more efficiently and sustainably than existing industrial methods.

This is where Mingming Wu comes in. Wu, a professor of biological and environmental engineering (CALS), is an expert in microfluidic devices. Traditional methods of identifying, isolating, and mutating microbes are labor and time intensive, requiring a lot of careful and repetitive pipetting.

"Buz and I started to talk about his work," says Wu, "and we realized that in microfluidics there already exists an established way of identifying and selecting 'super-bugs' that exhibit a desired characteristic."

This existing process is called directed evolution. Together with Sean Medin, a second-year Ph.D. student in Barstow's lab, the team is in the process of designing a microfluidic device that forces individual bacteria through a channel, with several "stations" along the way.

"We can put sensors in the device so that when a bacterium binds with a rare-earth element, it changes color and we can see it," says Wu. "Those that bind will be sent down one route in the device, and those that don't bind will be sent down another route."

The bacteria that worked will be directed back through the device to a station where they will be mutagenized and then sent through the device again. In this way, Barstow's team can create an improved variant of the bacterium that Medin will be using to adsorb rare earths.

Recycling Electronics and Waste Products

In addition to helping to craft the microfluidic device the group will use in their process, Medin is also working on an essential step in biomining rare earths — separation.

Once the rare earths have been leached out of the monazite or other ores, they still need to be separated from each other and from the impurities that make it through the leaching process. Current methods of separation, such as liquid-liquid solvent extraction and the ion-exchange process, are energy-intensive and result in large amounts of dangerous waste products.

Medin will instead use a bacterium called Shewanella oneidensis MR-1, and he will subject it to a similar directed evolution process that Schmitz is using with G. oxydans. Medin will be selecting for variants that show higher than average ability to adsorb rare earths. These variants will be subjected to several rounds of mutagenesis with the aim of creating a bacterium that is able to adsorb specific rare earths in high quantity.

Medin joined the Barstow Lab with the express intent of working on this project, and he hopes to someday start a company to commercialize some of the processes honed in the lab. However, his focus would be on recycling existing rare earths from electronics, mine tailings and fly ash, which is one of the waste products of coal combustion.

"Ideally," says Medin, "I'd like to be able to take fly ash or permanent magnets or other recycled sources of rare-earth elements, bioleach them, and then extract the rare earths out for reuse. And I'd like to do all of that in the U.S. and make sure it is environmentally friendly."

Currently, the United States imports most of the rare earths it uses, and recycles just a tiny percentage of rare-earth-containing products.

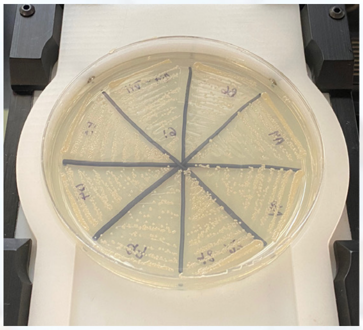
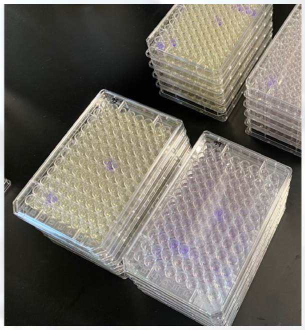
 

Figure 4, left: Each variants of G. oxydans *will be tested as a bioleaching agent for rare earths. Those that perform best will be further developed. Figure 5, right: The initial screening for genes that may be related to leaching of rare earths will happen in microplates that can be read spectroscopically.*

The Right Tools for the Job

Sabrina Marecos, a first-year Ph.D. student in the Barstow Lab, is working to validate the genetic models being used. Previous research at Cornell and elsewhere supports the theory that Barstow's Knockout Sudoku process should work with Gluconobacter oxydans.

"At the moment," says Marecos, "I am working on the verification of the knockout of the membrane-bound glucose dehydrogenase gene. This would confirm that it is possible to knock out genes in Gluconobacter. After that, I will proceed to try and validate the over-expression of another gene to confirm it can be done and which method is most suitable."

Once Marecos validates the methods Barstow, Schmitz and Medin plan to use, the resultant tools will supplement the relatively few that already exist. "This would allow us to engineer the bacteria using data indicating that some genes are more involved than others in the production of important acids," says Marecos. "By modifying the bacteria and observing its behavior, we will better understand the bioleaching process and how to enhance it."

'An Idea That Can Only Happen at Cornell'

Barstow makes a point of highlighting the importance of Cornell's culture of collaboration in enabling biomining research. In addition to his lab member's individual projects, there is one pivotal piece of the work none of them can do: synthesize monazite containing precisely quantified amounts of various rare earths.

In order to know exactly how effective and efficient the bacteria are at leaching and separating rare-earth elements, the team needs to know exactly how much of each element there is in the initial ore. After all, it does not help to know how many grams of lanthanum have been collected through bioleaching if you have no idea how many grams were there to start.

Lucky for Barstow, there are two recent faculty hires who can synthesize and characterize monazite in exactly the way he requires. It was a chance encounter at a Cornell Atkinson brown-bag lunch that would eventually bring the three Atkinson Faculty Fellows together.

Assistant Professor Megan Holycross's (ENG) specialty is understanding the processes that have differentiated the chemistry of earth's solid interior. "The instruments in my lab in Snee Hall are capable of achieving temperatures and pressures that recreate the conditions up to 120 kilometers deep in the earth," says Holycross. "I am studying what happens in the lower crust and the upper mantle of the earth."

Serendipitously, some of Holycross's lab equipment can also be used to create homogeneous samples of ores. "Buz and his team are running experiments to extract rare-earth elements from rocks using acids produced by microbes," says Holycross. "And in order for them to quantify the efficiency of their microbes, they need to quantify their inputs and their outputs precisely."

Holycross is growing synthetic monazite samples with Associate Professor Esteban Gazel (ENG) and postdoc Brian Balta. Gazel will use his geochemical expertise to characterize the samples, and he will also carry out mass balance calculations to help Barstow determine which mutant version of G. oxydans is most efficient — and therefore most commercializable.

"This is an idea that I believe could only happen at Cornell," says Gazel. "There is this culture of interdisciplinary collaboration here that is very hard to find elsewhere. Buz and Mingming knew as little about monazite as Megan and I knew about synthetic biology before collaborating."

Holycross agrees. "This is why I came to Cornell — to do interdisciplinary things like this and work on exciting problems with colleagues."

"The powerful perspective of our work is not only the fact that we are open to crossing the boundaries of disciplines," Gazel says, "but that we are all open to learning new areas and communicating with each other. It is in these interdisciplinary spaces where solutions to old and new problems can be found."

Magneto-Thermal Imaging Brings Synchrotron Capabilities to the Lab

By David Nutt
Cornell Chronicle
June 17, 2021

Coming soon to a lab tabletop near you: a method of magneto-thermal imaging that offers nanoscale and picosecond resolution previously available only in synchrotron facilities.

This innovation in spatial and temporal resolution will give researchers extraordinary views into the magnetic properties of a range of materials, from metals to insulators, all from the comfort of their labs, potentially boosting the development of magnetic storage devices.

"Magnetic X-ray microscopy is a relatively rare bird," said Greg Fuchs, associate professor of applied and engineering physics, who led the project. "The magnetic microscopies that can do this sort of spatial and temporal resolution are very few and far between. Normally, you have to pick either spatial or temporal. You can't get them both. There's only about four or five places in the world that have that capability. So having the ability to do it on a tabletop is really enabling spin dynamics at nanoscale for research."

His team's paper, "Nanoscale Magnetization and Current Imaging Using Time-Resolved Scanning-Probe Magnetothermal Microscopy," published June 8 in the American Chemical Society's journal Nano Letters. The lead author is postdoctoral researcher Chi Zhang.

The paper is the culmination of a nearly 10-year effort by the Fuchs group to explore magnetic imaging with magneto-thermal microscopy. Instead of blasting a material with light, electrons or X-rays, the researchers use a laser focused onto the scanning probe to apply heat to a microscopic swath of a sample and measure the resulting electrical voltage for local magnetic information. Fuchs and his team pioneered this approach and over the years have developed an understanding of how temperature gradients evolve in time and space.

"You think about heat as being a very slow, diffusive process," Fuchs said. "But in fact, diffusion on nm-length scales has picosecond times. And that's a key insight. That is what gives us the time resolution. Light is a wave and diffracts. It doesn't want to live down at these very small length scales. But the heat can."

The group has previously used the technique to image and manipulate antiferromagnetic materials — which are difficult to study because they don't produce a magnetic field — as well as magnetic metals and insulators.

While it is easy enough to focus a laser, the major hurdle has been confining that light and generating enough heat on a nanometer scale to get the process to work. And because some phenomena at that scale occur so quickly, the imaging needs to be equally speedy.

"There's a lot of situations in magnetism where stuff is wiggling, and it's small. And this is basically what you need," Fuchs said.

Now that they have refined the process and successfully achieved a spatial resolution of 100 nanometers and a temporal resolution below 100 picoseconds, the team can explore the real minutiae of magnetism, such as skyrmions, quasi-particles in which the magnetic order is twisted. Understanding these kinds of "spin textures" could lead to new high-speed, high-density magnetic storage and logic technologies.

In addition to magnetism, the technique's dependence on electrical voltage means it can be used to measure current density when the voltage interacts with a material. This is a novel approach, since other imaging techniques measure current by gauging the magnetic field the current produces, not the current itself.

Magneto-thermal microscopy does have limitations. Because samples need to be configured with electrical contacts, the material has to be patterned into a device. As a result, the technique can't be applied to bulk samples. Also, the device and the scanning probe must be scaled together. So if you want to measure a phenomenon at the nanoscale, the sample has to be small.

But those limitations are minor compared with the benefits of a relatively low-cost form of magneto-thermal microscopy in your own lab.

"Right now, people have to go to a public facility, like a synchrotron facility, for doing these types of measurements," Zhang said. "You write a proposal, you get a beam time, and you have maybe a few weeks to work, at best. If you didn't get the result you want, then it's maybe another couple of months. So this will be progress for the field."

Co-authors include Jason Bartell, Ph.D. '18; Jonathan C. Karsch '17 and Isaiah Gray, Ph.D. '20.

The research was supported by the Department of Energy and the Air Force Office of Scientific Research. The researchers made use of the Cornell Center for Materials Research, with funding from the National Science Foundation's Materials Research Science and Engineering Center program, and the Cornell NanoScale Facility, also supported by the NSF (Grant No. NNCI-2025233).

Monolayer Superconductor Exhibits Unusual Behavior

By David Nutt
June 10, 2021
Cornell Chronicle

Cornell researchers have discovered a rare "pseudogap" phenomenon that helps explain how the superconducting transition temperature can be greatly boosted in a single monolayer of iron selenide, and how it might be applied to other superconducting materials.

The group's paper, "Incoherent Cooper Pairing and Pseudogap Behavior in Single-Layer FeSe/$SrTiO_3$," published June 10 in Physical Review X. The paper's lead author is Brendan Faeth, Ph.D. '20.

A Cornell team sought to explore the properties of monolayer iron selenide because, as a high-temperature superconductor, it has the potential to help researchers create novel electrical devices that conduct with zero resistance and, therefore, much greater efficiency.

The team was led by Kyle Shen, the James A. Weeks Professor of Physical Sciences in the College of Arts and Sciences, who, together with Faeth, sought to explore the properties of monolayer iron selenide because, as a high-temperature superconductor, it has the potential to help researchers create novel electrical devices that conduct with zero resistance and, therefore, much greater efficiency.

One of the unusual traits of iron selenide is that, when it comes to conducting electricity, less is more. In bulk crystal form, the material becomes a superconductor at around 8 kelvin (or minus -445.27°F). But when grown as a single monolayer atop a substrate of strontium titanate, the compound superconducts at a much higher temperature: between 30 to 60 kelvin (minus 405.67 to minus 351.67°F).

"The magnitude of the enhancement is really big," Shen said. "Usually making materials really thin makes superconductivity worse. This is the total opposite. But the mechanism by which this enhancement was occurring was basically not known."

That mystery was compounded by mixed results from previous attempts to pinpoint the exact temperature of superconductivity in monolayer iron selenide.

"People were doing these different types of measurements, and some people were saying, 'Oh, my T_c (transition temperature) is 20 kelvin or 30 kelvin,' and other people would say, 'No, my T_c is 60 kelvin,'" Shen said. "So it wasn't really understood why people were reporting these T_c's that are completely all over the map. In doing our experiments, we see, 'Oh, actually, you're kind of both right.'"

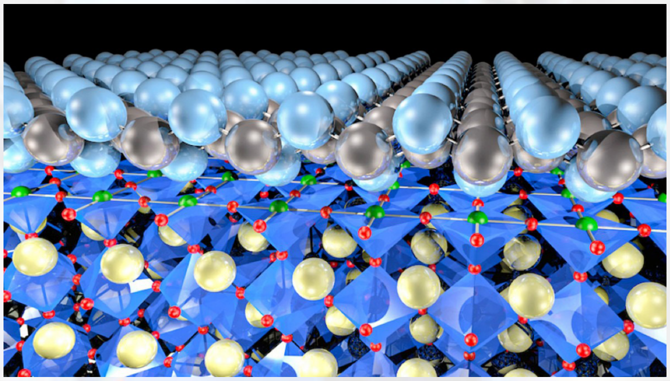


Figure 1: Monolayer iron selenide. Provided. (Also used for this issue's background.)

One reason this phenomenon has been difficult to study is that iron selenide in its monolayer form — which the researchers grow via molecular beam epitaxy — is incredibly fragile. If the material is removed from the ultra-high vacuum inside the growth chamber, the air will attack and disintegrate it. While scientists have been able to make partial measurements, no one has been able to piece together a complete and coherent picture of why the superconducting transition temperature in monolayer iron selenide is so much higher than in its bulk form, a situation that Shen compares to the parable about the blind men attempting to describe an elephant.

So Shen's team got creative. Faeth, currently a research associate at Cornell's Platform for the Accelerated Realization, Analysis and Discovery of Interface Materials (PARADIM), custom-built an elaborate system of ultra-high vacuum chambers docked together around a growth chamber. The system enabled the team to conduct a battery of measurements on monolayer iron selenide samples without removing or disturbing them.

"It's like a space station in reverse, because the vacuum is on the inside," Shen said. "We were able to do a whole sequence of different measurements. And in doing so, we were able to observe this so-called pseudogap phase, which had never been reported before in this system. That's sort of a hallmark of unconventional high-temperature superconductivity, also seen in the high-T_c cuprate superconductors. And it gives us some clues as to what might be the mechanism for this enhanced pairing temperature."

For a material to enter the superconducting state with zero resistance, two things must happen: the electrons need to form so-called Cooper pairs and then the quantum-mechanical "phase" of all those pairs must become uniform. In typical superconductors, those two things usually occur simultaneously. However, in some exotic high-temperature superconductors there is a lag between the two steps.

Faeth's measurements determined that an "unprecedentedly large" pseudogap begins around 60 kelvin, when incoherent Cooper pairs begin to form. However, the pairs don't actually form a genuine superconducting condensate until about 30 kelvin.

Now that the researchers have a clearer understanding of that mechanism, they can try to enhance the effect by changing the parameters of the substrate, or possibly employ it in other superconductors to boost their performance.

"People have been working for 100 years to make high-temperature superconductors," Shen said. "If you could actually do that, it would be revolutionary for energy transport, quantum information processing, electronics and any number of very important applications."

Co-authors include Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry; former Kavli Institute at Cornell for Nanoscale Science postdoctoral fellows Shuolong Yang and Jason Kawasaki; and doctoral students Jocienne Nelson and Chris Parzyck.

The research was primarily supported through the Air Force Office of Scientific Research, as well as the National Science Foundation and the Gordon and Betty Moore Foundation. The researchers also made use of the Cornell Center for Materials Research, which is supported by the NSF's Materials Research Science and Engineering Center program, and the CNF, also supported by the NSF (under Grant No. NNCI-2025233).

• CNF COMMUNITY NEWS • CNF COMMUNITY NEWS • CNF COMMUNITY NEWS •

CNF PI Alex Deyhim sent the following updates for two of his past CNF Users...

Mr. Karl Ashkar

R&D Leadership Program Associate, Pall Corporation

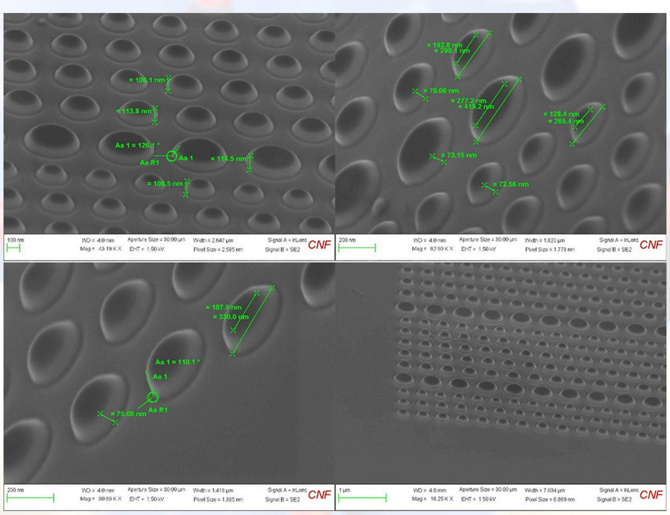
https://www.pall.com/

https://www.linkedin.com/in/karlashkar/

2021 May MSE MEng Graduate

Previous CNF Project with Deyhim: "Development of Metalenses for Optical Sensors"

The purpose of this project was to develop a process for the fabrication of metalenses to be used for optical sensors. This work involved characterizing the etched pattern, and then adjusting the EBL writing and etching parameters to yield a pattern with a 500nm depth and a vertical sidewall angle. The SEM images below left of the etched samples are shown, as well as the measurement of the etch depth and sidewall angles. Fabrication was supported by CNF and CNF staff.



Mr. Kelvin Ye

Associate Research Engineer, A123 Systems

http://www.a123systems.com/

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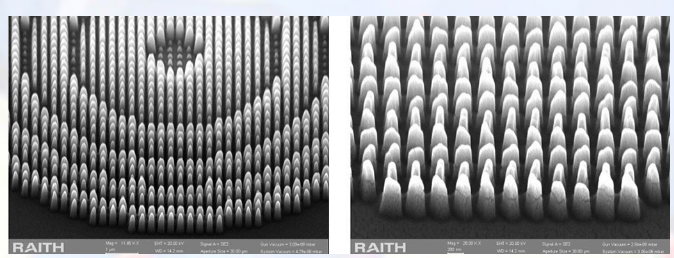
2021 May MSE MEng Graduate

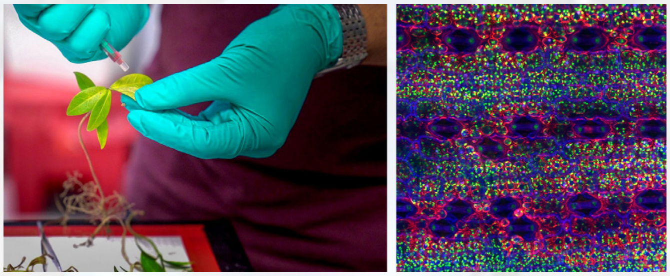
Previous CNF Project with Deyhim: Development of Metasurface Components with High Efficiency at Near-Infrared Wavelength

The goal for this project was to develop a-Si metasurface nanostructures on a glass (fused silica) wafer with target wavelength around 940 nm and high transmission efficiency when incident angle varies. Fabrication was supported by CNF and CNF staff members.



Nanoscale Sensors Measure Elusive Water Levels in Leaves

By Krishna Ramanujan
June 2, 2021
Cornell Chronicle



Left: A researcher injects AquaDust into leaves. Right: Fluorescent dyes in this maize plant leaf show epidermal cell walls (blue), chloroplasts (green) and hydrogel nanoreporters (AquaDust) that reveal water potential (red). Provided.

Water regulation in leaves is vital to a plant's health, affecting its growth and yield, disease susceptibility and drought resistance. A breakthrough technology developed at Cornell uses nanoscale sensors and fiber optics to measure water status just inside a leaf's surface, where it is most actively managed.

The engineering feat provides a minimally invasive research tool that will greatly advance the understanding of basic plant biology, and opens the door for breeding more drought-resistant crops. The technology could eventually be adapted for use as an agronomic tool for measuring water status in crops in real time.

Fluorescent dyes in this maize plant leaf show epidermal cell walls (blue), chloroplasts (green) and hydrogel nanoreporters (AquaDust) that reveal water potential (red).

The study in maize plants, "A Minimally Disruptive Method for Measuring Water Potential In-Planta Using Hydrogel Nanoreporters," published June 1 in the Proceedings of the National Academy of Sciences.

"One of the goals is to have tools that allow internal biology to be expressed out into the world in a way that can be captured and digitized," said senior author Abraham Stroock, the Gordon L. Dibble '50 Professor in the Smith School of Chemical and Biomolecular Engineering in the College of Engineering.

"Current techniques for measurements of water potential require destructive sampling of leaves or disrupting leaf function," said co-first author Piyush Jain, a doctoral student in mechanical engineering. The new method, he said, "provides minimally disruptive and spatially and temporally resolved measurements of water potential in leaves of intact plants."

Outside of leaves' transport tissues, called xylem (the veins), lies an interior zone called the mesophyll, where most of the plant's photosynthesis and water stress occurs. Biologists suspect that signals are sent from here to the rest of the plant for managing water. Also, at the surfaces of leaves and stems, pores called stomata open and close to control the rate of exchange of gasses, mostly water vapor and carbon dioxide. The new technology works in this microscopic zone.

"We are now sensing water right at that terminal place," Stroock said. "We've shown that by getting such a localized measurement, we can dissect the dynamics of water in the tissues" in minimally invasive ways, he said.

The technique involves injecting a nanoparticles formed of a soft synthetic hydrogel, called AquaDust, for measuring a leaf's water potential. The hydrogel, which occupies the interstitial spaces between cells in the mesophyll, is water-absorbent, swelling and shrinking based on water availability in the leaf.

The AquaDust contains dyes whose interactions allow it to fluoresce at different wavelengths depending on how close the dye molecules are to each other. By using fiber optics, the researchers can shine a light and get a spectrum back, which provides a measurement of water potential inside the leaf.

In the study, the researchers injected the AquaDust in multiple places along meters-long maize leaves and then measured the water gradients both along the length of the leaves and through the mesophyll. These measurements allowed them to develop a model of the tissue response to water stress and accurately predict the dynamics observed in the field.

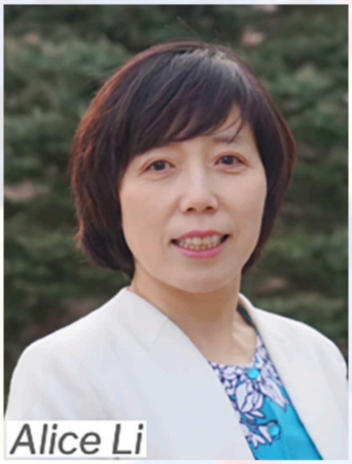
This technology may have commercial applications for crop research, production agriculture, and manufacturing industries, but for now the researchers' focus is on the invaluable measurements of very local physiology of water management in plants. As a research tool, it allows plant biologists to better understand extremes of water stress, which could lead to breeding more water-efficient crops.

Michael Gore, Liberty Hyde Bailey professor and professor of molecular breeding and genetics in the Plant Breeding and Genetics Section of the School of Integrative Plant Science in the College of Agriculture and Life Sciences, is a co-author. Weizhen Liu, a former PostDoc researcher in the Gore lab and current associate professor at Wuhan University, is co-first author.

The study was funded by the U.S. Department of Agriculture's National Institute of Food and Agriculture, the U.S. Air Force Office of Scientific Research, and the Rural Development Administration of the Republic of Korea. This work was performed in part at the CNF, a member of the NNCI, which is funded by the NSF (Grant No. NNCI-2025233).

Silicon Catalyst and Cornell University are Expanding Opportunities for Startups like Geegah

by Mike Gianfagna
06-24-2021
SemiWiki



SemiWiki has covered many aspects of Silicon Catalyst, from their business model to notable industry events and profiles of promising startups. In this post, I'll explore an aspect of the broader collaboration the organization is engaging in. It is well-known that Silicon Catalyst maintains a substantial network of product and service providers as well as a large network of advisors. All this is intended to help promising young semiconductor-based startups to take their idea to the next level. There is another aspect of the innovation pipeline, however. It's the journey from a great idea to proof that it's possible to implement. Through added collaboration, Silicon Catalyst is addressing this phase as well. Their work is having measurable impact for promising young companies. Read on see how Silicon Catalyst and Cornell University are expanding opportunities for startups like Geegah.

The Next Big Thing begins with an idea — perhaps not even an idea but a dream. I am a firm believer that the dreamers among us are the ones who will change the world. As an idea progresses to a commercial implementation, there are many hurdles to cross. For a semiconductor startup a lot of these hurdles have to do with access to technology, services, infrastructure, and design tools — all areas where Silicon Catalyst brings a lot to the party.

Let's get back to that dream of an idea. If someone is dreaming of a new application for semiconductor technology, the first step needs to be a reality check. Can the idea be implemented with current materials and fabrication techniques? Or perhaps something over the next horizon will be required. Answers to these questions often require fundamental research, but ultimately the new idea needs to address real world problems to build a viable business. This is an expanding area of Silicon Catalyst's ecosystem, working with university partners to find the next great innovation for the semiconductor industry. More on this...

Expanded Collaboration

I had the opportunity to speak with several folks who are part of the expanded Silicon Catalyst ecosystem. Some represent the university research point of view and others the licensing of that research. Still others ensure the many moving parts of these relationships continue to work smoothly. And of course, there's the growing list of startups who are the primary beneficiaries of all this work.

Collaboration between Silicon Catalyst and universities isn't new. There is an ongoing program that connects universities with the Silicon Catalyst ecosystem. One of the folks I spoke with is Laura Swan. Laura manages the university program at Silicon Catalyst. One of the key benefits of this program is to connect Silicon Catalyst's large advisor network with research work at partner universities. Universities must focus on the viability of their research from a commercial standpoint and the Silicon Catalyst advisor network is full of folks who can help with market discovery and validation of the innovations. This organization can help search for early-adopters and build a foundation for ultimate business success. This is one of many win/win scenarios that are part of this story.

Cornell University's Praxis Center for Venture Development

Cornell University is a member of the Silicon Catalyst University Program. Recall I mentioned that semiconductor startups often require fundamental research to establish the efficacy of an idea. This kind of research requires materials and physics expertise as well as the environment and equipment to experiment with new materials to see what happens when you build it. Cornell brings a lot to the table here — they operate a semiconductor research fab, the Cornell NanoScale Science and Technology Facility, or CNF.

The organization at Cornell that has developed a partnership with Silicon Catalyst is the Cornell Praxis Center for Venture Development. This is Cornell's on-campus incubator for engineering, digital and physical science startups. The program is run by Robert Scharf and Bob is one of the folks I got a chance to speak with. One of the first things Bob pointed out was the proximity to CNF — it's in the same building as the Praxis Center, so access to equipment and know-how couldn't be easier. Bob described a process whereby startup companies are evaluated for admission to the Praxis Center. This in many ways is similar to what Silicon Catalyst does, as part of their comprehensive applicant screening process.

Bob explained that entrants to Praxis can be very early in the maturation process — one click past "will it work?" if you will. Early results and fundamental research are focus areas for Cornell, and many other universities as well. Bob went on explain that, as startups mature, they can physically grow to a size that is hard to accommodate on campus at the Praxis Center. This is where Silicon Catalyst has formed a seamless fit for the startup as they continue their journey.

Before I discuss a promising new startup that is benefiting from all this collaboration, I'll finish the picture for Praxis. To do this I spoke with Alice Li, the executive director of Cornell's Center for Technology Licensing (CTL). As you will see if you visit its website, CTL supports inventors, industry, entrepreneurs and academia. Regarding entrepreneurs, their stated goal is this: We work to create successful transitions from innovation to new enterprise.

Licensing technology developed at Cornell turns out to be a two-way street. Certainly, startups benefit from access to cutting-edge research to create the foundation of a new enterprise. Cornell also benefits from the "grounding" that occurs when one attempts to apply fundamental research in a commercial setting. Alice explained that this process provides an important reality check for advanced research. After all, the goal of this work is to impact the world in a positive way and understanding what is relevant to that goal is a very important ingredient. Yet another win/win was discovered during my discussions with Alice.

Geegah — a Promising Startup and Beneficiary

To complete the story, I spoke with Amit Lal. He is the Robert M. Scharf 1977 Professor of Electrical and Computer Engineering at Cornell. He's also the director of the SonicMEMS Laboratory there, which focuses on micromachining technologies for making ultrasonic transducers for ultrasonic applications.

Professor Lal made an important breakthrough. He and his students came up with a way of post-processing a CMOS layer with piezoelectric films to create ultrasonic waves to deliver high-resolution, precision imaging. The resultant small, gigahertz-frequency waves have many potential applications,Äîfrom chip security to acoustic storage of computer memory, ultrasonic imaging, and ultrasonic analog computing.

Amit and his student Justin Kuo have created a new company, Geegah, to commercialize the technology. We discussed a couple potential applications. First is chip security. Consider the reverse engineering liability associated with a chip that has metal interconnect. Now consider the same device that implements on-chip communication with ultrasonic waves. There are no signal paths to observe (or copy), making chip copying difficult, if not impossible.

The imaging capability has significant applications as well. One that caught my attention has to do with agriculture. It turns out there are very small worms, called nematodes that eat plant roots. Sensing their presence, so they can be controlled is virtually impossible with today's technology — it's difficult to "see" inside of soil. The sensors being developed by Geegah can do this quite accurately, however. The implications on the worldwide food supply / agriscience markets are significant and can make farmer's lives more predictable. Similar to the problem of not being able to see nematodes in soil is the problem of not being able to see viruses in one's breath. Geegah is now extending the technology to enable imaging of viruses. This capability is not only needed for COVID-like viruses, but for many other body infections as well.

The combined resources of both Praxis and Silicon Catalyst should have a significant and positive impact on the trajectory of this promising new startup. Geegah has access to the Cornell cleanroom to extend the technology to commercial levels, while it also has access to an extended network of silicon commercialization experts via Silicon Catalyst.

In conclusion, fundamental university-based research continues to be a valuable resource to drive the next generation of semiconductor solutions to benefit our industry and ultimately our lives. The Cornell Praxis and CTL collaboration with Silicon Catalyst and Geegah provides a great example of this value. Laura Swan and her team are looking to further expand university collaboration and would welcome contact with other academic institutions and researchers to learn more. Post docs in search of a path to commercialization should consider applying to the Silicon Catalyst Incubator, as the deadline for the next application review cycle is July 2, 2021.

So, there's the summary of how Silicon Catalyst and Cornell University are expanding opportunities for startups like Geegah. Another win/win for each of these organizations and potentially a big win for our industry.

Dave Burbank/Cornell University.

$25M Center Will Use Digital Tools to 'Communicate' with Plants

By Krishna Ramanujan
September 9, 2021
Cornell Chronicle

A new multi-institution, transdisciplinary center will develop systems for two-way communication with plants, allowing scientists to remotely sense a plant's biology and its immediate ecosystem, in hopes of one day using the information to improve plant growth.

The new Center for Research on Programmable Plant Systems (CROPPS), funded by a five-year, $25 million National Science Foundation (NSF) grant, aims to grow a new field called digital biology.

CROPPS will be led by researchers from the College of Agriculture and Life Sciences, the College of Engineering and the Cornell Ann S. Bowers College of Computing and Information Science. Partner institutions include the University of Illinois, Urbana-Champaign (UIUC); the University of Arizona; and the Boyce Thompson Institute, at Cornell. Some members of the CROPPS team are pictured above, on Cornell campus. From left: Shannon Spencer, CROPPS program and operations manager; Joyce Van Eck, associate professor at the Boyce Thompson Institute; Abraham Stroock '95, CROPPS co-director and the Gordon L. Dibble '50 Professor in the Robert F. Smith School of Chemical and Biomolecular Engineering; José Martínez, the Lee Teng-hui Professor of Engineering in Electrical and Computer Engineering, and associate dean for diversity and academic affairs; Susan McCouch, Ph.D. '90, the Barbara McClintock Professor in the College of Agriculture and Life Sciences; and Bruce Lewenstein, professor of communication, CALS.

CROPPS will develop technologies connected to the internet and the cloud — creating an Internet of Living Things — to listen to and learn how plants sense and respond to their environments. As these tools develop, they will be made more interactive. The ultimate goal is two-way communication, where scientists receive information and respond to what a plant needs, or to work with the plant's genetics to affect physical outcomes.

"At the heart of this project are plants endowed with new ways of expressing biological processes — including hidden processes that occur inside tissues or underground — through a readable signal that we can develop technologies to capture," said Stroock.

"A new understanding of how a plant responds to its environment will help us breed plants that can respond more appropriately to novel and highly variable environments in which they did not evolve," said Susan McCouch, Ph.D. '90, CROPPS director and the Barbara McClintock Professor of Plant Breeding and Genetics in CALS. "We need to accelerate the natural process of evolution because climate change has disrupted plants' ability to 'read' the environment."

The information these systems gather will help researchers better understand how to manage nutrients and water, for example, and how microbes work with plants to help them grow. Eventually, such knowledge could help scientists improve crop management.

"Do we put nitrogen on at a certain time?" McCouch said. "We will learn when, how much and why. Importantly, we'll start to learn how much of the plant's vigor and growth and reproductive potential is better managed by microbes."

The project will also explore how to deliver molecular signals to prompt plants to respond to environmental stressors.

At first, the center will work toward developing digital plant sensing tools connected to the cloud and the internet. Some early examples include work by Stroock to develop nanoscale sensors and fiber optics to measure water status just inside a leaf's surface, where water in plants is most actively managed. Such a tool would be minimally invasive and will not only advance understanding of basic plant biology, but offer information for breeding more drought-resistant crops.

Another example of work that has helped define the concept of programmable plants comes from Margaret Frank, Ph.D. '14, a CROPPS participant and assistant professor of plant biology in the School of Integrative Plant Science in CALS, who studies how tomato plants capture natural signals in roots that communicate with the leaves to drive a biological response. Furthermore, those signals from roots, the hidden part of the plant, can be displayed via fluorescence in the leaves and reported via the internet. Frank is currently working on a project that uses computational analysis to determine the role of mRNAs in root-to-shoot signaling. She is investigating whether certain mobile mRNAs could be introduced in grafts where they carry genetic codes for proteins that engender a response to an environmental stress, such as those caused by climate changes.

"NSF Science and Technology Centers are large-scale initiatives intended to bring a fresh, vigorous approach to research integrating multiple disciplines," said Emmanuel Giannelis, vice president for research and innovation. "By bringing one of these centers to Cornell, this team's bold plan addresses a sustainability challenge of tremendous societal impact, and I look forward to the scientific and technological advancements that I am confident will result from their work."

Other principal investigators include José Martínez, the Lee Teng-hui Professor in Engineering in the Department of Electrical and Computer Engineering; Steve Moose, a crop geneticist at UIUC; and Rebecca Mosher, a molecular and cellular biologist at the University of Arizona. Hakim Weatherspoon, associate professor of computer science at Cornell Bowers CIS, will serve as an associate director of the center.

• CNF COMMUNITY NEWS • CNF COMMUNITY NEWS • CNF COMMUNITY NEWS •

Grow-NY
FOOD & AGRICULTURE BUSINESS COMPETITION

Pair of Ithaca Firms are Finalists in Grow-NY State Competition

by Brian Crandall
September 20, 2021
The Ithaca Voice

ITHACA, N.Y.—For a pair of small Ithaca businesses, it's time to polish their business pitch and cross their fingers. Ascribe Bioscience and Heat Inverse have been named finalists in this year's Grow-NY food and agriculture competition. As the Grow-NY contest bills itself, "Grow-NY is a business competition focused on growing an enduring food and agriculture innovation cluster in the Grow-NY region. The competition attracts innovative, high-growth food and agriculture startups from across the globe and engages them in the region's rapidly-growing startup ecosystem." The contest is jointly administered by Empire State Development, the state government's economic development wing, and Cornell University, as the state's land-grant institution with New York's premier food science and agriculture programs. Twenty selected Grow-NY competition finalists enter a second round in which they pitch their business ideas for a chance to win a $1 million prize, with two $500,000 prizes and four $250,000 prizes for the runner-ups. Actually receiving the prize money is contingent on a plan to stay and build their business in Upstate New York in either Central New York, the Finger Lakes, or the Southern Tier.

Heat Inverse, which has been a finalist in other startup competitions, is based out of the Rev business incubator in downtown Ithaca.

Past CNF User, Romy Fain's company has developed a thin-film "photonic metamaterial" that offers cooling solutions with none of the energy input or waste heat associated with conventional cooling—in laymen's terms (and laymen's benefits), "think passive air conditioning in a thin film." The firm states their work has the power to revolutionize cooling technologies in agriculture and food production, with the initial market involving applications to refrigerated trucking.

Ascribe Bioscience, founded in 2017 by Ithaca scientists Jay Farmer and Murli Manohar, is based out of the McGovern Center life science business incubator in Weill Hall on Cornell's campus. The firm uses naturally occurring molecules from the soil to produce a novel class of broadly-applicable, non-toxic biopesticides that prime the immune systems of plants to enhance resistance to pathogens and increase crop yields.

The firms will make their pitches to a live audience and panel of judges during a two-day program summit in Syracuse on Nov. 16-17, which includes a symposium and networking events alongside the business competition. The winner and runner-ups will be announced at the end of the summit.

heat^{-1}

Thermal Analysis Guides Future Design of 2D Hybrid Materials

By Syl Kacapyr
May 27, 2021
Cornell Chronicle

A first-of-its-kind study examining the thermal transport properties of a novel material is helping steer the future of 2D hybrid perovskites — a relatively new class of materials with exciting potential for photovoltaic, optoelectronic and thermoelectric applications.

The perovskite family of materials has shown great promise for improving solar cells, LED lights and other devices because of its unique mechanical, electrical and optical properties, and researchers, including Zhiting Tian, associate professor of mechanical and aerospace engineering in the College of Engineering, have also discovered unique thermal abilities in the family. But perovskites are notoriously unstable, limiting the lifespans of their applications. As a potential solution, some researchers are investigating a two-dimensional hybrid version of perovskites, with atomically thin organic and inorganic layers stacked together, creating the same crystal structure that defines a perovskite, but with more stability and control.

Led by Tian, a group of researchers conducted the first study of phonon dispersion in a 2D hybrid material, observing how X-rays scattered as they passed through, providing valuable data on the material's ability to transport heat. The results are detailed in the paper "Remarkably Weak Anisotropy in Thermal Conductivity of Two-Dimensional Hybrid Perovskite Butylammonium Lead Iodide Crystals," published May 3 in the journal Nano Letters.

The study of butylammonium lead iodide showed the 2D crystal structure shares some attributes of 3D perovskites. In particular, the material was found to have ultralow thermal conductivity, much like a 3D perovskite studied by Tian in 2019. But the 2D structure also showed remarkably weak anisotropy in thermal conductivity, meaning it showed comparable capabilities to conduct heat in different directions.

Just as a block of wood is weaker along its grain than perpendicular to the grain, various properties of crystals typically have different values when measured in different directions. This is especially true for layered structures. But the 2D crystal investigated by Tian was found to have similar thermal conductivity throughout the material.

"It was very interesting," Tian said. "I knew this material would be special because of its combination of organic and inorganic components and the preferential orientation of the organic chains, but I had never seen such low anisotropy before. We wanted to look deeper and try to explain it in detail."

Understanding the material's unique thermal transport ability requires a combination of techniques, including synthesis, characterization and computational modeling. To obtain the in-plane thermal diffusivity, Tian used a technique known as transient thermal grating, employing two laser beams to create a temperature grating on tmaterial, and then a third to probe the thermal response. This was the first in-plane thermal measurement of a 2D hybrid perovskite.

Tian also used a synchrotron-based inelastic X-ray scattering and spectral energy density calculations to determine the dispersion relation of phonons — particles responsible for heat conduction — which revealed details of the material's unique lattice dynamics — the way in which its atoms vibrate.

"It's a pretty challenging process because of the complex crystal structure. Also, the energy resolution of the inelastic X-ray scattering couldn't really go down to a very low frequency," Tian said. "That's why we combined the techniques with computation to get the dispersion."

What their detailed analysis found was that depending on the direction the phonons were traveling, the phonon lifetimes were slightly different while the phonon group velocities were fairly close. The result comes from several competing effects that offset each other, leading to the material's small anisotropy.

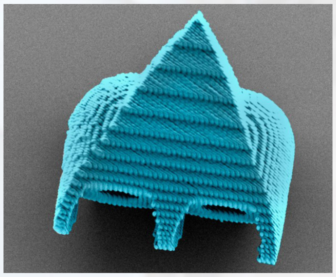
Aside from applications in thermoelectric devices that can convert heat directly into electricity, Tian said the research could help improve 'hot-carrier' solar cells, where ultralow thermal conductivity is desired to achieve high power conversion efficiency.

"The idea is you try to collect the excited charge carriers before they thermalize, and this material's nearly isotopically low thermal conductivity can provide just what you need to slow down that thermalization," said Tian, who added that more foundational research into 2D hybrid perovskites is required before understanding their true capabilities.

The study was funded by the NSF and the U.S. DOE, and was performed at the Argonne National Laboratory, the Cornell NanoScale Science and Technology Facility, and the Cornell Center for Materials Research.

Co-authors include Shefford Baker, associate professor of materials science and engineering (Engineering); Brad Ramshaw in the College of Arts and Sciences, the Dick and Dale Reis Johnson Assistant Professor; and researchers from Duke University, the University of Delaware and Cittadella Universitaria, Italy.

Micro-Robots Propelled by Air Bubbles and Ultrasound



By David Nutt
September 22, 2021
Cornell Chronicle

Some engineers find inspiration in the mechanics of bird flight and the architecture of bee nests. Others think much smaller. A team led by Mingming Wu, professor of biological and environmental engineering in the College of Agriculture and Life Sciences, created cell-size robots that can be powered and steered by ultrasound waves. Despite their tiny size, these micro-robotic swimmers — whose movements were inspired by bacteria and sperm — could one day be a formidable new tool for targeted drug delivery.

The team's paper, "Biologically Inspired Micro-Robotic Swimmers Remotely Controlled by Ultrasound Waves," was published Sept. 22 in Lab on a Chip, a publication of the Royal Society of Chemistry. The paper's lead author is former postdoctoral researcher Tao Luo.

For more than a decade, Wu's lab has been investigating the ways microorganisms, from bacteria to cancer cells, migrate and communicate with their environment. The ultimate goal was to create a remotely controlled micro-robot that could navigate in the human body.

"We can make airplanes that are better than birds nowadays. But at the smallest scale, there are many situations that nature is doing much better than us. Bacteria, for example, have had billions of years of evolution to perfect their way of doing things," Wu said. "That led us to think that can we actually engineer something similar. If you can send medicine to a targeted area, like cancer cells, then you won't have as many side effects."

Among their more ingenious attributes are the fact that bacteria can swim ten times their body length in one second and sperm can swim against the flow, Wu said. Wu's research team initially tried to design and 3D print a micro-robot that mimicked the way bacteria use flagellum to propel themselves. However, like the early aviators whose cumbersome airplanes were too birdlike to fly, that effort collapsed. When Luo joined Wu's lab, they began exploring a less literal approach. The primary hurdle was how to power it. As a person must crawl before they can walk, a micro-robot needs to be energized before it can swim.

"Bacteria and sperm basically consume organic material in the surrounding fluid, and that is sufficient to power them," Wu said. "But for engineered robots it's tough, because if they carry a battery, it's too heavy for them to move." The team hit upon the idea of using high-frequency sound waves. Because ultrasound is quiet, it can be easily used in an experimental lab setting. As an additional bonus, the technology has been deemed safe for clinical studies by the U.S. Food and Drug Administration. However, the team was stumped by the fabrication process. Working with the Cornell NanoScale Facility, Luo tried to create a prototype with photolithography, but it was time-consuming, and the results were unusable.

The project received a crucial boost when CNF purchased a new laser lithography system called a NanoScribe, which creates 3D nanostructures by direct-writing onto a photosensitive resin. The technology enabled the researchers to easily tweak their designs at the micrometer scale and produce new iterations quickly.

Within six months, Luo had created a triangular micro-robotic swimmer that looks like an insect crossed with a rocket ship. The swimmer's most important feature is a pair of cavities etched in its back. Because its resin material is hydrophobic, when the robot is submerged in solution, a tiny air bubble is automatically trapped in each cavity. When an ultrasound transducer is aimed at the robot, the air bubble oscillates, generating vortices — also known as streaming flow — that propel the swimmer forward.

Other engineers have previously built "single bubble" swimmers, but the Cornell researchers are the first to pioneer a version that uses two bubbles, each with a different diameter opening in their respective cavity. By varying the sound waves' resonance frequency, the researchers can excite either bubble — or tune them together — thereby controlling which direction the swimmer is propelled. The SEM above shows a cell-size robotic swimmer that can be powered and steered by these ultrasound waves.

The challenge ahead will be to make the swimmers biocompatible, so they can navigate among blood cells that are roughly the same size as they are. Future micro-swimmers will also need to consist of biodegradable material, so that many bots can be dispatched at once. In the same way that only a single sperm needs to be successful for fertilization, the volume is key.

"For drug delivery, you could have a group of micro-robotic swimmers, and if one failed during the journey, that's not a problem. That's how nature survives," Wu said. "In a way, it's a more robust system. Smaller does not mean weaker. A group of them is undefeatable. I feel like these nature-inspired tools typically are more sustainable, because nature has proved it works."

The research was supported by the National Cancer Institute. The work was performed in part at CNF, which is funded by the NSF (Grant No. NNCI-2025233).

Brewer Science's Bold Journey to Certified B Corporation

By Jessica Albright
July 19, 2021
semi

Understanding the significance of a B CorpTM comes down to measuring the success of a company in more than profits and return on investment. Can global impact, sustainability, and social justice deliver value to stakeholders too? At Brewer Science, we boldly answered, "yes!" and launched our journey to becoming a Certified B CorporationTM.

A B Corp is a for-profit, corporate entity that seeks to positively impact society, the community, and the environment, in addition to generating profit. The concept is catching on. Today, there's a worldwide network of almost 4,000 Certified B Corporations across 150 different industries and 74 countries.

The CNF has been partnering with Brewer Science for about 25 years. We congratulate them on this achievement!

In May 2021, Brewer Science announced that we are the first company in the semiconductor industry to become a Certified B Corporation. As a chip industry trailblazer for this certification, Brewer Science wanted to share a little about its journey and answer questions often posed by its suppliers, customers, and competitors: Why would a company go through the exhaustive auditing process, how does it work, who does it involve, and what comes next?

Why did Brewer Science seek to become a Certified B Corporation?

Certified B Corporations are the forefront of a growing global movement of people using business as a force for goodTM. Certification demonstrates a spirited commitment to high standards of social and environmental performance, transparency, and accountability.

"Certified B Corporation standards align with our mission of being a company of the people, by the technology, for the customer, to achieve fulfillment," said Dr. Terry Brewer, Founder and CEO of Brewer Science. "Becoming a Certified B Corporation exemplifies our commitment to our mission to continuously evolve our global footprint to the benefit of our employees, community, and customers, adding unexpected value throughout the world."

Certified B Corporations are held accountable for environmentally friendly business practices, being inclusive, and promoting local businesses. Besides providing a social benefit to our suppliers, customers, and employees, the certification also gives Brewer Science extensive opportunities to grow the business in collaboration with other mission-driven companies and people. For example, as Certified B Corporations, companies can attend the B Climate Collective and work synergistically with other B Corp companies to advocate for social change.

How did we become a B Corp?

Brewer Science completed a meticulous assessment process conducted by B LabTM, which examined over 170 factors in reviewing Brewer Science's customers and vendors, record of inclusion, community involvement, corporate governance, and environmental impact. B Lab also analyzed average employee tenure, charitable giving, energy savings plan, recycling policies, employee volunteer service, and employee upward mobility.

The process of becoming a B Corp begins with a self-assessment that the company's Board of Directors must certify and ends with a 90-minute review call during which B Lab reviews the company's responses and the company presents supporting evidence. The entire process is rigorous, with the company winning and losing points based on various criteria. These points are factored into weighing its strength as a candidate, and also in identifying opportunities where the company can improve.

B Corp Impact Report

B Corp status is granted when the company earns at least 80 out of 200 points. But, this is just the starting point of an ongoing process of growth and improvement to uphold the values of the B Corp into the future. The assessment is more than a scorecard. It's a thorough inspection of every facet of the company and helps guide it in making changes, since every question in the B Impact Assessment must be supported by an explanation and real-life example.

A key part of the certification requires choosing a Business Impact Area, which requires the company to prevent evidence of processes it has implemented to influence that area. This component counts for 29 of the 80 points required to achieve Certified B Corporation status. Brewer Science pursued the impact area of environmentally innovative manufacturing, requiring us to provide detailed evidence of how we manage waste in manufacturing and minimize our carbon footprint. We earned an Overall B Impact Score of 88.7.

Brewer Science also addressed other areas in the B Impact Assessment such as our human resource initiatives, community involvement, commitment to helping underserved communities, and seeking minority-owned businesses,Äìjust to name a few. The assessment incudes the five B Impact areas where Brewer Science scored the highest.

Who was involved in the B Corp process?

Brewer Science assembled an internal B Corp task force team of directors from departments across the company to provide a cohesive and complete view of the company ‚Äì a step that was necessary for us to meet the requirements of B Lab's extensive auditing of the company.

B Corp impact area scoresB Lab encourages the use of an outside consultant that serves as a liaison between the company and B Lab. Brewer Science's internal B Corp task force team held bi-monthly meetings with its consultant for nearly a year to answer the hundreds of questions in the questionnaire and gather evidence to corroborate each claim.

"It's a very extensive, but very rewarding process," said Karen Brown, Project Manager at Brewer Science, also known as the B Keeper by B Lab since she led the certification process within the company. "B Lab is very thorough with the process. It is detailed with what it means and what the questions stand for. It is firm with its requests to ensure that the certification is taken seriously."

What's next on Brewer's B Corp Journey?

Brewer Science's B Corp certification is valid for three years, at which we point we will apply for renewal ‚Äì a process that will require us to score even higher than on the previous certification. B Lab stresses continuous improvement, and B Corps must create an improvement plan that spells out areas they will enhance in the coming years.

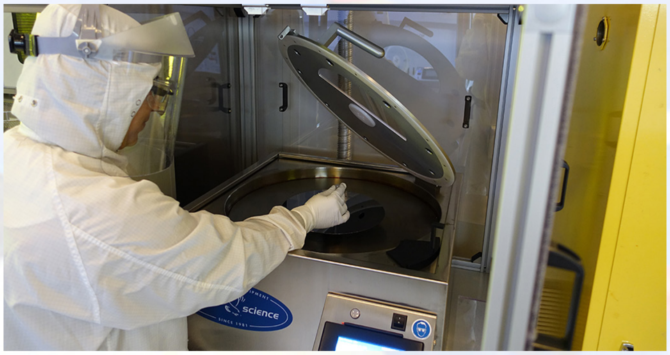
Brewer Science Resource Conservation

Brewer Science has already identified improvement areas for the recertification. Several of our new human resources initiatives ‚Äì such as flexible and expanded work options ‚Äì have not yet been committed to policy. Additionally, we have expanded our use of a cloud-based learning platform to increase training options for employees and hold performance conversations quarterly instead of annually.

As part of the assessment, Brewer Science won points for community involvement and charitable giving. However, we are expanding our community engagement by providing employees with a monthly charity or cause to support. Brewer Science became a Certified Employee-Owned company last year. Since 2020 marked the launch of our employee stock ownership plan (ESOP) and shares had not yet been dispersed, B Lab didn't fully recognize the program. These are just a few examples of how we plan to earn more points during the recertification.

At Brewer Science, we hope we can inspire other industry leaders to apply for certification. For more information about Certified B Corporations, and to get started on your company's application, visit the Certified B Corporation website.

Jessica Albright is a content marketer at Brewer Science, Inc.



Four Faculty Awarded with Endowed Professorships

By Sheri Hall
August 25, 2021
Cornell Chronicle

Four professors from the College of Human Ecology were awarded endowed professorships this summer that will fund ground-breaking research and outreach in a broad range of disciplines.

"I am so grateful for the generous donors who funded these endowed professorships, allowing us to honor some of our most highly-regarded and impactful faculty members," said Rachel Dunifon, the Rebecca Q. and James C. Morgan Dean of the College of Human Ecology. "Through their work, these scholars address issues critical for human health and well-being, and improve human lives."

Anthony Burrow was named the Ferris Family Associate Professor of Life Course Studies in Cornell's newly-formed Department of Psychology. Janet Loebach was named the Evalyn Edwards Milman Assistant Professor in Child Development.

Juan Hinestroza (right) was named the Rebecca Q. Morgan '60 Professor in Fiber Science and Apparel Design. Hinestroza's work explores the interface between the established field of textile science and the emerging and revolutionary field of nanoscale science.

His works aims to modify the properties of existing textiles by adding nanomaterials, create new nanofiber-based materials and develop tools to better understand issues in textile processing which can be addressed at the nanoscale.

Hinestroza plans to use the endowment funds to explore projects that combine fiber science with apparel design. "Most academic funding is allocated to either a science project or a design project, but rarely a project that merges both," he said. "I plan to use this funding to help students explore the interface between fiber science and apparel design." Specifically, Hinestroza's research lab is launching a new project to create apparel such as shirts or backpacks that have sensors to detect biomarkers in sweat.

"Sweat is one of the most misunderstood body fluids," Hinestroza explained. "Through sweat, we can detect glucose, lactic acid and urea. I want to find out if we can create clothing that will use sweat to give us information about what's going on with the human body." Such apparel could be used to help people who are diabetic to monitor their blood sugar, help athletes to train at optimal effort levels, and help people with kidney disease to measure and better understand their kidney function.

Saurabh Mehta was named the Janet and Gordon Lankton Professor in the Division of Nutritional Sciences. Mehta is a physician and epidemiologist

Left: CNF PI Juan Hinestroza, Rebecca Q. Morgan '60 Professor in Fiber Science and Apparel Design. Right: CNF PI Saurabh Mehta, Janet and Gordon Lankton Professor in the Division of Nutritional Sciences. Photo Credits: Robert Barker/Cornell University

with expertise in nutrition, infectious disease and diagnostics. The focus of his research is the interplay between nutrition, inflammation and disease during pregnancy and early childhood. This is achieved through a combination of active surveillance programs, invention of point-of-care diagnostics and randomized controlled trials in resource-limited settings in India, Sub-Saharan Africa and South America.

Mehta is currently the principal investigator on two randomized clinical trials — one in the urban slums of Mumbai and one in rural southern India — to determine the effects of delivering nutrients such as iron and vitamin A through biofortified crops on nutrition, immune function and the gut microbiome in infants. He is also the co-inventor of the Cornell NutriPhone and FeverPhone, a platform funded by the National Institute of Health and the National Science Foundation that provides point-of-care diagnosis of nutritional status and infections. This platform is field-friendly, non-invasive and inexpensive, requires minimal infrastructure or training, and yields results in as little as 15 minutes.

"I am very grateful to the College of Human Ecology and the Division of Nutritional Sciences for this honor and for the continued support of my research program," Mehta said. "The funds from this endowment will help generate pilot data for methods to evaluate biomarkers of nutrition, inflammation and infection to inform screening programs and interventions to improve the health of vulnerable populations."

Four Faculty Receive Carpenter Advising Awards

October 4, 2021
Cornell Chronicle

Four Cornell faculty members have received Kendall S. Carpenter Memorial Advising Awards, which recognize sustained and distinguished contributions of professorial faculty and senior lecturers to undergraduate advising. The awards were established by Stephen Ashley ‘2, MBA ‘4, in honor of his adviser, Kendall S. Carpenter, a professor of business management at Cornell from 1954 until his death at the age of 50 in 1967.

“Never has it been more important for students to be guided by faculty who are so deeply committed to their intellectual growth and personal well-being,” said Lisa Nishii, vice provost for undergraduate education.

Derek Chang, associate professor in History and interim director of the Asian American Studies Program in the College of Arts and Sciences (A&S), was described by his nominator as “a vital resource for students of color.” He offers empathy and insight for these students at Cornell.

CNF PI Margaret Frey. Provided.

A theme that emerged among all of the nominating materials for Margaret Frey, the Vincent V.C. Woo Professor in the Department of Fiber Science and Apparel Design in the College of Human Ecology, was her dedication to mentoring and advising undergraduates. In addition to working with students in traditional advising settings and welcoming them with an “open door” policy, she has also served in roles such as faculty fellow for Balch Residence Hall for first-year women and senior associate dean for undergraduate affairs. Wrote one student: “She is an amazing advisor and teacher, she takes her role in academia very seriously, and truly cares for those she advises.”

Jerrie Gavalchin, associate professor in the Department of Animal Science in the College of Agriculture and Life Sciences, who died in 2020 while bicycling with her daughter near her home in Groton, New York, received the award posthumously. In a 21-year Cornell career, she advised hundreds of students, who consistently described her generosity and encouragement. Wrote one advisee: “She went above and beyond for me at a point in my life where I didn’t even believe in myself anymore. I don’t know if I would have graduated, and my life would have been very different without her.”

Alexander Ophir, associate professor in the Department of Psychology (A&S), was praised for his commitment to mentoring students from underrepresented backgrounds and his willingness to serve as a lifelong mentor.

Congratulations to Sajag Poudel, NSF INTERN Award Winner!

Dear Melanie-Claire,

I am Sajag Poudel, a Ph.D. student in department of Mechanical & Aerospace Engineering, Syracuse University, NY. I work in the research group of Dr. Shalabh Maroo and we have the active project in CNF (#212312). Recently, I have been awarded with National Science Foundation Research Grant Award (NSF INTERN) in order to pursue collaborative research at Oak Ridge National Laboratory. This award is granted by NSF to the graduate students for getting involved in a short-term research experience outside of the university. During my P.hD. I have performed extensive research on porous nanochannels devices which are fabricated at CNF and my research experience on the same has enabled me to bag this grant. For this I am thankful to CNF as well.

More on this is also available here:

https://news.syr.edu/blog/2021/08/31/mechanical-and-aerospace-engineering-ph-d-student-awarded-nsf-intern-grant-for-research-at-oak-ridge-national-laboratory/

The staff at Xallent are pleased to announce that they have entered into a cooperative agreement with the National Institute of Standards and Technology (NIST) to develop a hybrid metrology platform for high-speed probing of semiconductors and thin films. Under this agreement, Xallent and NIST will be working together to realize the metrology solution. We are excited about this collaboration and look forward to sharing project results with our customers, stakeholders, and well-wishers.

2022 James C. McGroddy Prize for New Materials

Daniel C. Ralph, Cornell

"For pioneering studies of materials physics in spin-transport and related devices."

Dan Ralph is the F. R. Newman Professor of Physics at Cornell and a member of the Kavli Institute at Cornell for Nanoscale Science. He received the 2022 James C. McGroddy Prize for New Materials for work with his long-time collaborator Bob Buhrman, who passed away in April 2021.

James C. McGroddy Prize for New Materials

To recognize and encourage outstanding achievement in the science and application of new materials. This shall include the discovery of new classes of materials, the observation of novel phenomena in known materials leading to both fundamentally new applications and scientific insights, and shall also include theoretical and experimental work contributing significantly to the understanding of such phenomena. The prize consists of $10,000 plus a certificate citing the contribution of the recipient and an allowance for travel to the meeting of the Society at which the award is presented. It is awarded annually.

https://www.aps.org/programs/honors/prizes/prizerecipient.cfm?last_nm=Ralph&first_nm=Daniel&year=2022

2021 Regional Award Finalist / Post-Doc in the Blavatnik Awards for Physical Sciences and Engineering

Maxim Shcherbakov

Congratulations to Maxim Shcherbakov — a 2021 Regional Award Finalist / Post-Doc in the Blavatnik Awards for Physical Sciences and Engineering! Previously, Max was a CNF user with PI Gennady Shvets, and is now an Assistant Professor in Materials Science & Nanotech at the University of California, Irvine.

Max has been recognized for working with a special class of artificial materials, known as semiconductor metamaterials, that manipulate light in fascinating ways. He has utilized common semiconductor materials, like silicon and germanium, to engineer metamaterials that display unusual optical properties. Shcherbakov has made a number of important discoveries, including the first experimental observation of photon acceleration—an effect well-known in plasma physics that changes the frequency of light. His groundbreaking scientific discoveries will impact many areas from telecommunications to quantum computing.

Welcome to the Latest Nanooze!!

We recently released our 17th issue of our youth newsletter and this one focusses on "PHOTOLITHOGRAPHY; HOW SMALL CAN WE GO?" with articles like; Scale of Tiny Things, Itty-Bitty Transistors and Chips, Nanoscale Weirdness, and Q&A with a Photolithographic Process Engineer/Heavy Metal Rocker — CNF's own Garry Bordonaro!

Check it out online at https://www.nanooze.org/

Copies of Nanooze are FREE for K-12 teachers. Please visit nanooze.org for more information or email a request for copies: info@nanooze.org.

Stanford's 2020 Marsh O'Neill Awards Given to Kevin Manalili and Richard Tiberio

Stanford University
June 28, 2021

Stanford will award the 2020 Marsh O'Neill Award for Exceptional and Enduring Support of Stanford University's Research Enterprise to two members of the university staff: Kevin Manalili, director of facilities management and planning for the School of Engineering, and Richard Tiberio, senior research scientist at Stanford Nano Shared Facilities. The award presents one of the few opportunities for faculty to publicly acknowledge the contributions of outstanding staff members who support their research activities.

The award, which is accompanied by a $5,000 cash prize, was inspired by the extraordinary career of Marshall D. O'Neill, who was the associate director of the W.W. Hansen Laboratories from 1952 to 1990. O'Neill was the first recipient of the award. The selection and announcement of the 2020 winners were delayed due to the pandemic.

Kevin Manalili — 'Nothing Short of Heroic'

As director of facilities management and planning for the School of Engineering, Kevin Manalili oversees a 17-person team of building managers, project managers, safety specialists and operations support representatives. Kevin Manalili is director of facilities planning and management for the School of Engineering. "We provide places and resources that enable engineering, science and technology research and education to flourish," said Manalili, who joined Stanford in 2015. "It is our responsibility to ensure that all of our spaces are clean, safe and able to support cutting-edge research and education."

Manalili, who also played a key role on Stanford's Research Operations Continuity Working Group, said he was honored to be recognized with a Marsh O'Neill Award. "I'm glad I was able to play a role in safely restarting research," he said. "I'm very proud there were no cases of on-campus transmission in our labs and that the work we did kept everyone working on site safe. My team members were rock stars this past year, coming into work while most staff worked from home and providing COVID compliance support in addition to their regular tasks."

Richard Tiberio — 'Stalwart Core of Nanofabrication'

As the senior research scientist for Stanford Nano Shared Facilities, Richard Tiberio helps graduate students achieve their research goals and launch their science careers — work he described as rewarding and joyful, and full of challenging twists and turns.

(Richard Tiberio. Image credit: Andrew Brodhead)

"Every day is a new, fun surprise," said Tiberio, whose work also enables the research of postdoctoral scholars and faculty members in the schools of Humanities and Sciences, Engineering and Medicine. Tiberio, who arrived at Stanford in 2000 and has more than four decades' experience in electron-beam lithography, said it was an honor to be selected for a Marsh O'Neill Award.

"It provides inspiration to be even more creative for each new incoming class of students and researchers," he said.

Faculty members who nominated Tiberio for the award said he is known for his accessibility, exceptionally deep understanding of electron-beam lithography, a passion for sharing that knowledge and a willingness to solve any problems that arise — at any hour. David Goldhaber-Gordon, a professor of physics in the School of Humanities and Sciences, described Tiberio as "the stalwart core of the Stanford nanofabrication community."

"When someone comes to Rich with an idea, he draws on his extensive experience of process technology — beyond just electron-beam lithography — and his network of top lithographers worldwide, and often offers a transformative suggestion for how to accomplish the user's goal," he said.

"My group's research depends heavily on nanofabrication, and Rich has been a fantastic resource, going well beyond the call of duty."

Jennifer Dionne, associate professor of materials science and engineering in the School of Engineering and senior associate vice provost of research platforms/shared facilities, said Tiberio played a key role in campus COVID research during the pandemic.

"Shortly after the shutdown, my lab was approved for campus research to make chips for sensing COVID gene fragments," she said. "This research required nanopatterning in the cleanroom, and Rich was instrumental in getting students safely and swiftly into the cleanroom, training them on new COVID health and safety guidelines, and assisting with their research to address the COVID pandemic."

Jelena Vuckovic, a professor of electrical engineering in the School of Engineering, said if a member of her group faces a problem with e-beam lithography, Tiberio always comes up with solutions and ideas to try new things — even if that creates more work for him.

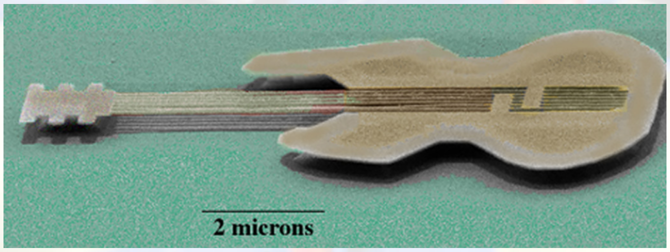
"For example, he helped one of my students develop an e-beam lithography process using a new type of resist that had not been used in our facility before," she said. "If Rich is not able to provide advice to my students, he shares his large network of nanofabrication experts with them and finds the right experts to help them with their processes."

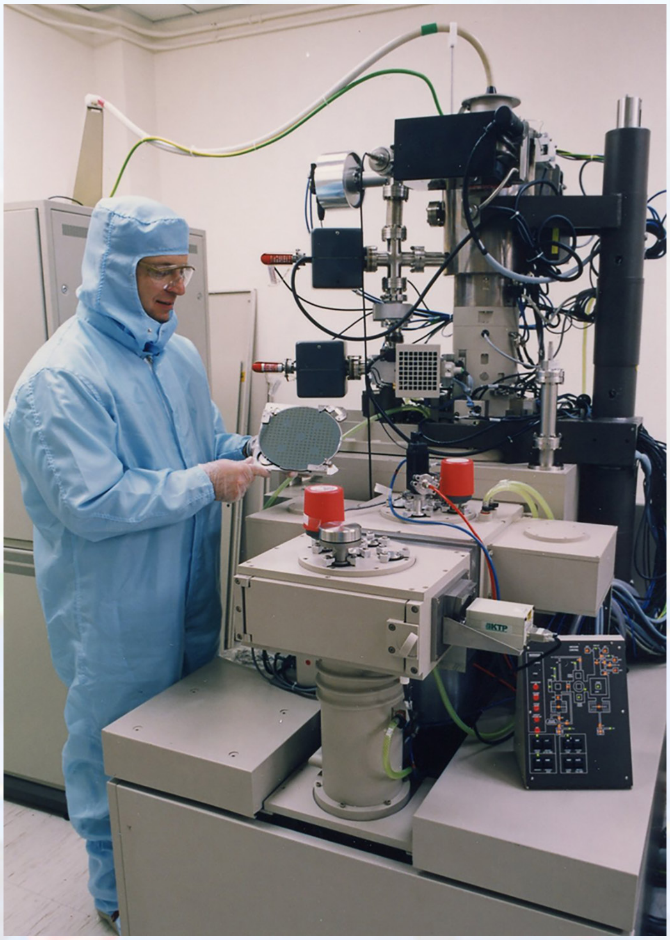
Tony F. Heinz, a professor of applied physics in the School of Humanities and Sciences and of photon science at SLAC National Accelerator Laboratory, said Tiberio "goes the extra mile" to understand the users' individual projects, suggesting prototypical lithography solutions and supervising starting attempts — thereby helping users to launch their new research directions. "My students and postdocs have greatly benefited from Rich's assistance and have expressed much enthusiasm for his nomination for this award," Heinz said.

As many know, Rich was the Senior Electron-Beam Lithography Associate at the CNF from 1979-2005.

He was maybe best known for coordinating the addition of the first publicly available electron-beam system, CNF's Leica VB6. The VB6 was used to create the world-famous Carr-Craighead nanoguitar in 1997 shown below.

The CNF staff offer Rich a hearty congratulations on this Marsh O'Neill Award!





Richard back in his CNF days, showing off our unique VB6!

Dear Rich,

Congratulations! You have been (are) a most unique and outstanding contributing player in the forward march of nanotechnology. As we both know electron beam lithography is the chief enabler for nanotechnology and you have led that charge at the two leading world class facilities in nanotechnology. Well done, Rich. I am proud of you as one of my graduate students and one of the first hires at NRRFSS. Our friendship has been special, thank you.

Ed

Edward D. Wolf, Ph.D.

Prof. Emeritus, Electrical and Computer Engineering
Director Emeritus,
NRRFSS and National Nanofabrication Facility
Cornell University, Ithaca, NY 14850

Defense R&D and Nuclear Nonproliferation Nominees Announced

Profile Photo: Dr. David Honey, ODNI Science and Technology Director, https://www.executivegov.com/2017/03/profile-dr-david-honey-odni-science-and-technology-director/

President Biden announced on August 4th that he is nominating David Honey to be deputy undersecretary of defense for research and engineering, and Corey Hinderstein to lead nuclear nonproliferation efforts at the National Nuclear Security Administration.

Honey is currently serving as a special assistant to the director of the Defense Advanced Research Projects Agency and previously was director of science and technology in the Office of the Director of National Intelligence and the deputy assistant secretary of defense for research. He earned a doctorate in solid state science from Syracuse University in 1994.

Hinderstein previously served in a senior nonproliferation staff role at NNSA from 2015 to 2017 and led preparations for the 2016 Nuclear Security Summit. Most recently, she was in charge of efforts to reduce proliferation risks presented by nuclear reactor fuel at the Nuclear Threat Initiative, a nonprofit organization she had previously worked for from 2006 to 2015.

The CNF staff remember Captain/Major David Honey as a research scientist at Rome Airforce Base, back in the days when it was Rome Air Development Laboratory. He became a CNF User on project 380-90 with PI Rebecca Bussjager, "Optical Interconnects for 3D Computer Architectures" — and performed his research in the old Knight Laboratory. David is remembered fondly and we send him our congratulations on this prestigious nomination!

Weiss Teaching Awards Honor Ten Exceptional Faculty

By James Dean
October 18, 2021
Cornell Chronicle

Ten faculty members have been selected to receive Stephen H. Weiss Awards honoring excellence in undergraduate teaching and mentoring, President Martha E. Pollack announced Oct. 18.

"The Weiss Awards highlight the centrality of undergraduate education at Cornell, and I'm delighted that we're able to recognize our exceptional faculty for their achievements," Pollack said. "It's especially wonderful to have such a large group of talented and accomplished teachers to celebrate this year, after last year's awards hiatus because of the pandemic."

Three awards are named in honor of the late Stephen H. Weiss '57, who chaired the Cornell University Board of Trustees from 1989-97. Weiss conceived of the Presidential Fellowship Award, first bestowed in 1992 to recognize a sustained record of commitment to undergraduate education. The board in 2016 introduced the Junior Fellowship Award, recognizing early-career tenured faculty, and the Provost's Teaching Fellowship Award, honoring nontenured faculty members.

A selection committee of six faculty members and three students (two graduate students and one undergraduate) recommended this year's recipients after reviewing 20 nominations detailing the instructors' skill and dedication inside and outside the classroom, based on course evaluations and letters from students and faculty or staff.

The Stephen H. Weiss Presidential Fellows are Sandra Greene, the Stephen '59 and Madeline '60 Anbinder Professor of African History, in the College of Arts and Sciences (A&S); Jane Juffer, professor in the Department of Literatures in English and Program of Feminist, Gender and Sexuality Studies (A&S); Lisa Kaltenegger, associate professor in the Department of Astronomy (A&S); Marvin Pritts, professor in the School of Integrated Plant Science (SIPS) Horticulture Section and the Department of Global Development, in the College of Agriculture and Life Sciences (CALS); David Putnam, professor in the Meinig School of Biomedical Engineering and Smith School of Chemical and Biomolecular Engineering, in the College of Engineering (ENG); and Michael Thompson, M.S. '82, Ph.D. '84, the Dwight C. Baum Professor in Engineering in the Department of Materials Science and Engineering (ENG).

David Putnam and Michael Thompson are CNF Principal Investigators and their profiles follow:

Putnam joined the College of Engineering in 2002 and is "the faculty member we all aspire to be," excelling in any class he teaches, nominators wrote, including a "legendary" drug delivery class.

He developed multiple innovative courses from scratch for a new curriculum and engages students with his creative lectures and teaching style — hopping around the room to illustrate an emitted electron, or challenging students with design problems faced by clinicians or engineers.

Putnam's student engagement extends to award-winning mentoring and involvement in internships, jobs and graduate programs. His research group focuses on the design and synthesis of functional biomaterials in areas including vaccine/adjuvant design and delivery, synthetic lubricants, surgical devices and drug delivery systems.

Thompson has been a member of the faculty since 1984 and for nearly 25 years taught juniors in materials science and engineering the fundamentals of thermodynamics, helping students gain an understanding of material that can be "abstract and generally non-intuitive," nominators wrote.

Thompson not only cares about his students and their learning, they said, but turns students into great researchers.


CNF PI David Putnam


CNF PI Michael Thompson

"[Thompson] is the epitome of the ideal university educator of technical subjects — from his innate ability to excite students about scientific principles — to his superb listening skills, tireless dedication, selfless personality, open-door office hour policy, and ability to connect with students," nominators wrote.

Said one student: "The lectures are intense and make me feel that I've learned a lot."

Find all the profiles at https://news.cornell.edu/stories/2021/10/weiss-teaching-awards-honor-10-exceptional-faculty

• CNF OUTREACH EVENTS • CNF OUTREACH EVENTS • CNF OUTREACH EVENTS •

Cornell Reunion 2021 & CNF Cleanroom Tour

On June 11th, 110 Cornell alum and guests joined us for an introduction to the CNF led by Dr. Lynn Rathbun, and a virtual tour of our cleanroom with CNF Tech Jeremy Clark.

This recorded event is available via Cornell's Video-On-Demand, https://vod.video.cornell.edu/

Just search for the CNF channel, then search that for "Reunion" and voila! We made the video public so anyone can watch it.

Enjoy!

Update on Wolf Telescope Collection

Edward D. Wolf
6/21/21
To: mallison@cnf.cornell.edu

Figure 1: Wolf historical telescopes on exhibit in the Circular Gallery, Beijing Planetarium, Beijing, China. All photographs on this page were provided by Edward D. Wolf.

Hi Melanie-Claire,

...my telescope collection is now beginning to go on exhibit at the Beijing Planetarium in Beijing, China (https://www.wolftelescopes.com/). They sent me a recent photo of a small subset display in the Circular Gallery. Starting next year it will begin to be on full exhibit on all three floors of the Beijing Ancient Observatory which the Planetarium manages as a museum. I have attached a few photos that may be of interest. Also, within the photos is a photo taken on our 65th wedding anniversary and some garden photos.

Warm regards,

Ed

Figure 2: Foucault/Secretan, Serial No., 4: one of the first silver-coated primary mirror reflector telescopes.

Ed and Marlene Wolf at their 65th wedding anniversary celebration!

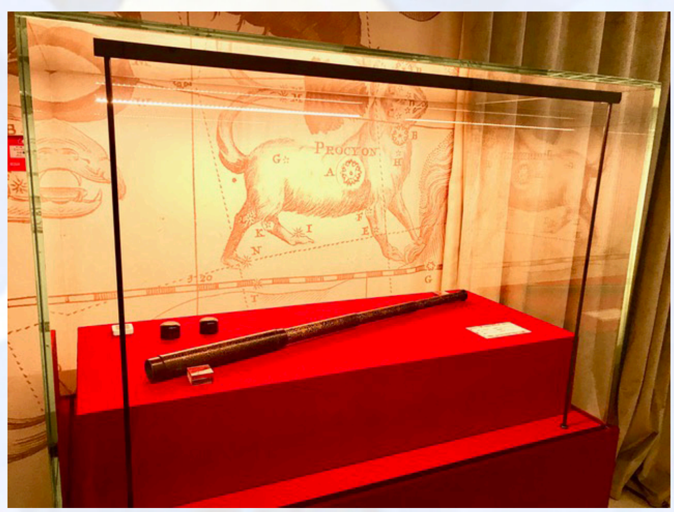


Figure 3: Mori Nizaemon Masatomi handheld refractor telescope. May be an important "spyglass" in early Japanese telescope history!

CNF's Youth Outreach Program Goes Nationwide

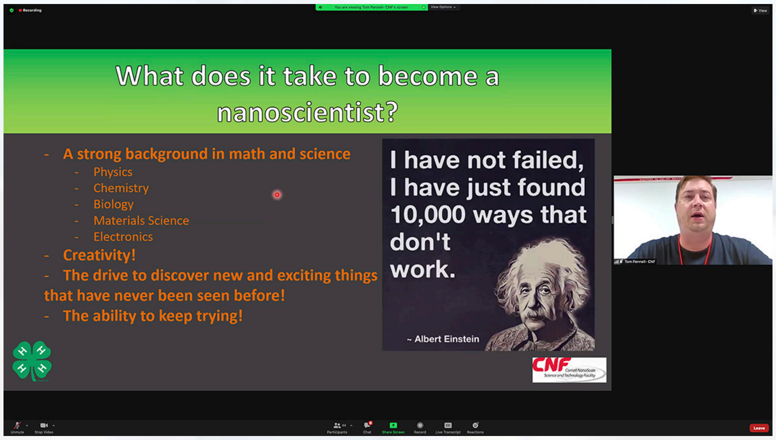
(and out of this world)!

CNF's youth outreach program took part in the national 4-H STEM Summit, teaching junior high and high school students and families from across the United States about nanotechnology and its many applications in space travel. The 4-H STEM summit is an annual event encouraging youth to learn about various STEM fields by meeting with experts in the field and engaging in fun and immersive activities.

This year's theme for the weekend long event was "Galactic Quest" where students designed their own solar sails, took part in a virtual space mission to mars and other exciting activities. Tom Pennell (CNF's Youth Outreach Program Coordinator) introduced the group of 87 middle and high school students from across the country to nanotechnology and explained its important role in interplanetary and interstellar space travel. He also gave students a virtual cleanroom tour and provided them with an at home nano-science activity. This was an energetic group of kids who were excited to learn about the world of nano.

Toward the end of the event, Tom Pennell and Cornell Professor Mason Peck (former NASA Chief Technologist and advisor to the Breakthrough Starshot program) took part in a career panel along with professors from Purdue University and an engineer from SpaceX. The youth in attendance asked a wide range of questions of the panel and were able to learn more about each panelists background and how they got their start in the scientific field.

For more information on CNF's youth outreach program, please contact Tom Pennell at pennell@cnf.cornell.edu.



CNF Sponsors Broadcom Science Challenger Dylan Arouh

Thomas Pennell
Melanie-Claire Mallison

Over the past summer, Tom Pennell was approached through CNF's partnership with 4-H by an educator in Rockland County, NY, about an interesting science project submitted by one of their students. Tom, Amrita Banerjee, and Michael Skvarla worked with young scientist Dylan Arouh, who is now 13-years-old, on his project for the Broadcom Science Challenge (https://www.societyforscience.org/broadcom-masters/); "Mask and You Shall Succeed: Pandemic Science Using "Breakfast of Champions" and Printing Products Sure to Im"PRESS" — What is the Effect of Nanotechnology/ Homemade Ferrofluid on Cleaning up Ocean Oil Spills?"

During the initial phase of the Covid-19 pandemic, Dylan used his passion for science and the environment to tackle the difficult problem of cleaning up oil spills using a very interesting platform: ferrofluids. Ferrofluid is a colloidal liquid containing nanoscale ferromagnetic particles in a carrier solution that exhibits interesting properties in the presence of a magnetic field (Figure 1).

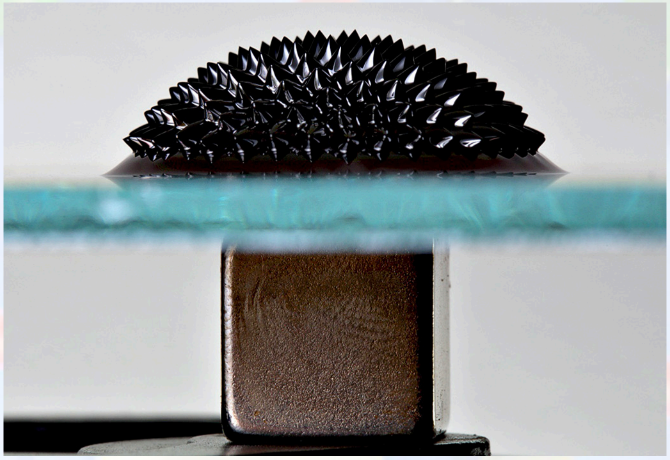


Figure 1: Ferrofluid in the presence of a magnet "Wikipedia"

The first challenge was "where can I find ferromagnetic nanoparticles during a pandemic?" Dylan did his research and harvested his own iron nanoparticles by processing iron fortified breakfast cereal in his kitchen! He also found that printer ink had ferromagnetic particles in it and could create a more homogenous solution. From there he created his ferrofluid and created controlled oil spills on water using mineral oil.

Adding different amounts of his special blend of ferrofluid to the spills he found that he could separate up to 90% of the spilled oil from water using a neodymium magnet housed in the corner of a zip-lock baggy as seen in Figure 2.

"This is such a big accomplishment, and after working so hard — I absolutely couldn't have done it without

Data Summary

Statistic	Control (0 drops)	1 drop	5 drops	10 drops
Average	2.13	1.20	0.69	0.24
Efficiency	15.00%	52.00%	72.50%	90.25%
one-way ANOVA	P < .0001			
Standard Deviation	0.147901995	0.187082869	0.134047566	0.027243118

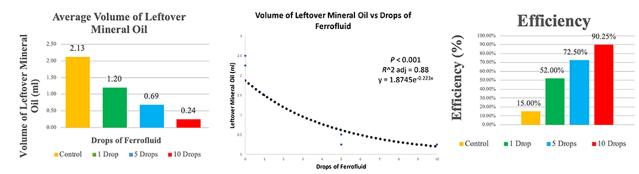


Figure 2: Arouh's data and results.

Tom, your mentorship, and my mom (Dr. Anna Eardley, MD), she's been so supportive and flexible ... you know — a bunch of different people."

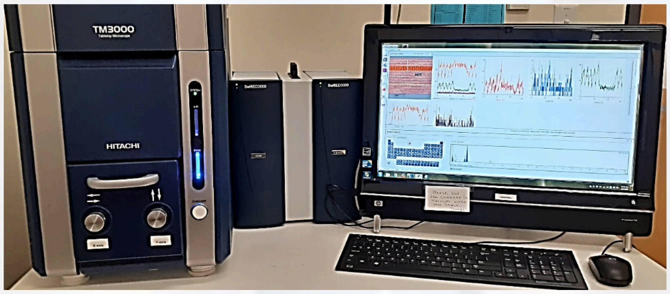
Next Dylan wants to expand upon this success, continue his studies in the environmental nanotechnology field, and consider subsequent steps for the practical application of his research. He's really excited about the many applications of nanotechnology and is currently investigating methods to use nanoparticles to remove microplastics from aquatic environments.

"I definitely want to continue as a young scientist in the nanotechnology field — advocating for the climate. What I find fascinating is you can do so much at such a small scale, and I mean — the power to make such big change in climate change and using nanotechnology to address that. You can just do so much on a small scale!"

We are so proud to be part of Dylan's very innovative work and look forward to seeing what he does next. In fact, CNF gave him a digital wifi-capable microscope to continue his studies and Tom is now supporting him in his endeavors for next year's competition, having also offered to mentor him thru his college years and into graduate studies, should he so choose.

At Cornell University ... and the Cornell NanoScale Facility, of course!

Dylan and his mom Anna. Provided.



SwiftED3000 EDS Installation on Hitachi TM 3000

In November 2020, CNF has acquired the SwiftEDS3000 Energy Dispersive Spectroscopy (EDS) Analysis tool from Oxford Instruments. It has been installed in Hitachi TM 3000. This was made possible in parts by a generous contribution from Cornell Material Science and Engineering department to support MSE undergraduate classes with their SEM imaging and EDS based elemental analysis of materials. The tool is now open to all CNF users and it is the only SEM/ EDS system that accepts biological samples.

EDS analysis provides elemental and chemical analysis of a sample inside SEM. Oxford instrument's EDS systems are well known to gather accurate data at the micro- and nanoscales. SwiftED3000 is equipped with the latest SDD (silicon drift detector). The detector has compact structure and designed to be housed within the main TM3000 unit. All users can take full advantage of the powerful analytical capability including point analysis, line scan, area analysis and element mapping

For more information or tool training, please contact Amrita Banerjee, banerjee@cnf.cornell.edu.

SwiftEDS3000 features and specifications at a glance:

- **Light element detection from boron upwards.**
- **Line scan, mapping and multiple point analysis available.**
- **No liquid nitrogen required. Quick and easy analysis obtained within minutes.**
- **Image and elemental data displayed on the same monitor.**
- **High throughput EDX with Point & ID that analysis of designated point or area is possible.**

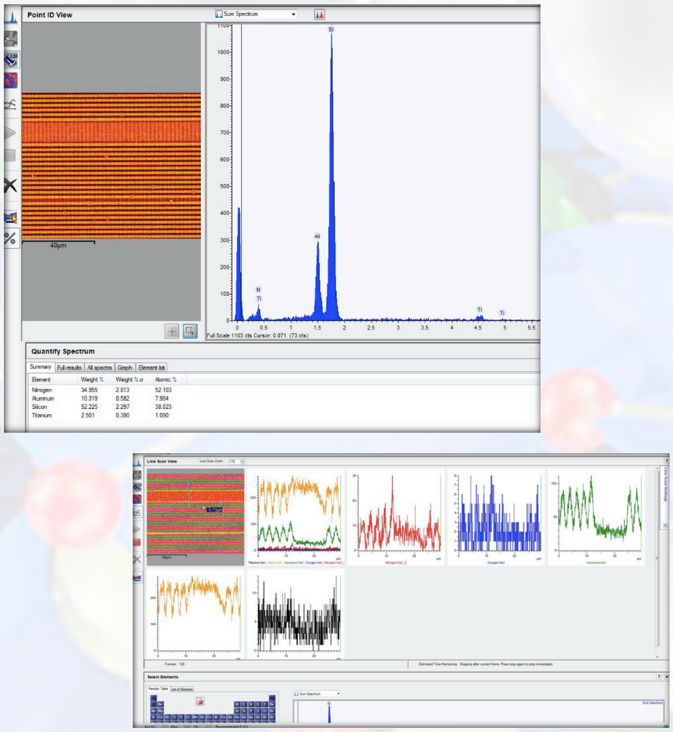
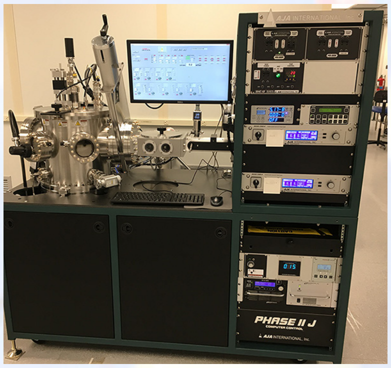


Figure 2: Area Scan of 1 µm wide lines (top) and Line Scan through a specific area (bottom) to monitor quantitative and qualitative analysis of a chip.

AJA Orion 5 System



CNF has installed a third AJA sputter deposition system in the facility. The new AJA Orion 5 system has three 2" diameter guns and can be upgraded to hold up to six 2" diameter guns total. The system has two DC power supplies, enabling users to co-sputter materials and is also capable of depositing magnetic materials. The tool also has an RF supply allowing users to perform i*n situ* substrate cleaning and biased deposition of specific materials.

The Orion 5 will be a category 4 tool, allowing users to deposit materials that are not permitted in the other AJA sputter tools. As an example; this tool will have gold sputtering capability. Other new target materials may be approved by staff upon evaluation of safety, vapor pressure, and other considerations. Targets currently available on the tool include titanium, aluminum, gold, nickel, cobalt and chromium.

Please reach out to Tom Pennell (pennell@cnf.cornell.edu) for further inquiries about the tool and its capabilities.

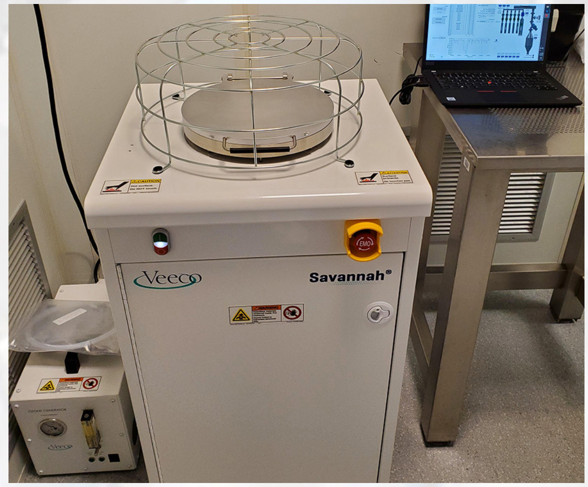
Plasma-Therm Takachi HDPCVD

CNF has completed installation of our new High Density Plasma Chemical Vapor Deposition (HDPCVD) system from Plasma-Therm's Takachi platform. HDPCVD is a special form of PECVD that employs an Inductively Coupled Plasma (ICP) source to generate a higher plasma density than that of a standard parallel plate PECVD system. This higher concentration of reactive species allows for much lower pressures and higher conformality deposition around existing features. Processes for high density, low stress SiO_2, Si_3N_4, a-SiC, and doped a-Si films at low temperatures, ranging from 80°C to 175°C, will all be available. SiO_2 and Si_3N_4 are both ready for use while SiC and and a-Si processes are currently under development.

The system includes an optical emission spectrometer (OES), which can measure photons emitted by the various species in the plasma, providing the elemental composition of the plasma as well as endpoint detection of chamber cleaning. Having this information ensures that the chamber conditions are maintained, resulting in improved run-to-run consistency.

These materials are exceptionally smooth, dense, and conformal; perfect for applications where ALD or PECVD may not be ideal due to rate or temperature limitations. This new system has been installed next to our Oxford PECVD and supports efforts in 2D Materials and Heterointegration, as well as Photonics, Biotech, MEMS and IoT.

For more information or tool training, please contact Jeremy Clark, clark@cnf.cornell.edu



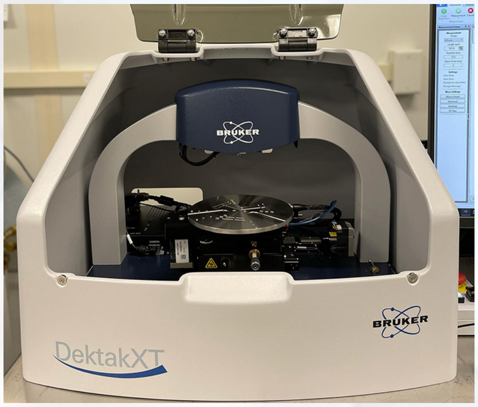
Veeco Savannah S200 for ALD

Veeco's Savannah S200 is CNF's newest Atomic Layer Deposition (ALD) system and has just been installed in the cleanroom. This open load system is capable of depositing very thin and controllable films on sample sizes ranging from small chips up to 200 mm wafers with temperatures ranging from 80°C to 350°C. Processes are available for depositing aluminum oxide and platinium while processes for ruthenium and palladium are under development. Ozone is available for decreasing the temperature required for deposition as well as shortening nucleation delays that can occur with ALD of some materials, including nobel metals such as platinium, ruthenium, and palladium. Hydrogen is also available for certain processes which require reducing metal oxides as part of depositing high quality metals.

Veeco's "Exposure Mode™" is also available, which lengthens the time that samples are exposed to precursors, allowing one to deposit conformal, uniform films on substrates with aspect ratios of greater than 2000:1 and often using less percursor than in traditional constant flow configurations. This allows for coating ALD metal thin films in through-wafer vias, over particles, and even inside channels or capillaries.

Noble metals are typically chosen in nanofabrication due to their resistance to oxidation, low chemical reactivity, and low electrical resistivity. The noble metals are also well known for their catalytic properties and can accelerate or control the rate of many oxidation, reduction, and hydrogenation reactions. Researchers from the groups of Paul McEuen, Itai Cohen, and Nicholas Abbott are already using the catalytic properties of platinium to fabricate nano-actuators for microrobotics and are excited to start using these new materials.

For more information or tool training, please contact Jeremy Clark, clark@cnf.cornell.edu



Bruker Dektak XT Profilometer

The Bruker Dektak XT Profilometer is a stylus profilometer with 4A repeatability. The diamond tipped stylus has a radius of curvature of 2 um, the same you would find on our Tencor P7 Profilometer. The advantages of using this profilometer come from several customization options. First, the sample stage can be easily changed to accommodate small pieces, all the way up to 200mm wafers. Each of these stages come with easy-to-install ball bearings for using the profilometer as a tool to measure film stress after deposition.

The analysis software, Vision64, is highly customizable. The user can create their own scan recipes, analysis workflows, database settings for storing sequential scans, display windows, and sequence recipes. Due to the software's stitching capability, scan lengths can be up to 200mm despite the optical flat being only 50mm wide. 3D map scans, like the penny pictured here, can be easily created with any user-defined horizontal resolution. Finally, automated sequence recipes can be made using either a scatter-point approach, or a grid-based approach. Up too 200 sites can be programmed into a single recipe for an easy way to measure a given feature across the many die printed on a wafer.

For more information or tool training, please contact George (Mac) McMurdy, gm482@cornell.edu

Figure 1: Mac took this screen capture from the Bruker training video series.

Angstrom Engineering Load Lock Evaporator

Since I started at the CNF as a thin film engineer, our cleanroom users have wished to perform their metal depositions quickly, but at base pressures in the 10-7 or 10-8 Torr range. This need for quick, high vacuum depositions led us to purchase a new Angstrom Engineering load lock evaporator.

Like the three AJA sputtering tools current at the CNF, our new Angstrom electron-beam evaporator has a low volume load lock chamber and a linear transfer arm. Substrates up to 150 mm in diameter can be easily transferred into the process chamber without breaking vacuum. This system enables users to achieve high vacuum in a significantly shorter time. The Telemark electron-beam gun has a 6kV power supply, with a programmable two-axis sweep controller and a turret with six, fifteen cubic centimeter pockets (almost twice the pocket volume of the hearths on both the odd/even hour evaporators). Angstrom Engineering's Aeres software will give users full control of not only their depositions but substrate angle and rotation. This evaporator has an automated variable angle deposition (VAD) stage capable of both +/- 170° tilt and rotation motions for glancing angle deposition (GLAD) applications.

The Angstrom evaporator will also be the first deposition tool at the CNF capable of *in-situ* ion beam substrate precleaning and ion assisted depositions. Other unique features on this new evaporator are a dual-crystal QCM rate sensor to extend the periods between breaking vacuum, substrate heating up to 400°C and shutters for both the source and substrate.

The Cornell NanoScale Facility strives to keep up with current research trends and listens to the needs of our user community. We believe that our new Angstrom evaporator will meet most of these needs.

Contact Aaron Windsor with questions or training on this tool, windsor@cnf.cornell.edu

Plasma-Therm had the pleasure of interviewing Ron Olson, Director of Operations at the Cornell Nanoscale Facility (CNF), as well as Vince Genova, CNF research staff scientist focused on Etch & Atomic Layer Deposition (ALD).

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Before his current role, Ron Olson was Manager of the SiC Technology Transfer Team for GE Global Research at SUNY Polytechnic Institute's Power Electronics Manufacturing Consortium (PEMC). He provided technical direction and facilities/operational excellence for high-volume manufacturing for next-generation SiC power semiconductor devices. Olson has worked for more than 32 years in industrial fabrication operations, and process and device development.

Vince Genova began his professional career with the IBM Corporation, spanning over a decade, as a staff engineer/scientist at the East Fishkill Development Laboratory. He was a member of the Yorktown/E. Fishkill Gallium Arsenide MESFET team. He was given the opportunity to return to his alma mater and joined the Cornell Nanofabrication Facility as a research staff member in 1999, where he was responsible for the MEMS Exchange program at CNF until 2005. Currently at CNF, he is active in process development and technical direction for the reactive ion etching (RIE) and atomic layer deposition areas, and assists the facility with projects involving MEMS, Si-CMOS, and advanced III-V based device processing. He serves as the National Nanotechnology Coordinated Infrastructure (NNCI) Etch Working Group leader and has conducted numerous workshops in plasma etching and atomic layer deposition.

What is the Cornell NanoScale Facility?

The Cornell NanoScale Science and Technology Facility (CNF) is one of 16 sites that make up the National Nanotechnology Coordinated Infrastructure (NNCI) — a national user consortium committed to providing researchers from industry and academia with access to facilities equipped with in-house expertise, as well as state-of-the-art fabrication and characterization tools.

CNF serves as an open resource to scientists and engineers from a broad range of nanotechnology areas, with emphasis on providing complex start-to-finish tools centered on the nanofabrication needs of the research community. The research goals of our users are met at CNF by operating an expertly-staffed user program that provides, affordable, hands-on 24/7 open access to an integrated set of advanced nanofabrication tools.

The CNF offers a flexible, uniquely sophisticated toolset with over 180 nanofabrication and characterization instruments together with a track record of enabling successful research projects. Our user program has both regional and national scope, drawing researchers from throughout the USA especially for projects that require particularly challenging multi-step micro- and nanofabrication processes, or access to unique instruments.

CNF continues to be an interdisciplinary facility with activities spread across the physical sciences, engineering, and life sciences. CNF actively seeks to stay at the technology forefront and is responsive to new user requests and research trends.

Every day we play a vital role in the intellectual convergence of many of the emerging engineering and science fields, bringing together researchers who provide clarity and vision to these fields and inspire young and diverse populations of students to pursue STEM studies.

What is the scope of the effort?

CNF, with its 17,000 ft^2 cleanroom, 180+ tools, and the most advanced lithography equipment in the network, serves on average 557 unique researchers/year from industry, government and academic institutions around the world. The average user from outside New York State travels 950 miles.

CNF is arguably the oldest micro/nanofabrication user facility in the country, operating continuously and exclusively as a user facility since 1977.

CNF employs technical management, administrative staff, and a laboratory technical staff who maintain the equipment and baseline processes while assisting users at all levels - particularly focusing on the needs of our user community.

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What kinds of research does CNF enable?

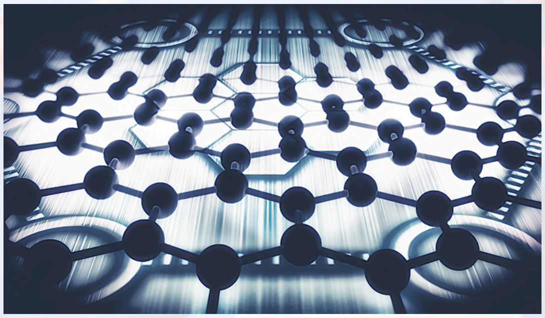
As a user facility, ultimately the activities in CNF are dictated by our users, who believe we are the best place to realize their research goals. It is necessary to plan our activities to align with those areas that best align with significant future research directions, both within the Cornell faculty and elsewhere. Five focused areas have been identified that help guide our future research and efforts. These include Heterointegration, 2-D materials, Biotechnology, Quantum Materials and Devices, and 3D Fabrication and Characterization. We believe these are the areas where CNF can have the most impact.

Heterointegration

The need for connecting and packaging wafers, chips, stacks of chips, electronics and photonics, and other heterogeneous materials has current needs among users and is growing. These can be complicated backend processes that may require highly customized methods include waveguide type interconnects as well as high pinout count packages. We envision increased applications of chips on chips, chips on flexible substrates, electronics on microfluidics, electronics on micromechanical systems, integration of photonics and electronics.

Device Research on 2-D Materials

2-D materials, including graphene and TMDs (transition metal dichalcogenides), have become increasingly important technologically, and increasingly of interest to CNF researchers. Cornell is also rapidly becoming a national center of activities in 2D materials. Thin film 2D materials are enabling both electronic structures with dramatic new electron, photon, and polariton properties and micromechanical structures based on graphene.



Increased Complexity in Biotechnology

For most of its 45 years, CNF has been a pioneer in the application of nanotechnology to the life sciences. Major activities include a variety of sensors and microfluidic devices. A new initiative in digital agriculture and the maturation of μfluidic chip technology make ripe the timing for more sophisticated tools and toolkits for biologists to engage in engineering projects to advance their research.

Materials and Processes for Quantum Devices

Fabricating and understanding a broad array of new materials provide the basis for advances in quantum information systems supporting a national imperative. CNF provides nanofabrication support to the new quantum materials and devices being designed and investigated nationally.

3D Fabrication and Characterization

Traditionally, micro- and nano- fabrication have focused on thin film structures. New capabilities for 3D fabrication and characterization needed to meet the demand of the electronics, photonics, and life sciences communities are now available to users through our partnership with the Rapid Prototyping Lab in the Mechanical Engineering Department and the Cornell Institute of Biotechnology (Biotech).

Highlights of CNF-enabled research include:

- Origami-like 2D self-actuating microdevices
- Nano-optical structures for rapidly sequencing the genome
- Microfluidics that reveal information about cancer cell migration
- Distributed sensors for digital agriculture
- New meta-material flat optics focused with artificial muscles
- Quantum-entangled devices to usher in a new age of computing
- New nanosystems for more efficient energy creation

In each case, access to our tools, methods, and expertise has been critical to realizing a distinct research vision.

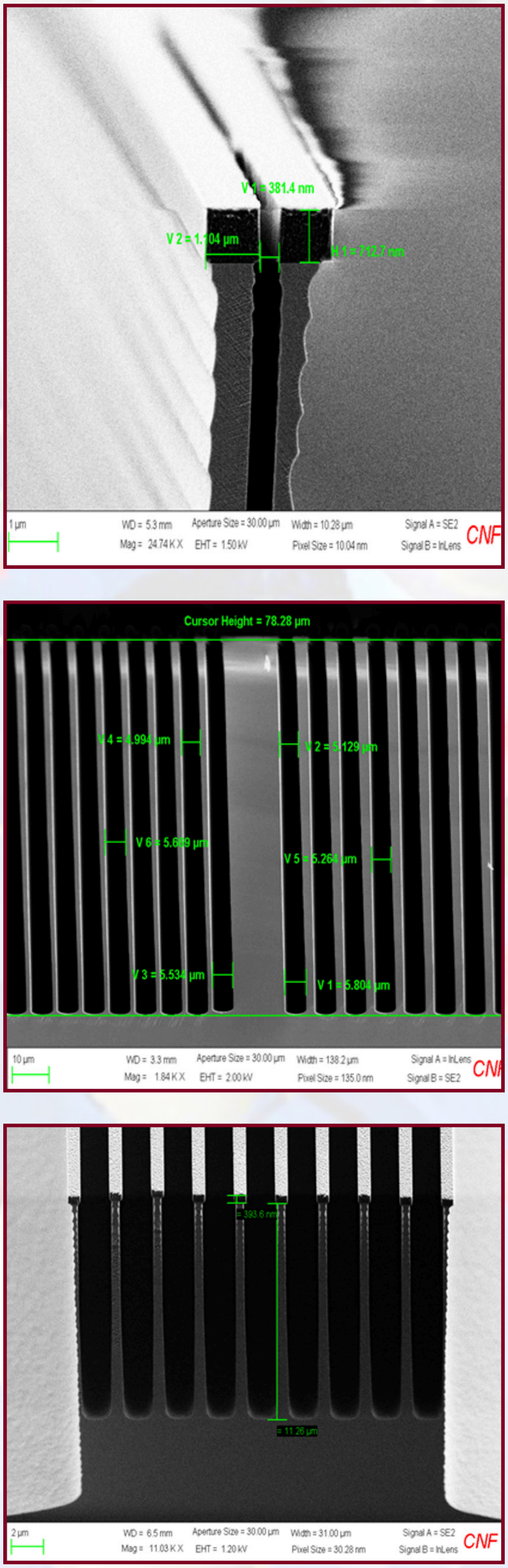
How do plasma processes such as dry etch and deposition contribute to your research?

Plasma etching is essential to the successful fabrication of many micro and nanoscale devices in electronics, photonics, MEMS, and quantum technology. Here at CNF, we have a plethora of etch systems, many of which are state-of-the-art, ICP-based, high-density plasma systems. That includes our latest Atomic Layer Etch system from Plasma-Therm. ALE produces highly anisotropic profiles with precise termination of the etch at a critical interface with little or no damage and preservation of surface stoichiometry.

Other benefits of ALE include etched wafer non-uniformities to less than 1%, along with pattern-independent based etching and high selectivity to an underlying layer. The ability to etch materials with resulting atomically smooth and flat surfaces can be extended to a wide variety of device applications in silicon, III-Vs, and 2D materials.

In the area of photonics, the fabrication of both passive and active optical devices is highly dependent on plasma etching to achieve perfectly anisotropic and smooth sidewalls for high quality low loss devices. We have been very successful in etching both dielectric and silicon-based waveguides, as well as active elements etched in both GaN and GaAs.

MEMS technology relies heavily on a few different etch strategies, one of the most important being deep reactive ion etching (DRIE). Here at CNF, we are fortunate to have two DRIE systems from Plasma-Therm. The time-multiplexed process allows us to fabricate devices in bulk silicon and bulk germanium. Those structures etched in Ge have been applied to the fabrication of x-ray optics used by Cornell's High Energy Synchrotron Source (CHESS). CNF is also actively involved in piezo-MEMS research, which relies heavily on the etching of AlN and AlScN.



TOP: Deep silicon etch of DUV/e-beam lithography hybrid: 32:1 gap aspect ratio. MIDDLE: Deep Ge etch with Plasma-Therm's Versaline — smooth sidewalls with 78 µm depth. BOTTOM: Deep silicon etch in PT SLR ICP using nanoimprint lithography (800 nm lines, 14:1 aspect ratio).

The fabrication of silicon, III-V and SiC based electronic devices requires an effective and highly specific etch strategy. This is especially appropriate in the fabrication of AlGaN/GaN HEMT enhancement mode lateral devices where the removal of AlGaN in the gate recess step is needed to carefully tune the threshold voltage. Care is needed to etch the AlGaN in a damage free manner so as to not degrade transistor mobility. These objectives are quite suitable for the application of ALE. For advanced silicon-based devices, the fabrication of through-silicon-vias (TSVs) is dependent on a customized high-quality deep silicon etches. In the area of silicon carbide devices, CNF has developed a smooth perfectly anisotropic SiC etch free of artifacts such as microtrenching, which are detrimental to device performance.

Plasma-based deposition systems are critical for the successful fabrication of devices in many technological areas. CNF has recently installed an HDPCVD system from Plasma-Therm. This ICP-based system will allow researchers to deposit films at low temperatures (80-150°C) for BEOL and thermal budget-limited devices. This system will also enable superior trench fill capability especially at high aspect ratios. This system is vital for fabricating electronic and photonic based devices. CNF is fortunate to have state of the art plasma enhanced atomic layer deposition (PEALD) for the formation of high quality thin high-k dielectric films. Films such as HfO_2, Ta_2O_5, and TaN are essential in the development of advanced transistor devices.

A key addition for the successful development of piezo-MEMS devices is CNF's OEM AlN deposition system. Plasma-Therm has recently acquired this technology from OEM. This dedicated AlN and AlScN system allows us to deposit high-quality, low-stress crystalline films.

Plasma etch and deposition technology are key wafer processing solutions for Quantum Information Processing and Quantum Sensing Devices. The formation of high-quality nitrides such as AlN and NbN via ALD are essential for high-performance Qubits and resonators. Effective etch processes are also needed for superconducting metals such as Al and Nb, along with Josephson Junction barrier layers such as Al_2O_3, AlN, and others. Smooth sidewalls free of residue with great profile control ensure surfaces of minimal loss. Quantum photonic components require ultra-smooth waveguide etches for low losses. TSVs enable 3D integration along with scaling to a larger number of Qubits.

CNF has developed and continues to develop process solutions for these quantum-based process issues.

Plasma-Therm

Ron Olson

Thoughts on our summer program from our interns … from left to right….

2021 CNF REU Intern Kareena Dash; Learning how to establish myself as a confident researcher was a critical skill the CNF REU taught me, as I was able to integrate myself in a research environment with professionals, students, & faculty who were open to sharing their knowledge & experience with me.

2021 "Adoptee" Francesca Bard; Over the summer, I did research with the Ober group on creating new photoresist material for DUV photolithography. It was really exciting to work in the cleanroom and learn from the very supportive CNF staff and group members!!

2021 CNF REU Intern Niaa Jenkins-Johnston; It was so exciting to work with microfluidic devices and breast cancer cells this summer. I really enjoyed getting to apply concepts covered from my Biomedical Engineering coursework as well as learning about new tools and improving upon my interpersonal and technical skills.

2021 CNF REU Intern Zhangqi Zheng; This summer at CNF was one of the most rewarding ones. She enjoyed working in the cleanroom & appreciates all the research skills she learned. She cannot be more excited about continuing to work on her CNF projects in future semesters.

2021 CNF REU Intern Elisabeth Wang; I had a fantastic internship experience. I learned so many new skills using the tools in the Cornell NanoScale Facility, and my project about studying cancer cell migration helped me realize some of the fascinating applications and possibilities for micro- and nanotechnology.

An Even Smaller Nanoscale McGraw Tower Now Features the Infamous Pumpkin

Mark H. Anbinder
October 29, 2021
14850 Magazine (Abridged)

This past spring, Ed Camacho, a photolithographer at the Cornell NanoScale Science and Technology Facility, led a team that created a scale model of Cornell's iconic McGraw Tower that's just a millimeter tall.

Now, just in time for Halloween, he's followed up that feat with an even smaller model that includes the infamous pumpkin that pranksters placed atop the McGraw Tower on October 8th, 1997. At the time, no one knew why, or how, it had gotten there.

"In fact, for a while, no one even knew — for sure — if it was a pumpkin," says a 2017 NPR article. It ultimately fell from its perch the following March, as campus officials prepared to remove it, but it has remained in Cornell lore.

In May, the Cornell NanoScale Facility (CNF) said the "achievement of epic proportions was accomplished using one of CNF's newest tools: the NanoScribe GT2 Laser Lithography System, a two-photon polymerization volumetric 3D printer."

According to CNF, "the state-of-the-art NanoScribe GT2 can create 3D nanostructures using a near infrared, femtosecond laser via direct-write onto a photosensitive resin."

The NanoScribe GT2 has the same basic idea as consumer 3D printers, which hobbyists can use to make figurines or toys, or industrial 3D printers, which might make false teeth, or scale models of cars or ships. On a large scale, 3D printers can even be used to build a house or a bridge.

Back in the spring, Camacho told 14850 Magazine that he planned on "pushing the envelope" of the NanoScribe GT2 on an "even smaller, higher-resolution print with more of McGraw Tower's fine detail." The goal of that project was to 3D print a 200-micron-tall clock tower, just a fifth the size of the current nanoscale model.

That's what the team accomplished this fall, but Camacho decided to add one extra detail to the new model — the mystery pumpkin atop the McGraw Tower spire that caught the world's attention in 1997 — and Camacho added a jack-o'-lantern face to his mystery pumpkin.

The appeal of the Mystery Pumpkin lives on!

Figure 1, left: On a bright day in October 1997, the impaled pumpkin sits atop McGraw Tower. Right: In October 2021, a full-color rendering of Camacho's CAD model shows its intricate detail.

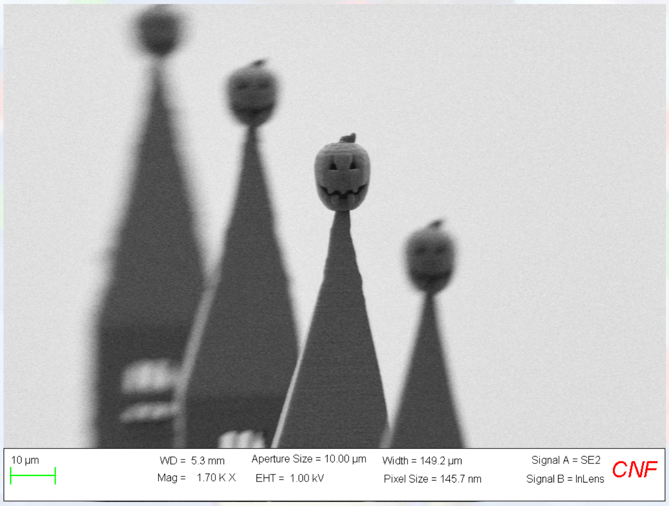


Figure 2: Camacho says he printed four of the new 200-micron scale models, complete with pumpkin. Each took about 19 minutes on the NanoScribe GT2. (See back cover of this issue of the NanoMeter.)

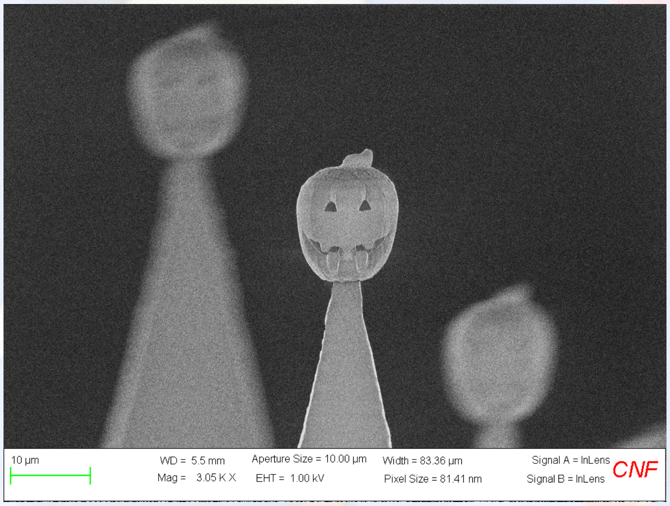


Figure 3: Close up of Camacho's Jack-o-Lantern. (See front cover of this issue of the NanoMeter.) These SEMs were taken by fellow tech staff member John Treichler.


10 µm
Width = 342.8 µm
Pixel Size = 334.8 nm