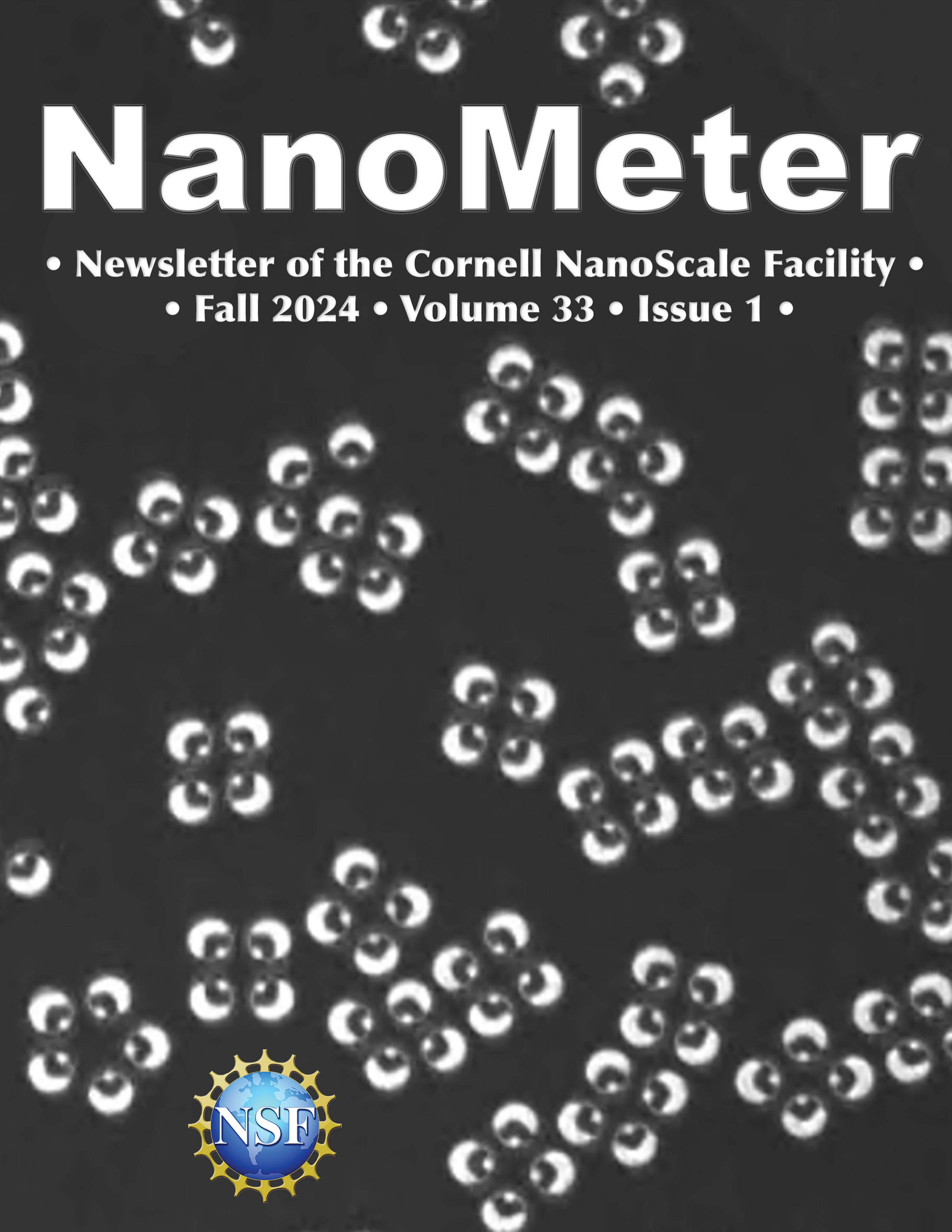
NanoMeter

• Newsletter of the Cornell NanoScale Facility •
• Fall 2024 • Volume 33 • Issue 1 •



In This Issue...

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The cover image for this issue is from Melody Lim's research — see page 10. The rest of the graphics and photographs come from CNF staff, Cornell Chronicle, University Photo and "provided". The NanoMeter is formatted by Melanie-Claire Mallison.

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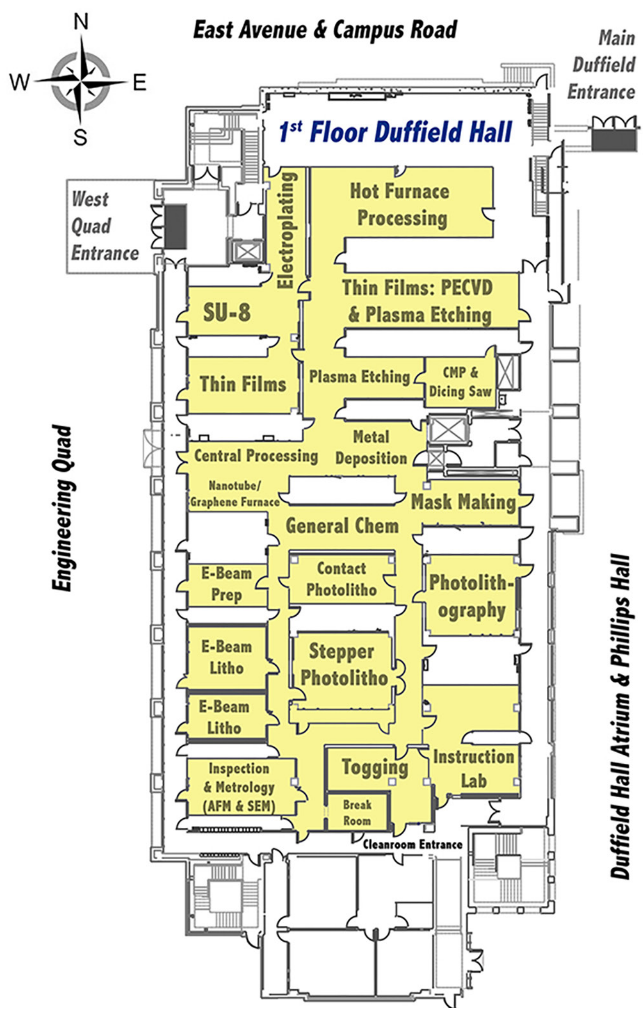


:: DIRECTORS' COLUMN ::

"The moment we believe that success is determined by an ingrained level of ability as opposed to resilience and hard work, we will be brittle in the face of adversity."

~ Joshua Waitzkin

INTRODUCTION

The 2023-2024 year at the Cornell NanoScale Facility (CNF) was marked by a series of unique challenges that tested our resilience and adaptability. Throughout this period, our commitment to maintaining excellence and supporting our community remained steadfast.

This year, we needed to adapt to a temporary adjustment in our cleanroom schedule due to compliance issues raised by New York State's updated building codes and subsequent enforcement. From October 10, 2023 until April 1, 2024 the CNF cleanroom operated under a reduced schedule. The technical staff at CNF, as well as other key individuals who support CNF, contributed hours above and beyond their normal work schedules in order to keep the CNF open and operational.

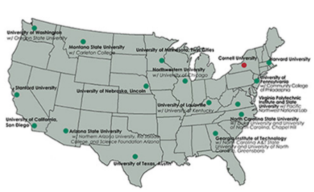
We would like to extend our gratitude to the CNF staff as well as Brian Bowman, Steve Button, Kyle VanDelden and Marcus Gingerich. The dedication and exceptional work ethics demonstrated by these individuals were instrumental in navigating critical challenges. The willingness to embrace additional responsibilities and go "above and beyond" defined roles was exemplary.

To our valued users, we remain committed to supporting your work and ensuring the highest standards of service. We deeply appreciate the patience and understanding you extended during this period given the many restrictions. Thank you for your ongoing support and being an integral part of our community.

NNCI

The CNF is excited to maintain its membership within the National Nanotechnology Coordinated Infrastructure (NNCI), supported by the National Science Foundation (NSF) and the New York State NYSTAR/ESD Matching Grant Program.

National Nanotechnology Coordinated Infrastructure



This ongoing relationship is crucial for maintaining CNF's leadership in the field of nanofabrication. Cornell is one of 16 collaborative NNCI sites within the national user consortium, dedicated to delivering cutting-edge fabrication and characterization tools and services to a diverse range of users from both academia and industry. Earlier this year the CNF submitted "The Year 9 Annual Report" and actively engaged in a successful virtual, reverse site visit, reaffirming our commitment to our cooperative agreement with the NNCI. With the anticipated conclusion of the current National Nanotechnology Coordinated Infrastructure (NNCI) award on 8/31/2025, the CNF is looking to the future and the next nanotechnology infrastructure.

NNN

CNF continues to lead the NYS Nanotechnology Network (NNN). The 2024 NNN Symposium was hosted by the Rochester Institute of Technology (RIT) on September 27, with the topic "Growing the Semiconductor Workforce"—and included presentations by students and industry members, a panel discussion, a poster session, and a career fair. And of course, meals and opportunities to network.

NNN New York State Nanotechnology Network

A 'shout out' to our student poster award winners — Lilian Neim, Olya Noruz Shamsian, Dmitry Shinyavskiy, Jeelka Solanki, and Natalie Williams. Congratulations to you all! Good work!!

STAFF UPDATES

Departures:

In February 2024, George (Mac) McMurdy — who arrived at the CNF in 2019 — departed for a new position at MIT Lincoln Laboratory. A graduate of RIT, George contributed significantly to our team during his tenure.

After 28 years of dedicated and methodical service to CNF, Melanie-Claire Mallison is retiring! Wednesday, October 2nd is her last day. We wish her well in this new chapter of her life, and know she will enjoy many good times with her delightful grandchildren.

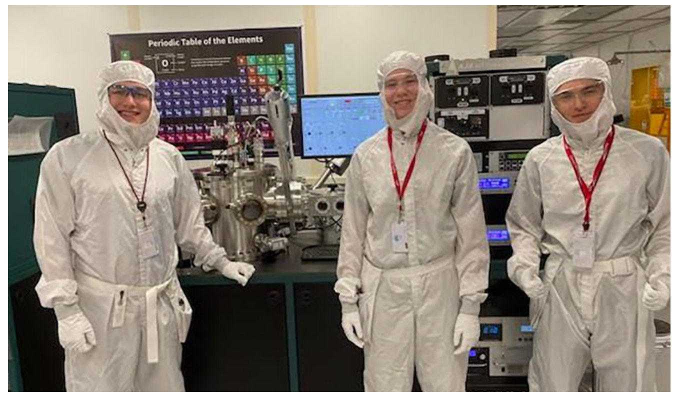
Welcome:

In January 2024 Professor Allison Godwin, professor of Chemical Engineering, was appointed as Associate Director for Workforce Development. She joined Cornell in 2023 from a faculty position at Purdue University. Her research specialty is Engineering Education. As Associate Director, she will support and expand CNF's growing workforce development programs in support of both NNCI and other programs.

In March 2024, Paul Pelletier returned to CNF after serving as the Director of Facilities at Odyssey Semiconductor, a local power semiconductor start-up. As previously with CNF from 2004 to 2014, Paul will focus on thin film processing and tool installations. His timely return will be beneficial as CNF progresses with the ME Commons equipment installations.

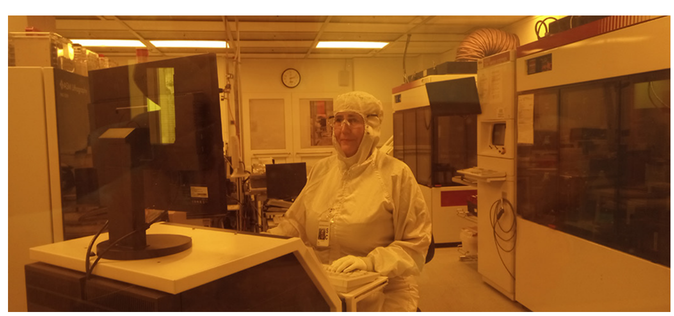
INTERNS

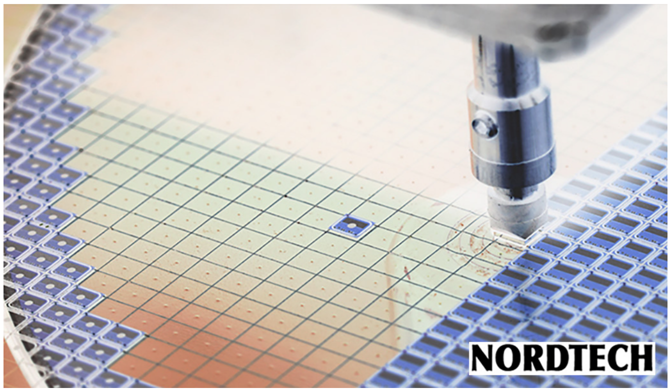
This year CNF hosted four summer interns supported by NORDTECH workforce development funds — Ben Infante, Elyas Talda, Julius Won, and David Syracuse. Ben, Julius, and Elyas (pictured below) maintained necessary chemicals and supplies for the cleanroom, received hands-on tool training, executed routine processes, and characterized etch recipes on RIE tools. They also installed compressed air lines, assisted with orbital welding, and observed equipment setup. CNF staff members Phil Infante, Tom Pennell and Jeremy Clark assumed training and mentoring roles. As a third-year intern, Ben was responsible for leading and helping Elyas and Julius through the processes.



Summer intern David Syracuse, a BOCES New Visions Engineering teacher, focused on education/outreach and workforce development activities as part of the ME Commons Program. David took an active role in CNF outreach activities.

Sherri Ellis' internship, supported by a FuSe proposal, provided her with the opportunity to work with Cornell graduate student, Rachel Wang. Their work focused primarily on investigation of new lithography materials, associated fabrication processes and characterization for directed, self-assembly plus extreme ultraviolet lithography. CNF staff members Dr. Giovanni Sartorello and Garry Bordonaro assumed training and mentoring roles for Sherri to insure she developed the necessary processing skills required to assist with this project. The skills acquired and the experience garnered will pose Sherri (pictured below) for a technician role in the semiconductor industry.





NEW EQUIPMENT AND CAPABILITIES

In 2023, the Department of Defense launched the Microelectronics (ME) Commons Hub program, funded at $2 billion over five years through the CHIPS and Science Act. The program aims to enhance U.S. microelectronics development and manufacturing and support DOD mission priorities by facilitating the transition from research to production.

In late 2023, eight ME Commons hubs were created through a national competition. Cornell is a founding partner of NORDTECH, the Northeast Regional Defense Technology Hub, alongside IBM, SUNY-CNSE, NY CREATES, NYU, and RPI.

Cornell was awarded funds for new capital equipment. A significant portion of the Cornell funding was earmarked to support the Quantum Science and heterointegration technology and ensure capabilities for 200 mm wafer processing. Funding for the new equipment, which represents the largest capital expansion of CNF since its establishment in 1977, was provided by the U.S. Department of Defense ME Commons program through NORDTECH.

New tools scheduled to arrive by the end of the year include: Keyence VHX7100 Digital Inspection Microscope (available now), Heidelberg MLA150-Maskless Photolithography System (arriving in October), 200 mm Zeiss Gemini 560 Scanning Electron Microscope, (arriving in October) Osiris Temporary Bonding/Debonding System (arriving in October), Yield Engineering PB8 Polymide Cure Oven (already here), Logitech Orbis 200 mm hardware kit for Chemical Mechanical Polishing of 200 mm wafers and a Nano-Master SWC-4000 (post-CMP brush cleaner).

Equipment arriving in early 2025 include: a 200-mm-capable Oxford PlasmaPro ASP Atomic Layer Deposition system specifically for superconducting materials and nitride materials; a Angstrom UHV Evaporator and Oxidation System designed to deposit quantum qubit PVD thin materials, it has *in-situ* oxidation capabilities to directly form Josephson junctions *in-situ*; a versatile AJA Orion 8 UHV Sputtering System designed for quantum projects, including Josephson junction deposition, hot sputtering for refractory metal superconductor films (Ta, Nb), and deposition of nitride films for magnetic field-compatible superinductance; a SEKI Diamond CVD System that will be utilized in the growth of diamond quantum technology materials; a Disco Wafer Back Grinder with 200 mm capability; a Plasma-Therm Plasma Dicing/Singulation tool; an Oxford PlasmaPro 100 Cobra 300 Deep Oxide/Diamond Etcher (ICP RIE); a KLA-SPTS high-temperature vapor XeF_2 etch system; and a custom ReynoldsTech 200 mm-capable Electroplating System that supports indium and Sn/Ag/Cu plating.

In addition to the NORDTECH equipment listed above, the CNF will also be getting a new Fiji XT cluster system configured with dedicated ALD and ALE chambers. The Jena-Xing group was awarded funding for this system by the US Department of Defense (DoD) under the Defense University Research Instrumentation Program (DURIP). Initial baseline process will be focused on the deposition of AlN, TiN, SiN, HfO_2, $BaTiO_3$, and Ruthenium while initial thermal and plasma ALE processes will be focused on AlGaN, and GaN. This tool is scheduled to arrive in early 2025.

On August 2, 2024, the CNF received the new AJA system which will be exclusively dedicated to deposition of superconducting films for quantum device applications. Facilities work is in progress for the installation of this tool.

The beginning of 2024 was marked by the installation of a long-awaited upgrade to the CNF lab management software. The previous 20-year-old system (CORAL) was successfully replaced with NEMO, an intuitive and user-friendly laboratory logistics software suite developed by NIST. NEMO is designed to manage tool reservations, enable and disable tools, track usage, and facilitate the billing of user charges. To ensure a smooth transition to the new software, the staff performed training sessions for users.

THE 2024 SUMMER PROGRAMS AT CNF AND NIMS!

For thirty-four years, CNF has hosted a National Science Foundation-Funded Research Experiences for Undergraduates (REU) Program.

The CNF REU Program is a hands-on, immersive ten-week summer research program for exceptional undergraduates selected from a diverse, highly talented pool of applicants. To date over 335 students have participated in the CNF REU programs.

This year, the CNF supported six undergraduates in the CNF REU Program and specifically worked with the Cornell College of Engineering to support a Morgan State University CNF REU student. In addition, we incorporated four undergraduates hired via Prof. H. Grace Xing's Army Educational Outreach Program (AEOP). To assist several smaller summer programs on campus, we managed the logistics for five additional students including two hosted by our new Associated Director, Prof. Allison Godwin.

Additionally, seven students from the 2023 NNCI REU class and four students from the NNCI Global Quantum Leap Program traveled to Japan to work with our partners at the National Institute for Materials Science (NIMS) in Tsukuba.

These competitive programs provided unique learning opportunities for all who participated.

Final student reports and videos can be found online at https://www.cnf.cornell.edu/education/reu/2024

WORKFORCE DEVELOPMENT, EDUCATION AND OUTREACH

It has been an impactful year for CNF's Education, Outreach and Workforce Development (EWD) programs that reached over 5,000 individuals primarily from the K-12 demographic. Public engagement in nanotechnology will continue to be a key tenet of the CNF's efforts to help expand the future workforce of Central New York and beyond.

A core principle of the EWD program at CNF is community engagement; an effort that requires regional involvement. The CNF established several key partnerships allowing for a more expansive outreach initiative. Working closely with Tompkins Cortland Community College (TC3) on several programs to connect with the community at large, the Microfabrication and Nanotechnology Certificate Program for Veterans and their dependents began in August 2024. This new program allows Veterans and their dependents to immerse themselves in an exciting 12-week course. During this time direct access is provided to leading semiconductor manufacturers (Micron, Global Foundries, Menlo Microsystems, etc.) with the intention of providing exposure to various career opportunities in the industry. This program is in partnership with Penn State University and is funded by the National Science Foundation (NSF).

The CNF has been working in support of TC3 by assisting with equipment acquisition and curriculum development focused on semiconductor education. The CNF looks forward to completion of a dedicated classroom space on TC3's campus in Dryden, NY; just 20 minutes from the Cornell campus.

A partnership with the New York State Board of Cooperative Educational Services (BOCES) has proven to be a valued relationship within the greater community. BOCES continues to serve high school districts in NYS by providing Career and Technical Education (CTE) for high school Juniors and Seniors. The CNF first launched the ATLAS program for the New Visions Engineering program of Tompkins, Seneca, and Tioga BOCES (TST BOCES) in 2023. Due to the program's positive reception the CNF offered an additional two-week immersive program in 2024. Two 2023 participants were selected to returned to CNF as REU students and two from the 2024 cohort returned as CNF summer interns. The interest and participation in these programs both demonstrate the success of early outreach and its ability to spark interest in the in young students.

Again, partnering with TST BOCES as well as Swagelok Inc. the CNF helped to create an Ultra High Purity (UHP) welding program for high school seniors already enrolled in the welding program offered at their respective high schools. The CNF and Swagelok staff went into the classroom to teach students about the relevance of this important technique to the expanding industry in the local area. Students learned how to measure, cut, bend, weld and leak check the stainless-steel tubing critical for the infrastructure in semiconductor manufacturing facilities. The course culminated in a visit to the CNF where students received an in-person facility tour providing further exposure to nanotechnology career paths.

To support the expansion of this program, nine CNY BOCES welding instructors were certified in orbital welding by Swagelok in August 2024. As a result, these instructors can now incorporate Ultra High Purity (UHP) welding into their curriculum.

Additional workforce development efforts include collaboration with the Cornell Center for Teaching Innovation (CTI) to develop an exciting, virtual reality semiconductor educational platform. This new content will allow students with a Wi-Fi connection to connect face-to-face with CNF staff. This immersive educational experience has the potential to join students from around the world with experts in the CNF cleanroom. Focusing on the core principles and toolsets of the cleanroom environment, the objective is to expand Cornell NanoScale Facility's educational reach beyond the walls of the cleanroom.

WE ARE GRATEFUL FOR EVERYTHING OUR USERS HAVE DONE TO AID IN OUR SUCCESS.

WE WELCOME YOUR COMMENTS AND QUESTIONS.

Judy Cha, Lester B. Knight Director
director@cnf.cornell.edu

Allison Godwin, Associate Director
godwin@cnf.cornell.edu

Ron Olson, Director of Operations
olson@cnf.cornell.edu

2023 CNF ANNUAL MEETING

Many thanks to those who took part in the 2023 CNF Annual Meeting! It was a really fun, informative, and delicious day! Thank you especially to our keynote speaker Dr. Sophie V. Vandebroek, Founder and Owner of Strategic Vision Ventures, LLC, and all our other invited speakers. Find our speaker list, proceedings and photograph album online at https://www.cnf.cornell.edu/events/past/annual_meetings/2023

Please join us in congratulating our student award winners, pictured below!

2023 CNF ANNUAL MEETING BEST USER POSTER AWARDS

Gustavo Alvarez; "Cross-Plane Thermal Conductivity of h-BN Thin Films Grown by Pulsed Laser Deposition"

Ludovico Cestarollo; "Controlling Actuation at the Microscale: MEMS-Inspired Device with Magnetic-Field Driven Actuation"

Fei Yu; "Patternable Mesoporous TF Superconductors via Block Copolymer Self-Assembly: An Emergent Technology toward Quantum Metamaterials?"

2023 CNF ANNUAL MEETING BEST USER PRESENTATION AWARD

Wenwen Zhao; "Temperature Dependent Properties of Ku-Band Epitaxial AlN FBARs"

2023 CORNING INCORPORATED BEST USER PRESENTATION AWARD

Hanyu Alice Zhang; "Chemically Driven Palladium Based Actuators"

2023 CNF ANNUAL MEETING NELLIE YEH-POH LIN WHETTEN MEMORIAL AWARD

Melody Lim; "Programmable Nanomagnets for Microscopic Self-Assembly" **(see her profile on page 10)**

The 2023 CNF Annual Meeting was supported by the following

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2023 Nellie Yeh-Poh Lin Whetten Memorial Award Profile:

MELODY LIM

Melody Xuan Lim is currently a Postdoctoral Fellow in the Kavli Institute and Department of Physics at Cornell University, and is the 2023 recipient of the 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, professional and personal courtesy, and exuberance for life (see page 12 for the full award description).

Melody received her Bachelor's degree from Duke University in 2016, and her Ph.D. in Physics from the University of Chicago in 2022. Her research is focused around new experimental platforms for the self-assembly of dynamic structures, particularly those with the ability to manipulate and program complex functions.

Self-assembly is a process by which a set of components spontaneously forms an organized structure. These components (which are pre-designed) form this final structure by means of inter-component interactions, rather than external intervention (i.e. without direct manipulation of the components into the correct relative position). Self-assembly is thus both an interesting field of scientific inquiry (what physics governs the assembly of dynamic structures?), as well as a challenging engineering problem (how can we program interactions to make one structure, without mistakes?).

In her doctoral work, Melody explored these themes by developing a new experimental platform for the manipulation and assembly of millimeter-sized particles: acoustic levitation. In these experiments, particles are suspended in an intense ultrasound field, allowing for their observation without the interference of solid boundaries. In addition, scattered sound from levitated particles establishes attractive interactions between levitated particles, creating forces that draw particles together. These experiments served as a useful model system for the assembly of small clusters of particles, and opened possibilities for creating dynamic, tunable acoustic materials.

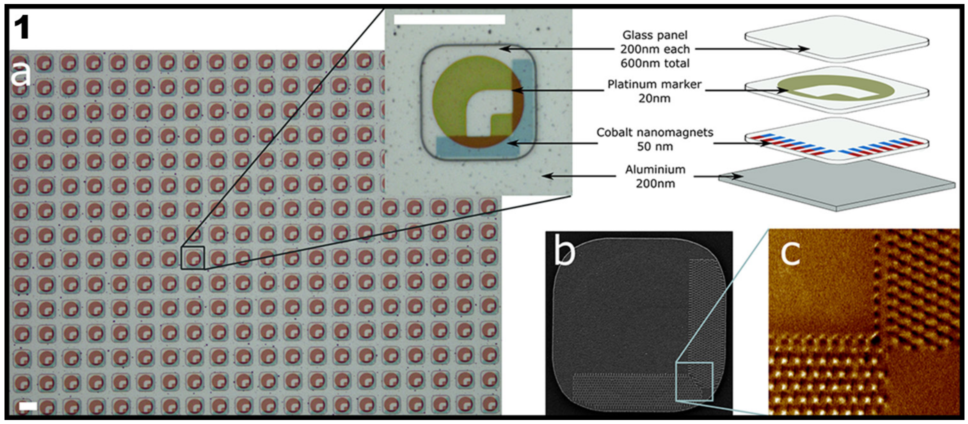
In her postdoctoral work at Cornell, Melody has extended these themes to the micro- and nanoscale, where there are many more options for directing the assembly of dynamic structures. One possibility is to fabricate particles that are precisely patterned with magnetic patches. Magnetic interactions have the inherent advantage that they are long-ranged, such that forces can be significant several particle-lengths away. They do not require particular solvents or chemical environments to function, and can additionally be manipulated from a distance with an external magnetic field. Crucially, since magnets are inherently dipolar, patterning a group of magnets with a particular sequence of north and south poles will ensure that the attractive force is strongest only when it meets a complementary sequence of magnets. These attributes — long-range, selective interactions, that enable actuation at a distance, make magnetic materials a promising candidate for the self-assembly of complex, dynamic, functional microstructures.

These particles can be entirely fabricated at the Cornell NanoScale Facility (see Figure 1 for device schematic).

On top of a silicon wafer and aluminum/aluminum oxide sacrificial layer, single-domain cobalt nanomagnets are fabricated using electron-beam lithography, and metallized by liftoff. These nanomagnets are then embedded in silicon oxide thin films, whose shape and size are precisely patterned by a deep-ultraviolet (DUV) stepper. The combination of photolithography and electro-beam lithography allows for the creation of magnetic devices where the strength and shape of the magnetic interaction, placement of magnets, and contact interactions from the silicon oxide panel can all be harnessed to design a landscape for magnetic self-assembly.

One particular goal is to self-assemble structures that terminate at a finite size, rather than growing indefinitely. Such structures require a mechanism to detect when a cluster of a specific size is formed, and to prevent larger clusters from growing.

One possibility, which Melody has been working on, relies on the aforementioned programmable magnetic interactions.



The strategy leverages the fact that the net moment of a magnetically assembled cluster is the vector sum of the constituent moments. If a completed cluster is thus designed to have no net magnetic moment, it spontaneously decouples from external magnetic driving. This spontaneous decoupling ensures that once a cluster is fully formed, it achieves stability and ceases to interact with the external driving field. Consequently, this halts the cluster's growth at a specific size, while other magnetically driven particles remain actively engaged in mixing and assembly (see Figure 2 for schematic).

Widening the design space to include more magnetic directions will greatly increase the complexity of structures that can be assembled. In addition, the low bending stiffness of atomically thin ALD films can be exploited to create magnetic elastic devices — the beginnings of a magnetic micromachine. Melody looks forward to leveraging these ideas to generate complex structures, particularly those that harness energy from external magnetic fields to perform useful functions.

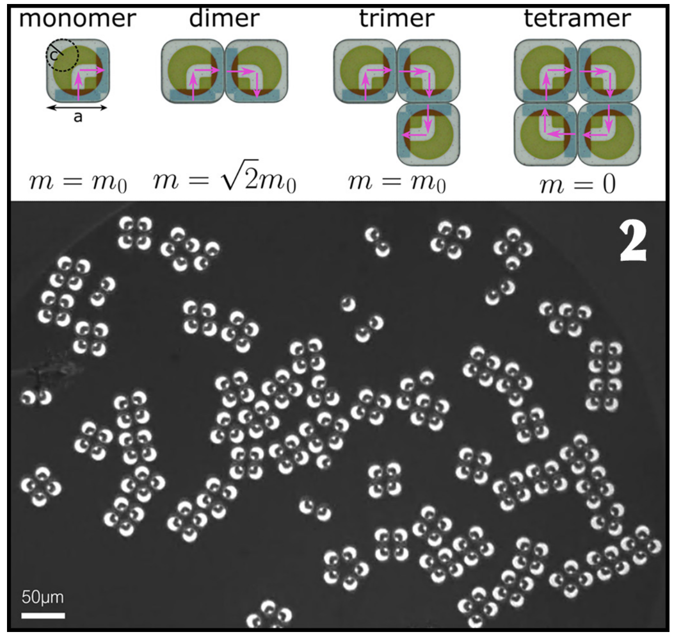
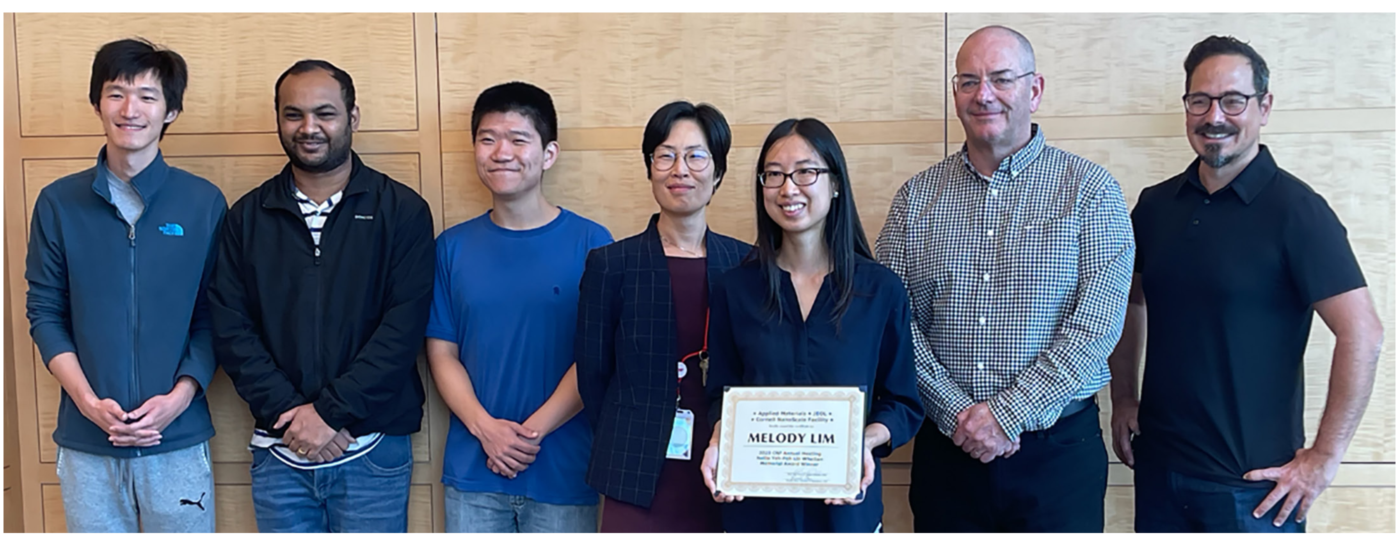


Figure 1, top: Highly parallel nanofabrication of magnetic particles. (a) Particles are created in massive parallel by photolithography. Device layer schematic shown in inset. (b) SEM image of a single particle, showing the arrays of single-domain nanomagnets (defined by electron-beam lithography). (c) Magnetic force microscopy image of magnetic domains, showing the single-domain magnetic structure.

Figure 2, bottom: Designing self-limiting magnetic assembly by spontaneous decoupling. (a) Designed reaction scheme for a self-limiting cluster of four particles. When the final structure is correctly formed, it has no net magnetic moment. (b) Optical microscope image of the final product of a magnetic reaction: almost all the individual particles are clustered into groups of four, as designed. (See the front cover!)



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

CNF's Nellie Yeh-Poh Lin Whetten Memorial Award

Photograph provided by Tim Whetten

This award is given in fond memory of Nellie Yeh-Poh Lin Whetten (left) — 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 is 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."

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

There's Two Sides to This Semiconductor, and Many Simultaneous Functions

By David Nutt
Cornell Chronicle
September 25, 2024

Gallium nitride-based semiconductors have been a boon for high-frequency and power electronics. They've also revolutionized energy-efficient LED lighting. But no semiconductor wafer has been able to do both at the same time efficiently.

Now Cornell researchers, in collaboration with a team at the Polish Academy of Sciences, have developed the first dual-sided — or "dualtronic" — chip that combines its photonic and electronic functions simultaneously, an innovation that could shrink the size of functional devices, make them more energy efficient and reduce manufacturing costs.

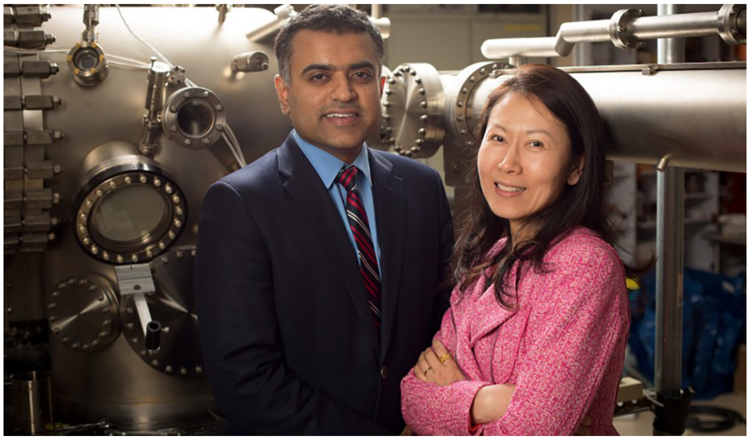
The paper, "Using Both Faces of Polar Semiconductor Wafers for Functional Devices," published Sept. 25 in Nature. The co-lead authors are doctoral students Len van Deurzen and Eungkyun Kim.

The project was led by Debdeep Jena, the David E. Burr Professor of Engineering in the School of Electrical and Computer Engineering and Department of Materials Science and Engineering, and Huili Grace Xing, the William L. Quackenbush Professor of Electrical and Computer Engineering and of Materials Science and Engineering, both in Cornell Engineering.

Gallium nitride (GaN) is unique among wide-bandgap semiconductors because it has a large electronic polarization along its crystal axis, which gives each of its surfaces dramatically different physical and chemical properties. The gallium, or cation, side has proved useful for photonic devices such as LEDs and lasers, while the nitrogen, or anion, side can host transistors.

The Jena-Xing Laboratory set out to make a functional device in which a high electron mobility transistor (HEMT) on one side drives light-emitting diodes (LEDs) on the other — a feat that hasn't been achieved in any material.

"To our knowledge, nobody has made active devices on both sides, not even for silicon," van Deurzen said. "One of the reasons is that there's no additional functionality you get from using both sides of a silicon



wafer because it's cubic; both sides are basically the same. But GaN is a polar crystal, so one side has different physical and chemical properties than the other, which gives us extra degree in designing devices."

The project was initially conceived at Cornell by Jena and former postdoctoral researcher Henryk Turski, a co-senior author of the paper, along with Jena and Xing. Turski worked with a team at the Polish Academy of Sciences' Institute of High Pressure Physics to grow transparent GaN substrates on a single crystal wafer roughly 400 μm thick. The HEMT and LED heterostructures were then grown in Poland by MBE. After the epitaxy was completed, the chip was shipped to Cornell, where Kim built and processed the HEMT on the nitrogen polar face.

"The nitrogen polar side is more chemically reactive, which means during device processing the electron channel can be damaged quite easily," Kim said. "A challenge with nitrogen polar transistor fabrication is to make sure all the plasma processes and the chemical treatment do not damage the transistors. So there was a lot of process development that had to be done for fabricating and designing that transistor."

Next, van Deurzen built the LED on the metal polar face, using a thick positive photo resist coating to protect the previously processed n-polar face. After each stage, the researchers measured their respective device characteristics and found they had not changed.

"It's actually a very feasible process," van Deurzen said. "The devices do not degrade. And this is obviously important if you want to use this as a real technology."

Since no one has made a double-sided semiconductor device before, the team had to invent a new method to test and measure it. They assembled a "crude" double-side-coated glass plate and wire-bonded one side of the wafer to it, which allowed them to probe both sides from the top. Because the GaN substrates were transparent for the entire visible range, the light was able to transmit through.

The single HEMT device succeeded in driving a large LED, turning it on and off at kilohertz frequencies — plenty for a working LED display.

Currently, LED displays have a separate transistor and independent fabrication processes. An immediate application for the dualtronic chip is microLEDs: fewer components, occupying a smaller footprint and requiring less energy and materials, and manufactured quicker for lower cost.

"A good analogy is the iPhone," Jena said. "It is, of course, a phone, but it is so many other things. It's a calculator, it's a map, it lets you check the internet. So there's a bit of a convergence aspect of it. I would say our first demonstration of 'dualtronics' in this paper is convergence of maybe two or three functionalities, but really it's bigger than that. Now you may not require the different processors to perform different functions, and reduce the energy and speed lost in the interconnections between them that requires further electronics and logic. Many of those functionalities shrink into one wafer with this demonstration."

Other applications include Complementary Metal-Oxide-Semiconductor (CMOS) devices with a polarization-induced n-channel transistor (which uses electrons) on one side and a p-channel transistor (containing holes) on the other.

In addition, because the GaN substrates have a high piezoelectric coefficient, they can be used as bulk acoustic wave resonators for filtering and amplifying radio frequency signals in 5G and 6G communications. The semiconductors could also incorporate lasers instead of LEDs for "LiFi" — i.e., light-based — transmissions.

"You could essentially extend this to enable the convergence of photonic, electronic and acoustic devices," van Deurzen said. "You're essentially limited by your imagination in terms of what you could do, and unexplored functionalities can emerge when we try them in the future."

Co-authors include doctoral students Naomi Pieczulewski; Zexuan Zhang, Ph.D. '23; David Muller, the Samuel B. Eckert Professor of Engineering in Cornell Engineering; and researchers from the Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw.

The researchers made use of the Cornell NanoScale Facility, a member of the National Nanotechnology Coordinated Infrastructure (NNCI), which is supported by the National Science Foundation, and the Cornell Center for Materials Research with support from the NSF's Materials Research Science and Engineering Centers program.

Benjamin A. Ash ’26: Goldwater Scholar for 2024

Spotlight on AEP sophomore Ben Ash: Harnessing the power of light

April 30, 2024
By: Diane Tessaglia-Hymes

Benjamin A. Ash ’26, a sophomore in the School of Applied and Engineering Physics who works in Professor Peter Mc Mahon’s lab, has recently been awarded a Goldwater Scholarship for 2024. Students must be nominated by their academic institutions to compete for the Goldwater scholarships, named after former Arizona Senator Barry Goldwater. Ben is one of two Cornell students, and one of 64 engineering students nationwide who were awarded the scholarship in 2024 and will receive up to $7,500 per full academic year for the next two years.

Ash, who is from Pittsburgh, Pennsylvania, chose Cornell because of the range of world-class research facilities and the wide variety of courses available to students. “I feel quite fortunate to be able to take upper-level courses in photonics, nanofabrication and metamaterials as an undergraduate,” said Ash. “Also, there are amazing research facilities at Cornell. I was particularly excited that the Cornell NanoScale Facility allows users to fabricate a wide variety of nanoscale devices from a diverse array of materials. When compared to other academic nanoscale facilities, what Cornell has to offer is quite unique.”

Within a month of arriving at Cornell, Ash began working in Professor Peter McMahon’s lab where he is mentored by Dr. Tatsuhiro Onodera, Dr. Ryotatsu Yanagimoto and Ph.D. student Martin Stein (CNF Project 2971-21).

“The independence and available facilities for undergraduates in AEP is really special,” he said. “I have fantastic mentorship in Professor McMahon’s group, and everyone has devoted immense amounts of time and effort to help me develop as a scientist.”

In the McMahon lab, Ash has been working on a programmable optical 2D waveguide — a device that shapes light within a confined 2D plane — since September 2022. This past summer, his most notable accomplishment was to design a nanofabrication recipe that allowed 1 μm features to be etched into a 3- or 4-μm thick layer of a substrate (in this case, silicon-rich silicon nitride or silicon oxide).

As a result of this modification, members of the group are able write periodic structures in which all the features are smaller than was possible before. “These high-resolution features allow us to write an index of refraction patterns that is more complex,” Ash explained. “This means we can more easily perform separate operations on different wavelengths or create optical routers with more input and output ports.”

He added that from a practical point of view, the programmability of the device could be useful in the telecommunications sector which often has to route signals over fiber optics from one array of input fibers to a different array of output fibers.

“Performing separate operations on different wavelengths is known as ‘wavelength division multiplexing,’ and is one of the key advantages of photonic circuits. Unlike electronic circuits, we can perform multiple transformations at the exact same time in the exact same space. This type of spatial parallelism is really unique to photonic systems.”

Like other Goldwater scholars, Ash has already coauthored several papers in journals and conference proceedings. He is currently third author on “Scaling on-chip photonic neural processors using arbitrarily programmable wave propagation.”

In the summer of 2024, Ash will work in McMahon’s group as a research intern for the Nippon Telegraph and Telephone Public Corporation’s Physics and Informatics Laboratory, with the goal of merging the nanofabrication recipes he developed to create a practically useful direct-current, programmable, 2D waveguide device. He is also interested in exploring other novel ways of manipulating light using metamaterials, plasmonics, or acousto-optics.

“Digging deeper into fabricating other micro-scale devices also has a lot of appeal,” he said. “I find the process of designing, fabricating and testing devices to be extremely fulfilling, and I hope that my inventions can be used by other people to perform more complex computations than our current computers can perform.”

When not focused on his studies and research, Ash enjoys hiking, skiing, or playing board games (Settlers of Catan has been a recent favorite). One of his main interests besides physics is learning about the cultures and politics of different societies; he likes to be engaged in the present, but to understand the past to put current events in perspective. "What is always exciting about this hobby is that the second you think you are understanding a certain topic, you jump down a random rabbit hole and realize how much more there is to know," he said.

To those considering affiliating with AEP, Ash recommends that they should be passionate about science. "AEP is very rewarding and worth the effort but can be conceptually tricky at times. A solid passion for science and what you can do with it will help motivate you and keep you on track. Let your scientific interests guide your course selections so you can take what will be most engaging to you. Also, join groups that interest you — whether research or project teams — and devote the necessary amount of time to contribute to the project. If you do, you will be given far more creative flexibility once others realize you are invested and experienced. And, for me at least, a lot of the fun in science is not only in the theory but in making something interesting out of it."

As a final word of advice, he encourages students to advocate for themselves. "There are a bunch of amazing opportunities available and getting the most out of them requires you to make yourself known. Once you open the first door, many more will open."

Kourkoutis' Cryo-Imaging Continues to Drive Quantum Discoveries

By David Nutt
Cornell Chronicle
August 6, 2024

It wasn't nostalgia that brought Judy Cha, Ph.D. '09, back to Cornell University. Among the reasons she left Yale University and joined the Department of Materials Science and Engineering two years ago was the prospect of working with an old friend: Lena Kourkoutis, M.S. '06, Ph.D. '09.

Figure 1: Lena Kourkoutis, M.S. '06, Ph.D. '09 and Judy Cha, Ph.D. '09, pictured together in 2023, were in the first cohort of doctoral students in the research lab of David Muller in 2003. Credit: Provided.

In 2003, they were in the first cohort of doctoral students in the research lab of David Muller, the Samuel B. Eckert Professor of Engineering in Cornell Engineering, and Cha and Kourkoutis shared an office for six years. Now they were both established academics with research labs of their own. Kourkoutis had pioneered a form of scanning transmission electron microscopy (STEM) that could be conducted in situ at cryogenic temperatures, and Cha looked forward to using the imaging technique for her work, exploring novel electronic properties and phase transformations of quantum nanomaterials.

"I was so excited to work with Lena," Cha said. "It was like — finally, we are both now established, our identity is secure, let's work together."

But just as their collaboration was beginning, it was over. Kourkoutis died in June 2023 at the age of 44.

However, their brief collaboration generated enough findings for a series of papers, the latest of which was published Aug. 6 in Proceedings of the National Academy of Sciences.

"I consider it her parting gift for me," Cha said. "I hope that she's proud of the work. I truly mean that."

Cornell Engineering recently held a memorial symposium that honored Kourkoutis and the impact of her scientific research, professional service and community leadership. Approximately a hundred mentees, collaborators and colleagues gathered for the weekend-long event. (https://www.aep.cornell.edu/lena-f-kourkoutis-memorial-symposium)

'She debugged everything'

Cha's team set out to study the microstructure of tantalum disulfide (TaS_2), a nanomaterial that features a phenomenon known as charge density wave (CDW), in which atoms distort in a periodic order, changing the material's electronic properties. CDW has been known to transition TaS_2 from a conductor to an insulator. But when the material is thinned out, CDW disappears. Nobody knows why.

"Our original idea was to directly locate it inside the electron microscope as a function of thickness and try to see if we can add to this puzzle," Cha said.

To make CDW appear in tantalum disulfide, the material needs to be cooled to minus 190 degrees Celsius — liquid nitrogen temperature. That meant the researchers needed an electron microscope that could function at minus 200°C.

"Cornell is one of the few places in the world that has expertise in that," Cha said. "And this was pioneered by Lena."

Kourkoutis' cryo-imaging method has enabled scientists to study the structure of energy, quantum and even biological materials at picometer precision while varying the temperature.

In recent years, this method has produced a wide range of discoveries, from revealing why lithium batteries were failing, to capturing the physical and chemical interactions that sequester carbon in soil, to exposing the tiny chemical flaws that lead to tooth decay.

"If you cannot control the temperature, you cannot repeat the experiment on the same sample. It's just a one-time observation," Cha said. "Lena made it so that we can control the temperature and still take amazing images. She debugged everything and solved all the technical challenges. Now it really allows you to do science."

Members of Cha's research group worked with Kourkoutis's team to learn their cryo-STEM techniques. Kourkoutis was also generous in letting the Cha group use her lab's experimental setup.

"I learned so much from Lena and her group through the course of this collaboration," said the paper's co-lead author James Hart, a former postdoctoral researcher who is now with the Naval Research Lab. "Her cryo-STEM expertise guided all of the experiments. Working with Lena was a true pleasure."

The imaging produced so much high-dimensional data, the researchers turned to Eun-Ah Kim, professor of physics in the College of Arts and Sciences, who used machine learning to sift through the team's terabyte-scale datasets to identify TaS_2's underlying behavior.

"Our machine-learning technique was developed for large volumes of X-ray diffraction data, but I always thought this approach is applicable to other types of probes," Kim said. "It was exciting to take a stab at cryo-STEM data as the first new experimental probe to be tested. We are enthralled that this first adventure was fruitful."

The researchers ultimately found that as TaS_2 is made thinner, its layers contain more and more stacking defects. The defects alter the CDW phase transition temperature by nearly 75 Kelvin, and the transition gets pinned at the specific defect site. This prevents conducting CDWs from transitioning into insulators.

By controlling these defects, the researchers anticipate being able to create potential memory devices.

On a larger scale, the findings demonstrate the important role that a material's microstructure — particularly defects — can play in affecting its properties. While introducing defects into metals is a common way to create a stronger, more ductile product (think of blacksmiths hammering away in their shop), for electronic and quantum materials, defects have been strenuously avoided. Cha hopes to change that.

"Traditionally, we always study perfect bulk crystals, as perfect as we can get them, and we do neutron or diffraction scattering or some sort of transport measurements that are a global property," she said. "This real-space information of microstructure is largely missing. We don't think about it. This is a ripe time to think about it, especially because we now have cryo-STEM that can go down to relevant temperatures."

Cha's group has several more papers in the pipeline with Kourkoutis listed as a co-author, as do a number of other engineering faculty.

"I think there are still many papers that will come out for the next at least two to three years, because science takes a long time," Cha said. "She was involved in many projects until about a month prior to her death. She was such a dedicated researcher, and her impact is far-reaching. I really want to pay homage to her."

Postdoctoral researcher Haining Pan was the paper's co-lead author. Other co-authors include Kim; doctoral students Saif Siddique, Noah Schnitzer and Shiyu Xu; and postdoctoral researcher Krishnanand Mallayya.

The research was supported by the U.S. Department of Energy, the Gordon and Betty Moore Foundation's EPiQS Initiative, the National Science Foundation (NSF) and the Schmidt Futures program.

Researchers made use of CNF, the Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM), and Cornell Center for Materials Research (CCMR) — all NSF supported.

Microscale Kirigami Robot Folds Into 3D Shapes and Crawls

By David Nutt
Cornell Chronicle
September 11, 2024

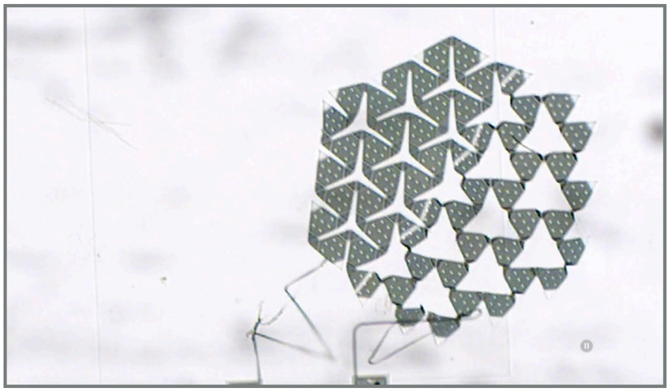


Figure 1: Screen capture from the video available at https://news.cornell.edu/stories/2024/09/microscale-kirigami-robot-folds-3d-shapes-and-crawls

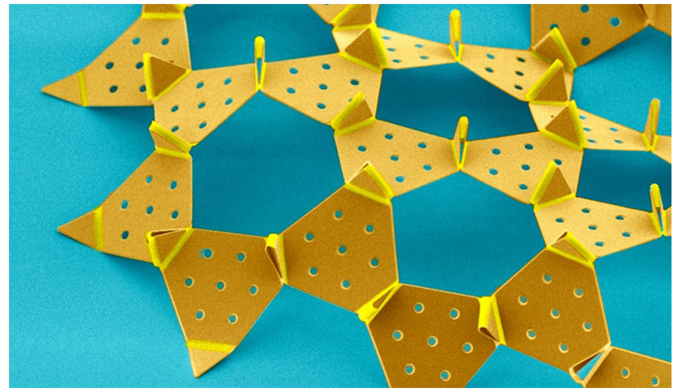


Figure 2: The kirigami robot is a hexagonal tiling composed of approximately 100 silicon dioxide panels that are connected through more than 200 actuating hinges. Provided.

The legacy of microscale robotics at Cornell continues to unfold — and refold and unfold itself again. The latest addition is a robot less than 1 millimeter in size that is printed as a 2D hexagonal "metasheet" but, with a jolt of electricity, morphs into preprogrammed 3D shapes and crawls.

The robot's versatility is due to a novel design based on kirigami, a cousin of origami in which slices in the material (the Japanese word "kiru" means "to cut") enable it to fold, expand and locomote.

The team's paper, "Electronically Configurable Microscopic Metasheet Robots," published Sept. 11 in Nature Materials. The paper's co-lead authors are postdoctoral researchers Qingkun Liu and Wei Wang, Ph.D. '24. The project was led by Itai Cohen, professor of physics in the College of Arts and Sciences (A&S), whose lab has previously produced microrobotic systems that can actuate their limbs, pump water via artificial cilia and walk autonomously.

The kirigami robot is the next step in that evolution, and is the result of longtime collaborations with Paul McEuen, the John A. Newman Professor of Physical Science (A&S); Hadas Kress-Gazit, the Geoffrey S.M. Hedrick Sr. Professor in Cornell Engineering; Nicholas Abbott, a Tisch University Professor in the Robert F. Smith School of Chemical and Biomolecular Engineering; Alyssa Apsel, the IBM Professor of Engineering in Cornell Engineering; and David Muller, the Samuel B. Eckert Professor of Engineering in Cornell Engineering — all co-authors of the paper.

In a sense, the origins of the kirigami robot were inspired by "living organisms that can change their shape," Liu said. "But when people make a robot, once it's fabricated, it might be able to move some limbs but its overall shape is usually static. So we've made a metasheet robot. The 'meta' stands for metamaterial, meaning that they're composed of a lot of building blocks that work together to give the material its mechanical behaviors."

Such metamaterials can often be designed to have properties that are difficult to achieve with natural materials, Wang said.

The robot is a hexagonal tiling composed of approximately 100 silicon dioxide panels that are connected through more than 200 actuating hinges, each about 10 nanometers thin. When electrochemically activated via external wires, the hinges form mountain and valley folds and act to splay open and rotate the panels, allowing the robot to change its coverage area and locally expand and contract by up to 40%. Depending which hinges are activated, the robot can adopt various shapes and potentially wrap itself around other objects, and then unfold itself back into a flat sheet. Such is the craftiness of kirigami.

"In origami, if you wanted to create three-dimensional shapes, usually you have to hide the excess material inside the 3D object that you're making," Cohen said. "But with kirigami, you don't have to hide anything. Of course, it's not a contiguous sheet, so there are holes in it, but you don't have to lose any material. It's a much more efficient way of generating a 3D shape."

Creating this kind of a machine at the microscale was a long, intricate process, from figuring out how to thread electrical wires through the various hinges to

determining the ideal balance of floppiness and rigidity for the robot to make and hold its shape. Among the most significant challenges was devising a way for something with so many moving parts to move itself.

"When you have a kirigami sheet, you have hundreds of potential contact points with the ground. And so for the longest time, we were confused about which parts of the robot were contacting the ground to make the robot move," said postdoctoral researcher and co-author Jason Kim.

Researchers wrapped a millimeter-scale metasheet around a portion of the arm and body of the Statue of Liberty on a U.S. quarter. The metabot changed its shape to fit the contours of the statue.

Figure 3: Researchers wrapped a millimeter-scale metasheet around a portion of the arm and body of the Statue of Liberty on a U.S. quarter. The metabot changed its shape to fit the contours of the statue. Credit: Provided.

Kim eventually realized that if, instead of using friction, they could make the robot swim through its environment by changing its shape, the forces became much more consistent. Of course, swimming at the microscale is very different than swimming in a pool. At that scale, it is more akin to swimming through a vat of honey.

"By changing the robot's shape so that different parts were closer to the ground at different points in the swimming gait, we could reliably use fluid drag forces to propel the sheet forward," Kim said.

That's one of the unique things about making microscopic robots, Cohen said. "The physics of locomotion at the microscale is often different from the physics of locomoting robots that are macroscopic."

Cohen's team is already thinking of the next phase of metasheet technology. They anticipate combining their flexible mechanical structures with electronic controllers to create ultra-responsive "elastronic" materials with properties that would never be possible in nature. Applications could range from reconfigurable micromachines to miniaturized biomedical devices and materials that can respond to impact at nearly the speed of light, rather than the speed of sound.

"Because the electronics on each individual building block can harvest energy from light, you can design a material to respond in programmed ways to various stimuli. When prodded, such materials, instead of deforming, could 'run' away, or push back with greater force than they experienced," Cohen said.

"We think that these active metamaterials — these elastronic materials — could form the basis for a new type of intelligent matter governed by physical principles that transcend what is possible in the natural world."

Co-authors also include postdoctoral researcher Itay Griniasty; Michael Reynolds, M.S. '17, Ph.D. '21; Michael Cao '14; and doctoral students Himani Sinhmar, Jacob Pelster and Paragkumar Chaudhari.

This work was supported by the National Science Foundation's Emerging Frontiers in Research and Innovation program (EFRI); the Army Research Office; Cornell Center for Materials Research, which is supported by the NSF's MRSEC program; the Air Force Office of Scientific Research; and the Kavli Institute at Cornell for Nanoscale Science. The researchers made use of the Cornell NanoScale Facility, a member of the National Nanotechnology Coordinated Infrastructure, which is supported by the NSF, and the Cornell Institute of Biotechnology.

Bio-Based Tool Quickly Detects Concerning Coronavirus Variants

By David Nutt
Cornell Chronicle
July 8, 2024

Cornell researchers have developed a bioelectric device that can detect and classify new variants of coronavirus, and potentially other viruses, such as measles and influenza, to identify those that are most harmful.

The sensing tool uses a cell membrane, aka biomembrane, on a microchip that recreates the cellular environment for — and the biological steps of — infection. This enables researchers to quickly characterize variants of concern and parse the mechanics that drive the disease's spread, without getting bogged down by the complexity of living systems.

The team's paper, "Recreating the Biological Steps of Viral Infection on a Cell-free Bioelectronic Platform to Profile Viral Variants of Concern," published July 3 in Nature Communications. The co-lead authors are postdoctoral researchers Zhongmou Chao and Ekaterina Selivanovitch.

"In the news, we see these variants of concern emerge periodically, like delta, omicron and so on, and it kind of freaks everyone out. The first thoughts are, 'Does my vaccine cover this new variant? How concerned should I be?'" said Susan Daniel, the Fred H. Rhodes Professor in the Robert Frederick Smith School of Chemical and Biomolecular Engineering in Cornell Engineering, and the paper's senior author. "It takes a little while to determine if a variant is a true cause for concern or if it will just fizzle out."

Daniel's group developed the platform with a team from the University of Cambridge led by professor Róisín Owens. Daniel and Owens first collaborated almost a decade ago on an effort to put biomembrane patches on electronic devices as a way to conduct toxicology measurements — a precursor to the new platform.

While plenty of biological elements have been put on microchips, from cells to organelles and organ-like structures, the new platform differs from those devices because it actually recapitulates the biological cues and processes that lead to the initiation of an infection at the cellular membrane of a single cell. In effect, it fools a variant into behaving as if it is in an actual cellular system of its potential host.

Studying viruses in cellular systems is exponentially difficult. Not that designing the biomembrane platform was simple.

"In order to recreate the complex process of infection outside of a cell, you need to know what the essential biological elements and cues are," Daniel said. "You also have to know how to fabricate these microelectrodes and put these tiny membrane patches on them. It's quite tricky to get them to lay down onto that little microelectrode patch in just the right way. That may be perhaps the hardest part, honestly."

The researchers worked with the Cornell NanoScale Facility to fabricate the microelectrode arrays, which resemble tiny gold-patterned spiders, and each electrode pad was coated with a cell membrane. A membrane sample from, say, a lung cell, is placed on the microelectrode and then the virus is added. If the virus detects the desired receptor on that patch, it will bind. The biosensor measures how the electrical resistance changes as the variant interacts with the membrane host layer and attempts to deliver its genome across the host cell membrane so it can release its instructions on the other side.

"There could potentially be a correlation between how well a variant can deliver its genome across the biomembrane layer and how concerning that variant can be in terms of its ability to infect humans," Daniel said. "If it's able to release its genome very effectively, perhaps that's an indicator that a variant of concern should be something we should monitor closely or formulate a new vaccine that includes it. If it doesn't release it very well, then maybe that variant of concern is something less worrisome. The key point is we need to classify these variants quickly so we can make informed decisions, and we can do this really fast with our devices. These assays take minutes to run, and it's 'label-free,' meaning you don't actually have to tag the virus to monitor its progress."

Because the researchers are able to faithfully recreate the biological conditions and cues that activate a virus, they can also change those cues and see how the virus responds.

"In terms of understanding the basic science of how infection occurs and what cues can assist or hinder it, this is a unique tool," Daniel said. "Because you can decouple many aspects of the reaction sequence, and identify what factors promote or impede infection."

The platform can be tailored for other viruses, such as influenza and measles, so long as the researchers know what cell type has the propensity to be infected, as well as what biological idiosyncrasies allow a specific infection to flourish. For example, influenza requires a pH drop to trigger its hemagglutinin, and coronavirus has an enzyme that activates its spike protein.

"Every virus has its own way of doing things. And you need to know what they are to replicate that infection process on chip," Daniel said. "But once you know them, you can build the platform out to accommodate any of those specific conditions."

Co-authors include doctoral student Ambika Pachaury; and Konstantinos Kallitsis and Zixuan Lu of University of Cambridge

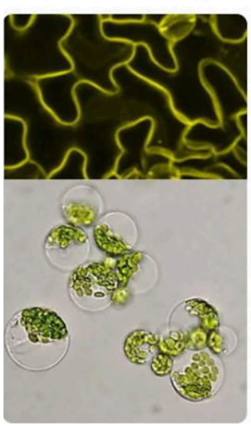
The research was supported by the Defense Advanced Research Projects Agency (DARPA), the Army Research Office, Cornell's Smith Fellowship for Postdoctoral Innovation, the Schmidt Futures program and the National Science Foundation.

What We Study

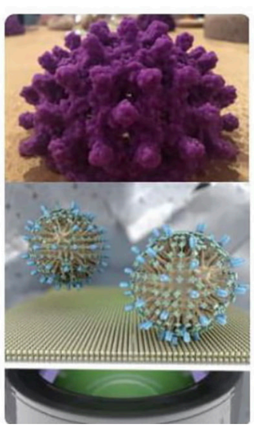
The Daniel Team investigates phenomena that occur at the biological interface known as the **cell membrane**. Our team pioneered the use of **biomembrane microfluidics** to conduct cell-free studies of membrane functions and biological processes. This platform is composed of **supported bilayers**, ranging from simple lipids to complex cell membranes, and chips equipped with spatio-temporal environmental control enabled by **microfluidics and bioelectronics**.

Using this platform, we study:

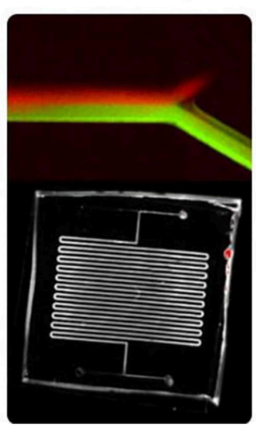
Membrane Biophysics & Biochemistry



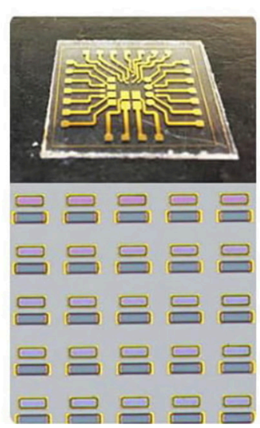
Host-Pathogen Interactions



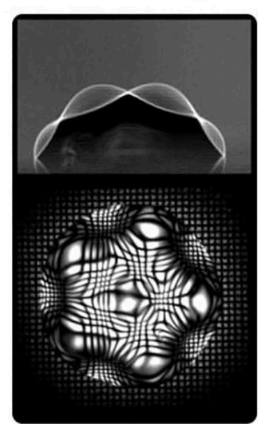
Cellular Processes On A Chip



Bioelectronic Biomembrane Devices



Interfacial Engineering & Wetting



Semiconductor Defects Could Boost Quantum Technology

By David Nutt
Cornell Chronicle
February 12, 2024

In diamonds (and other semiconducting materials), defects are a quantum sensor's best friend.

That's because defects, essentially a jostled arrangement of atoms, sometimes contain electrons with an angular momentum, or spin, that can store and process information. This "spin degree of freedom" can be harnessed for a range of purposes, such as sensing magnetic fields or making a quantum network.

Researchers led by Greg Fuchs, Ph.D. '07, professor of applied and engineering physics in Cornell Engineering, went searching for such a spin in the popular semiconductor gallium nitride and found it, surprisingly, in two distinct species of defect, one of which can be manipulated for future quantum applications.

The group's paper, "Room Temperature Optically Detected Magnetic Resonance of Single Spins in GaN," published February 12 in Nature Materials. The lead author is doctoral student Jialun Luo.

Defects are what give gems their color, and for this reason they are also known as color centers. Pink diamonds, for example, get their hue from defects called nitrogen vacancy centers. However, there are many color centers that have yet to be identified, even in materials that are commonly used.

"Gallium nitride, unlike diamond, is a mature semiconductor. It has been developed for wide bandgap high-frequency electronics, and that's been a very intense effort over many, many years," Fuchs said. "You can go and buy a wafer of it, it's in your computer charger, probably, or electric car. But in terms of a material for quantum defects, it has not been explored very much."

In order to search for the spin degree of freedom in gallium nitride, Fuchs and Luo teamed up with Farhan Rana, the Joseph P. Ripley Professor of Engineering, and doctoral student Yifei Geng, with whom they had previously explored the material.

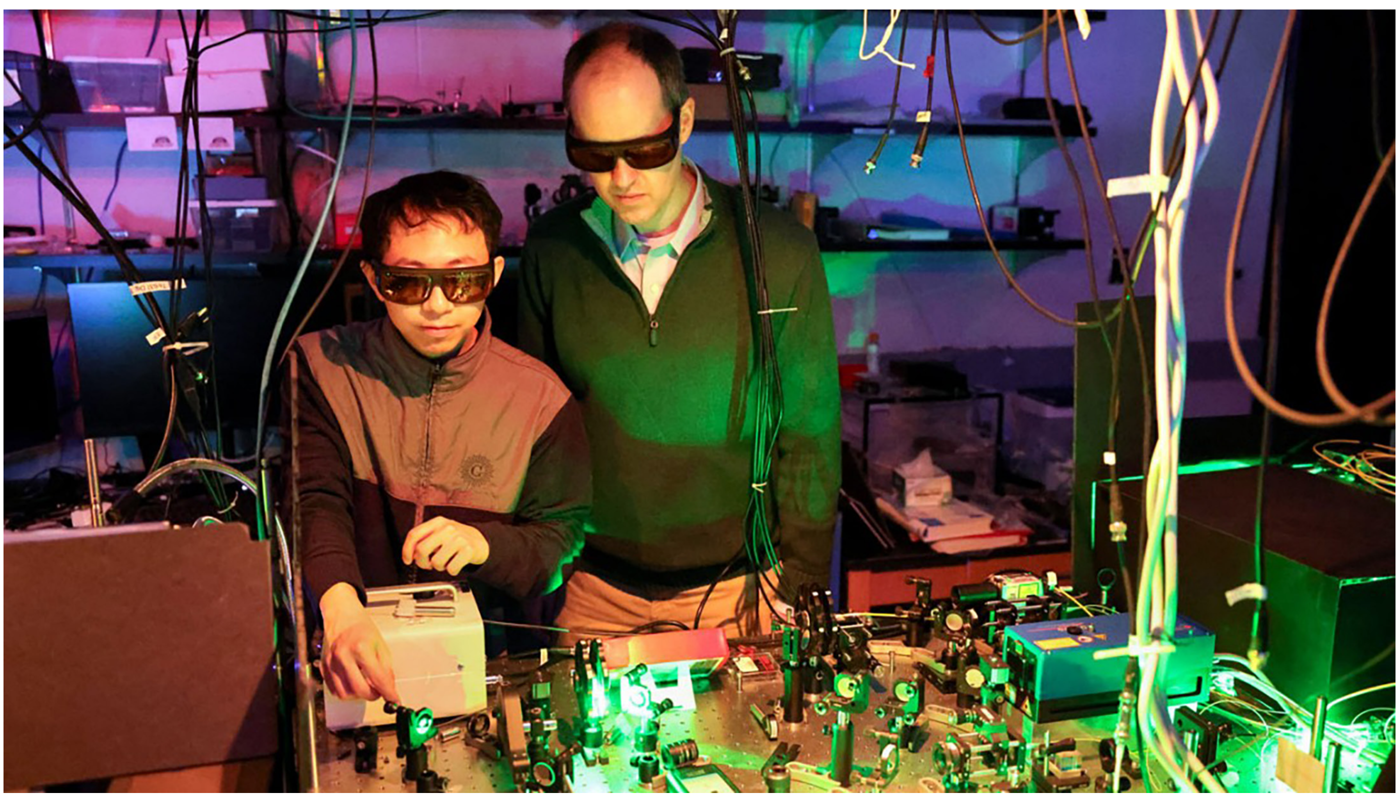


Figure 1: Doctoral student Jialun Luo (left) and Greg Fuchs, Ph.D. '07, professor of applied and engineering physics in Cornell Engineering, searched for a "spin degree of freedom" in the popular semiconductor gallium nitride and found it, surprisingly, in two distinct species of defect. Credit: Charissa King-O'Brien/Cornell Engineering.

The group used confocal microscopy to identify the defects via fluorescent probes and then conducted a host of experiments, such as measuring how a defect's fluorescence rate changes as a function of magnetic field, and using a small magnetic field to drive the defect's spin resonant transmissions, all at room temperature.

"At the beginning, the preliminary data showed signs of interesting spin structures but we couldn't drive the spin resonance," Luo said. "It turns out that we needed to know the defect symmetry axes and apply a magnetic field along the correct direction to probe the resonances; the results brought us more questions, waiting to be worked out."

The experiments showed the material had two types of defects with a distinct spin spectra. In one, the spin was coupled to a metastable excited state; in the other, it was coupled to the ground state.

In the latter case, the researchers were able to see fluorescence changes of up to 30% when they drove the spin transition — a large change in contrast, and relatively rare, for a quantum spin at room temperature.

"Usually the fluorescence and spin are tied together very weakly, so when you change the spin projection, the fluorescence might change by 0.1%, or something very, very tiny," Fuchs said. "From a technology standpoint, that isn't great, because you want a big change, so that you can measure it quickly and efficiently."

The researchers then performed a quantum control experiment. They found they could manipulate the ground-state spin and that it had quantum coherence — a quality that allows quantum bits, or qubits, to retain their information.

"That's something that is pretty exciting about this observation," Fuchs said. "There's still a lot of fundamental work to do, and there's many more questions than there are answers. But the basic discovery of spin in this color center, the fact that it has a strong spin contrast up to 30%, that it exists in a mature semiconductor material — that opens up all kinds of interesting possibilities that we now are excited to explore."

The research was supported by the Cornell Center for Materials Research (CCMR), with funding from the National Science Foundation's Materials Research Science and Engineering Center program; the Cornell Engineering Sprout program; and the NSF's Quantum Sensing Challenges for Transformational Advances in Quantum Systems program.

The researchers made use of the Cornell NanoScale Facility, also supported by the NSF.

Allison Godwin Appointed Associate Director of Cornell NanoScale Facility

By J. Edward Anthony
Cornell Chronicle
January 31, 2024

Allison Godwin, an expert in engineering education and associate professor of chemical and biomolecular engineering in Cornell Engineering, has been appointed associate director of the Cornell NanoScale Facility (CNF), effective Jan. 3, 2024.

Godwin will oversee CNF's education and workforce development programs.

"Allison's role at CNF is an application of her research and draws on her accomplishments and institutional leadership in workforce development and supporting diversity in engineering," said Judy Cha, Ph.D. '09, the Lester B. Knight Director of CNF and professor of materials science and engineering. "CNF is renowned for research excellence in nanoscience and technology. We are now positioning ourselves to become a thought leader in education and workforce development."

"It's an exciting and pivotal time for engineering education. As one example, the CHIPS and Science Act has created a lot of energy around workforce development for semiconductor research and manufacturing in the United States," Godwin said, referring to 2022 federal legislation to increase the competitiveness of the microchip industry in the United States.

"Cornell and CNF are taking a leading role in this effort, as exemplified by our part in the NORDTECH regional Microelectronics Commons hub. With this massive infusion of funding comes a responsibility to think strategically about how we recruit and train engineers and the larger workforce needed. CNF has a major role to play as we move forward."

Godwin previously served as director for engineering workforce development for the Center for Innovative and Strategic Transformation of Alkane Resources (CISTAR), a National Science Foundation Engineering Research Center (NSF ERC) at Purdue University, where she was an associate professor of engineering education and chemical engineering. Godwin also served on a team to develop a standardized assessment of engineering workforce development programs across all NSF ERCs. She joined the Cornell faculty in January 2023.

Godwin's research focuses on engineering student identity development and practices and policies that support inclusive engineering education.

"I think about how a student's understanding of who they are as a person interacts with educational experiences to shape career choices and outcomes," Godwin said. "Student identity development matters for almost every educational outcome we care about: retention, persistence on difficult tasks, academic success, well-being and career satisfaction. It matters for motivation to pursue engineering career pathways and smaller-scale efforts like motivation to do homework. These essential outcomes drive the types of questions I ask in my research."

Education and outreach are an established part CNF's mission, with programs for college and K-12 students throughout the year.

"Nationally, opportunities to engage in engineering prior to college aren't equal," Godwin said. "And even when a student gets to college, often the experiences are not equal. That says to me that workforce development is an equity issue. Being located in Ithaca, at Cornell and now part of the NORDTECH Microelectronics Commons hub, CNF is uniquely positioned to have real impact, particularly among populations such as first-generation students, students from rural communities, veterans and others who have been underrepresented in the engineering workforce in upstate New York and nationally."

Godwin's appointment at CNF complements her work as part of a growing cohort of Cornell Engineering faculty whose research scholarship focuses on engineering education.

"We hear quite a lot these days about the promise that modern universities offer for workforce development and for up-skilling nontraditional students for new jobs in advanced manufacturing, including in the semiconductor and microchip manufacturing sectors. Yet, few traditionally trained faculty actually know how to develop the pedagogies and practices to deliver on these promises. Allison is exceptionally well prepared to teach all of us how to fill this gap," said Lynden Archer, the Joseph Silbert Dean of Engineering and the James A. Friend Family Distinguished Professor in Engineering.

With the announcement of Godwin's three-year appointment, Cha thanked CNF's previous associate director, Claudia Fischbach, the Stanley Bryer 1946 Professor of Biomedical Engineering. "The value of our facilities for life sciences research wasn't always widely recognized. Claudia helped build our connections, particularly with biomedical researchers. She significantly expanded the profile of users that CNF serves," Cha said.

Course for Veterans to Expand Microchip Workforce in New York State

By Syl Kacapyr
Cornell Engineering
Cornell Chronicle
April 15, 2024

The Cornell NanoScale Facility (CNF) has partnered with two academic institutions to offer a free Microelectronics and Nanomanufacturing Certificate Program to veterans and their dependents.

The 12-week program will be offered in the fall 2024 semester and will cover the basic technologies and skills used to fabricate microelectronic devices, including laboratory safety, vacuum technology, patterning, microscopy, characterization, and thin-film deposition and etching.

"CNF is proud to offer this program that supports veterans and their families, while also addressing the growing demand for laboratory and manufacturing technicians in New York, particularly in the semiconductor industry," said Judy Cha, CNF director and professor of materials science and engineering.

Participants completing the program will receive a certificate from the Penn State Center for Nanotechnology Utilization and will have the option to test for three technical certifications offered by the American Society for Testing and Materials.

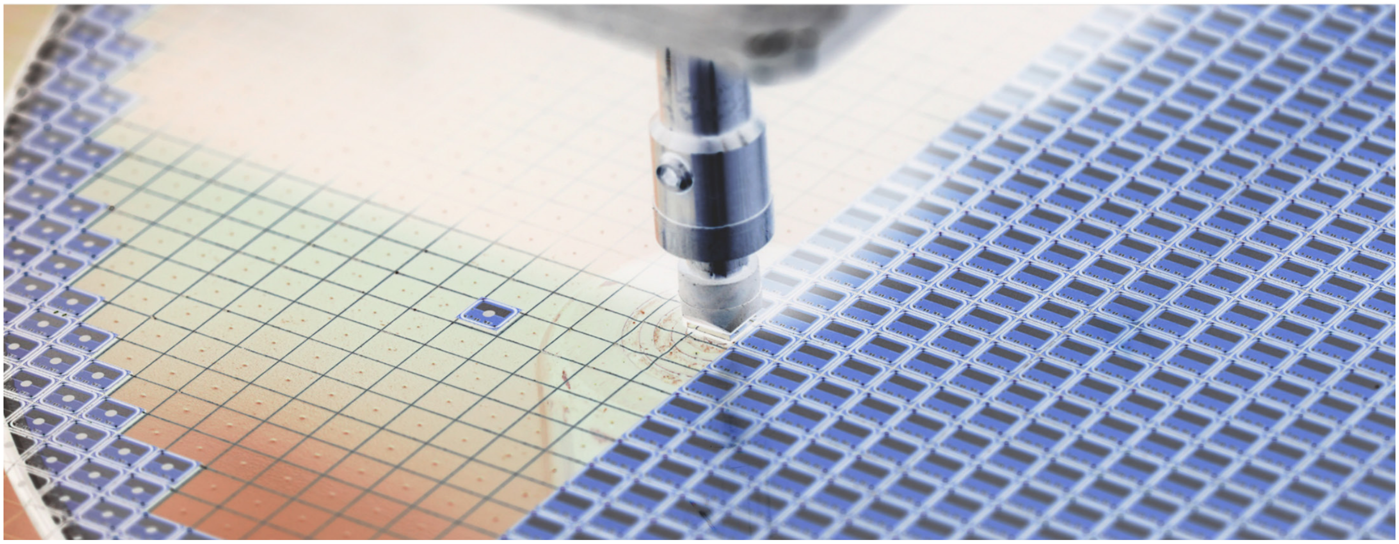
"These certificates will position program participants as qualified candidates for well-paying jobs in nano and microelectronics, and the skills and topics covered in the program can be useful in other industries as well," said Ron Olson, CNF director of operations. "During weekly employer-led presentations, students will hear firsthand about job opportunities from our industry partners."

The program — funded by the National Science Foundation and managed by The Pennsylvania State University — is being offered in New York State for the first time, with CNF providing laboratory access and hands-on training, while Tompkins Cortland Community College will provide academic and career support services such as advising and job placement assistance. Daily lectures will be streamed from Penn State.

Applications will be reviewed starting on June 1 for rolling admissions for the term beginning September 3. CNF anticipates enrolling a cohort of six participants for the fall semester with a second cohort in spring 2025.

For more information or to apply, visit the CNF website, https://www.cnf.cornell.edu/education/veterans

The Northeast Regional Defense Technology Hub (NORDTECH)



Cornell NanoScale Science and Technology Facility (CNF) Joins NORDTECH Hub in the Microelectronics Commons Network

By Jaida Anekwe
January 22, 2024

The Cornell NanoScale Facility (CNF) is excited to announce our involvement in the Northeast Regional Defense Technology Hub (NORDTECH), a collaborative initiative aimed at advancing semiconductor research and development. This move was made possible by the CHIPS (Creating Helpful Incentives to Produce Semiconductors) and Science Act of 2022, enacted to explore the critical role of semiconductor technology in national security and defense.

Funded by the Department of Defense, the CHIPS and Science Act's primary focus is to propel America toward global leadership in research and development through substantial investments in fields such as nanotechnology and quantum computing. NORDTECH is one of the major outcomes of the CHIPS and Science Act, as this consortium aims to develop new cut-throat microelectronics equipment for the semiconductor industry. NORDTECH comprises over 50 affiliates and partners, and CNF serves as one of the eight core facilities. This collaborative effort is driven by the need to bridge the gap between laboratory-scale semiconductor research and their industry applications, a process known as "lab to fab" innovation. Because of the Department of Defense (DOD)'s increasing reliance on computation power and cyber infrastructure, NORDTECH is a crucial element of the The CHIPS and Science Act.

CNF was selected as one of NORDTECH's five participating institutions, because of its 45 years of rich history serving the nanoscience industry. As one of the first institutions selected to partake in President Bill Clinton's National Nanotechnology Initiative (NNI), CNF is one of the longest running nanoscale initiatives in the country. With expanded capabilities as an academic institution, Cornell boasts state of the art materials that allows CNF to serve over 1,000 users annually; and with NORDTECH's contributions CNF plans on installing five to eight key instruments enabling facility users to design and build devices from scratch to end product.

"This is a really exciting time for CNF [...] because we have users and capabilities to serve the nation and the community [...] with the incoming [NORDTECH] funds we are able to bring in new capabilities, and users can now do things that were not previously possible," said

Figure 1: NORDTECH logo with headshots of contributing Cornell University faculty members; Judy Cha, Ph. D. '90, Darrel Schlom, Chris Ober, Greg Fuchs, Valla Fatemi, Karan Mehta, Jose Martinez, and Chris Batten.

Judy Cha, CNF Director. "We are in a unique position to really train folks with hands-on experiences [...] we have comprehensive tools that can make devices from scratch to the end product."

The implementation of NORDTECH and The CHIPs and Science Act directly facilitates the growth and expansion of the semiconductor industry. With the influx of funds CNF and other participating institutes can foster extensive workforce development, as tens of thousands of technicians and engineers will be needed in the next five to ten years. CNF is well-positioned to train this next generation of experts.

CNF's collaboration with NORDTECH marks a milestone in advancing semiconductor research and development. As a key player in this collaborative initiative, CNF brings its rich history in nanofabrication, unique capabilities in handling diverse materials, and commitment to training the future workforce.

Cornell Chronicle article, https://news.cornell.edu/stories/2024/01/cornell-partners-supercharge-nys-microchip-industry

ABOUT NORDTECH, https://www.nordtechub.org/

The Northeast Regional Defense Technology Hub (NORDTECH) is a regional coalition of public and private sector experts in the Microelectronics Commons (ME) region in and around New York State.

NORDTECH's five founding members who comprise the leadership team / governance committee of the hub include: NY CREATES, the University at Albany College of Nanotechnology, Science, and Engineering (CNSE), Cornell University, Rensselaer Polytechnic Institute (RPI), and IBM.

NORDTECH's board is advised by diverse members of planned participants in NORDTECH's response to the U.S. Department of Defense's call for an ME Commons Hub, including small and medium semiconductor manufacturing companies, community colleges and universities, and major corporations who are service providers and leaders in semiconductor device design, fabrication, and production.

In Memoriam: Frederick Sachs (1941 – 2023)

By University at Buffalo's Department of Physiology and Biophysics

It is with profound sadness that we announce the passing of Frederick Sachs, a distinguished American biologist and SUNY Distinguished Professor in the University at Buffalo's Department of Physiology and Biophysics, on December 27 at the age of 82. Born in 1941, Sachs' remarkable journey from a farm in Hudson Valley to becoming a pioneering figure in the field of physiology is a testament to his unwavering dedication and passion.

Frederick Sachs earned his Bachelor of Arts degree in physics from the University of Rochester in 1962. After briefly working in the aerospace electronics field in Los Angeles, he returned to pursue a Ph.D. in physiology from the State University of New York Upstate Medical University in 1971. His thesis, "Electrophysiology properties of cultured heart cells in a linear array" was based on a novel cell culture technique that he developed. His illustrious career spanned decades, leaving an indelible mark on the scientific community.

After a postdoctoral research position with Nobel Prize biophysicist George von Békésy in Hawaii, he joined the National Institutes of Health as a staff fellow. In 1978, he accepted an assistant professor position in the University at Buffalo's Department of Pharmacology.

It was in this role that in 1983, Sachs made his seminal discovery, identifying and characterizing the first mechanosensitive ion channels, which form the basis of our senses of hearing, touch, balance and tissue volume.

This discovery led to the creation of a revolutionary drug called GsMTx4, which inhibited these channels. Undeterred by initial industry reluctance, Sachs co-founded Rose Pharmaceuticals in 2009, naming the company after his grandmother and pet tarantula. Later the drug was designated as an orphan drug for Duchenne muscular dystrophy by the Food and Drug Administration, and his laboratory rapidly became a center for researchers worldwide to learn his investigative techniques. This finding opened doors to a new class of compounds for treating the causes of atrial fibrillation. Other research was done to address arthritis, Alzheimer's disease, and cancer. Sachs also developed novel experiments through the innovative use of quantitative electrophysiology, Bright Field, fluorescence, internal reflection, atomic force and electron microscopy, auditory biophysics, mathematical modeling, programming, instrument design, and microfabrication. He also developed a software program called QuB so that other researchers could analyze their data.

In 2012, Sachs and his colleague Harvey transformed Rose Pharmaceuticals into Tonus Therapeutics, setting up headquarters at UB's New York State Center of Excellence in Bioinformatics and Life Sciences.

In addition to his numerous accomplishments, Frederick Sachs was recognized by the 1987 Guinness Book of World Records as the inventor of the world's smallest thermometer, the ultra-micro-thermometer. This device, about 1/5 of the thickness of a human hair, played a pivotal role in measuring the temperature of single cells.

Recognized for his exceptional contributions, Sachs received several prestigious awards, including the SUNY Chancellor's Research Recognition Award (2003), SUNY Distinguished Inventor (2002), UB Distinguished Professor (2002), UB MiniMed Lecture (2002), Stockton-Kimball award (2001), NSF Nanotechnology Review Panel (2001), a Fogarty Fellowship (1992), and the 2013 Kenneth S Cole award from Biophysical Society. He was awarded the Entrepreneurial Spirit Award by SUNY in 2015.

He was nominated for a Nobel Prize in 2011.

Beyond the scientific realm, Fred enjoyed playing banjo and regularly joined a folk music group for weekly jam sessions. Kayaking, a favorite form of meditation, allowed him to immerse himself in the rhythmic flow of the intersecting waves of the Niagara River. Additionally, Sachs expressed his artistic side through metal sculptures, using principles of physics to explore motion, wind, and balance.

Frederick Sachs is survived by his wife, Jane Jacobson, and his four children: Shana Pergande, Janna Willoughby–Lohr, Benjamin Sachs, Robert Sachs, four grandchildren, and two brothers Jon and Dan Sachs. His son Chris predeceased him in 2008.

Frederick Sachs leaves behind a legacy of scientific innovation, resilience, and a profound impact on the world of biology. His work will continue to inspire future generations of researchers and clinicians as they strive to unlock the mysteries of the natural world. Our thoughts are with his family, friends, and colleagues during this difficult time.

https://medicine.buffalo.edu/news_and_events/news/2024/01/sachs-in-memoriam-18954.html

(Note; Prof. Sachs was a CNF PI for several projects over the years — 434-91, 591-96, 883-00.)

John Silcox Passed Away on April 25th

Dear friends:

We are very sad to inform you that Prof. John Silcox passed away on April 25th.

John was a great friend to the Cornell NanoScale Facility. In fact, he was one of our very first principal investigators back in 1978! Projects #14 and #15, "Exploratory STEM Studies" and "Interfacial Studies using STEM Techniques".

John also served as our interim director (2006-2007) and was a CNF champion while he served as Cornell's Vice Provost of Research (1998-2003).

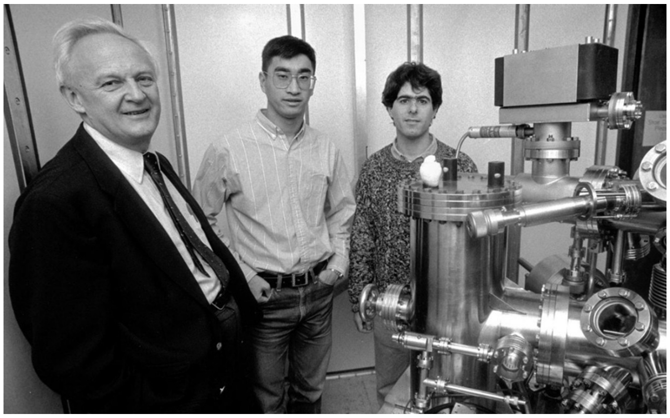
John and Ed Wolf both attended our CNF 45th Anniversary Celebration in 2022 and it is heartbreaking to realize they have both left us now.

Official Obituary of John Silcox
May 26, 1935 ~ April 25, 2024 (age 88)

John passed away in Ithaca NY on April 25th surrounded by loved ones. John was born and raised in Southwest England by his parents Janet Jones and Arthur Leonard Silcox. He is preceded in death by his wife of 50 years, Heather Penhale Silcox. He is survived by his younger sister, Ann L. Silcox and his close companion, Cynthia Robinson. He is also survived by daughters Heather J. (Ron) Andelora, Allison T. Silcox, and Laurie E. (Jon) Clarke and grandchildren Tristan Clarke, Grace Clarke and Josh (Diana) Andelora.

John spent his early childhood in Saltash during WW II. At age 10, John outgrew the capabilities of his local school and was sent to Totnes, Devon to attend King Edward VI Grammar School as a boarding student, as his father had before him. John taught himself further physics and mathematics after reaching the school instruction limits. Forever pushing himself, he contacted the University of Cambridge and asked them to send him sample entrance exams for practice. He won an exhibition scholarship to the University of Bristol. In that town of Totnes, John met his future wife Heather P. Penhale, at age 13, after stealing her hat at a local event.

John earned his B.Sc. degree with first class honors in physics from Bristol University in 1957 and a doctorate in physics from Cambridge University in 1961. He spent his early research years at the highly regarded Cavendish Laboratory at Cambridge University. He held a research fellowship at Cambridge University for electron microscopy studies of magnetic materials. Heather and John were married in April, 1960 and in 1961, John and Heather emigrated to the US on the Empress of Canada's final ocean voyage, where he joined the Cornell faculty as a 26 year old assistant professor in the School of Applied and Engineering Physics. John and Heather settled into Cayuga Heights initially, followed by a move to East Hill where their three daughters were raised and attended local schools. The family were members of the St. John Episcopal Church congregation.



Dr. Silcox spent the next 48 years on the faculty of the School of Applied and Engineering Physics, serving as director of the department twice. In 1985 he earned the Tau Beta Pi Excellence in Engineering Teaching Award. In 1988 he was named the David E. Burr Professor of Engineering and served as Director of the Cornell Materials Science Center from 1989-1997. He was especially proud of his work in securing a multi-million-dollar NSF research grant to continue funding for the Center. From 1998-2003 he served as the Vice Provost for Research for Physical Sciences and Engineering and served for a time as Director of the Cornell NanoScale Facility. He retired in 2009.

John Silcox was a fellow of the American Physical Society and a member and past president of the Electron Microscopy Society of America, from whom he received the 1996 Distinguished Scientist Award in physical sciences. The award is the highest honor bestowed by the world's leading professional association of electron and optical microscopists. He won the award for "internationally recognized research accomplishments and distinguished contributions to microscopy". Dr. Silcox served on the Solid State Sciences Committee of the National Academy of Sciences/National Research Council from 1978-82. He was a member and chair of the Materials Research Advisory Committee for the National Science Foundation, and also served as co-chair of the NSF Panel on High Resolution Electron Microscopy. He also served on the Advisory Committee to the Arizona State University (high resolution). He chaired the Advisory Committee for the Electronic Microscopy Center for Materials Science at Argonne National Laboratory. He published numerous research articles describing his work in materials science and electron microscopy.

John spent sabbatical leaves in France and Great Britain in 1967-68 as a Guggenheim Fellow, at Bell Laboratories in 1974-75 and at Arizona State University in 1983. His work in physics was a lifelong passion and he was especially proud of his work as a scientist and educator. He enjoyed his time advising and mentoring undergraduate and graduate students.

John loved puzzles, the harder the better and loved to do Black Belt Sudoku and physics equations. Other interests included Single Malt scotch which his grandson Joshua has inherited. He was a big believer in the power of education and funded his grandchildren's higher education, a gift through which they will forever be empowered.

After losing his beloved wife Heather in 2010, John came to find peace again and bought a home in Tucson AZ near his eldest daughter Heather Jane. After seven winters in Arizona he made the decision to return to Ithaca to live amongst many Cornell and Ithaca friends. He found love again over the puzzle table at Kendal. His middle daughter Allison, a NYC resident, spent many a weekend visiting and caring for John.

He will be missed by many.

I initially worked for John Silcox as a Ph.D. student. That's when I learned how to use the VG H501 STEM (very old, ancient machine) that used to be in Clark Hall. My very first paper was with John, in Science in 2006.

Judy Cha
Professor, Materials Science and Engineering
Lester B. Knight Director, CNF

Direct Determination of Local Lattice Polarity in Crystals; K. A. Mkhoyan, P. E. Batson, J. Cha, W. J. Schaff, J. Silcox; Science, 2 Jun 2006, Vol 312, Issue 5778, p. 1354, DOI: 10.1126/science.1124511 https://www.science.org/doi/10.1126/science.1124511

Where Were We?

We go to the ends of the Earth
for the CNF REU program …

In this case, near Borgen Bay in the Antarctic Peninsula. We traveled 6,900 miles by air to Ushuaia Argentina, then another 750 miles or so by ship to a variety of places down there. Lots of penguins, a few elephant seals lying around daring the penguins to just try to make 'em move, and a few whales feeding in the bays.

Plus ice in the most fantastic shapes and forms — on land, as floating bergs, and grounded ones being slowly eroded by the seawater.

We went ashore on Zodiacs seven times to see the critters up close … penguins are as cute as advertised (a foot or so tall, 6-8 pounds, but constantly moving around with great seriousness and determination).

Thanks,
Dennis Costello, ASE
OpenVMS Systems Engineer (And past CNF staffer!)

Hwang Awarded the IEEE Leaster F. Eastman Award

Tuesday, September 12, 2023

Lynn and Ron;

Last Friday, I received a call from the president of the IEEE Electron Devices Society to tell me that I won the IEEE Leaster F. Eastman Award for outstanding achievement in high-performance semiconductor devices. It is a culmination of my career, but I hope I have not peaked out.

James C. M. Hwang, Professor
Department of Materials Science and Engineering
School of Electrical and Computer Engineering
Cornell University
https://eds.ieee.org/awards/lester-f-eastman-award

David Muller Wins Cowley Medal and Keithley Award

By Diane Tessaglia-Hymes
Cornell Chronicle
October 26, 2023

David A. Muller, the Samuel B. Eckert Professor of Engineering in Applied and Engineering Physics at Cornell University, has been honored with two prestigious awards for his achievements in microscopy: the 2023 John M. Cowley Medal from the International Federation of Societies for Microscopy and the 2024 Joseph F. Keithley Award for Advances in Measurement Science from the American Physical Society.

The John M. Cowley Medal is the highest award bestowed by the International Federation of Societies for Microscopy and is awarded only once every four years to recognize the outstanding contributions of individual scientists and their achievements in diffraction physics and microscopy.

Muller, who is the director of the Electron Microscopy Facility at PARADIM, and co-director of the Kavli Institute at Cornell for Nanoscale Science, has focused his research on understanding the behavior of materials and devices at the atomic scale, with an emphasis on renewable energy applications. His group's inventions and advances in new microscopy technology had already been recognized by Guinness World Records for the highest resolution microscope.

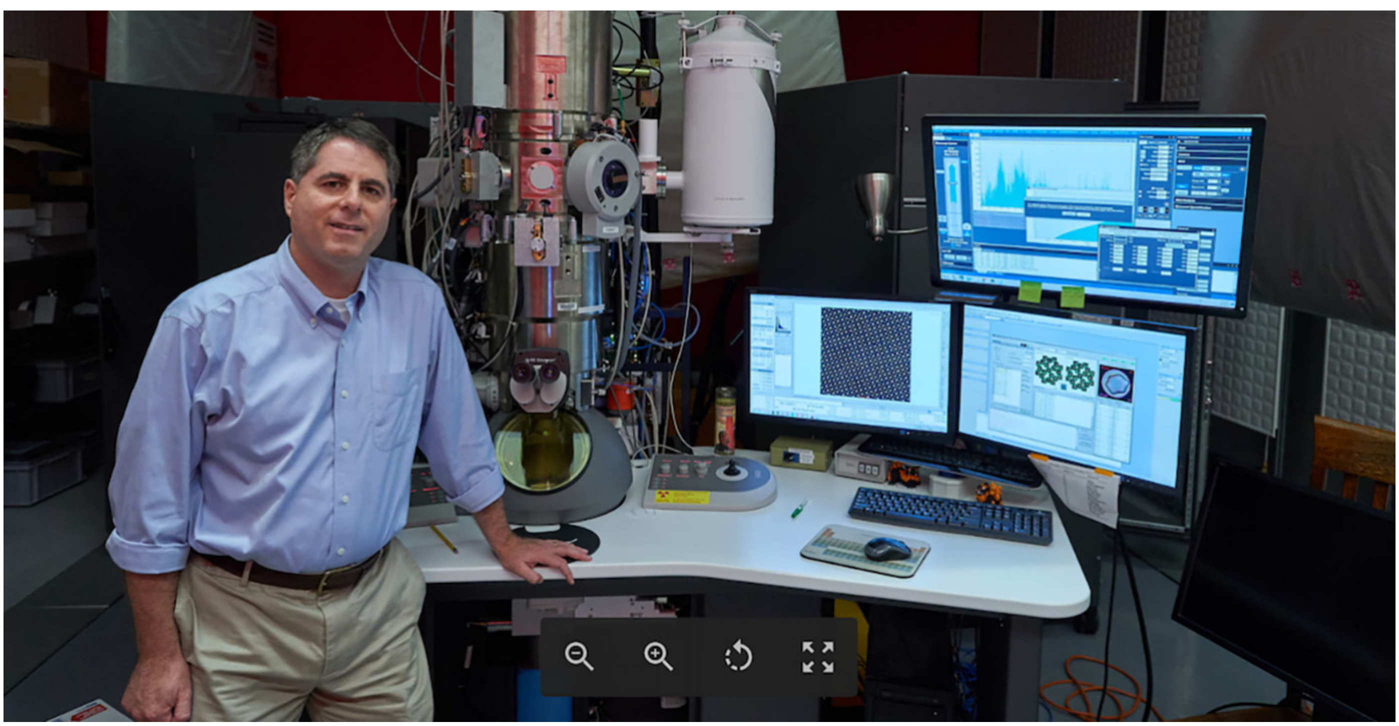
"By using these unique instruments, placed in specially designed and environmentally isolated rooms," Muller said, "my group explores the atomic-scale chemistry, structure and bonding that occurs inside objects as diverse as transistors, turbine blades, fuel cells and batteries. The impact of this research on devices, both large and small, has the potential to be significant."

Muller received The Joseph F. Keithley Award "For pioneering a new generation of electron detectors and phase-sensitive reconstruction algorithms leading to significant advances in the resolution and capabilities of electron microscopes."

This award is made annually to one or a few individuals working in the area of sensitive and precision instrument development and measurement techniques for outstanding advances in measurement science or products that impact the physics community by providing better measurements.

"Previous electron microscopes allowed us to see atoms, but only just barely. Our work over the past 15 years has been to improve the resolution of the electron microscope to be about tenth of the distance between neighboring atoms. That has allowed us to not only see where the atom's nucleus is, but also how it's wobbling around," said Muller.

"I am very honored to have received both of these prestigious awards."



X-Ray Probes, Microfluidics, Nanomaterials Earn Research Excellence Awards

By Patrick Gillespie
December 7, 2023
Cornell Chronicle

Imaging the atomic details of materials as they function, forming microfluidic structures to study plants and animals, and new techniques for manufacturing polymer nanomaterials are among some of the research themes that helped six faculty members earn Cornell Engineering Research Excellence Awards — the highest research honor given by the Ivy League's top-ranked engineering college. The awards were presented at the Engineering Faculty Reception and Meeting held on December 6 (2023).

Recipients of the annual awards are nominated by their departments and selected by a committee for more than just their individual research outcomes. Awardees are also recognized for their impacts on society, reputation in the field, leadership, mentorship and citizenship within the college and university.

"At the forefront of academic excellence, this year's award recipients exemplify a spirit of collaborative leadership and elevate Cornell Engineering's standard of research," said Lois Pollack, associate dean for research and graduate studies at Cornell Engineering. "We proudly acknowledge and celebrate their impact on our academic community and on the broader realm of science and engineering."

The 2023 recipients who are also CNF PIs are:

Matthew Paszek, associate professor, Smith School of Chemical and Biomolecular Engineering

Paszek has developed multiple protein engineering strategies in two challenging contexts: localized mechanosensors and sequence-defined glycoproteins. At Cornell, he has designed new biomaterials to tailor and probe the mechanical environment of cells. In support of these experimental approaches, he has developed powerful, predictive biophysical theories and created custom imaging approaches, including hardware and software, to visualize nano-scale dynamics in living cells. Each of these developments has been described as a technical tour-de-force of its own right. Paszek has used them to make seminal advances at the forefront of cell biology and to enable important applications in bioprocess and biomedicine.

Andrej Singer, assistant professor, Materials Science and Engineering

Singer's research program focuses on probing the atomistic details of functional materials during their operation by developing the full capabilities of next-generation X-ray sources. Specifically, he uses in situ coherent X-ray imaging and spectroscopy to investigate the behavior of materials at the nanoscale. His research vision is to develop a mechanistic understanding of out-of-equilibrium processes will enable the rational design of materials for a wide-range of applications from energy technologies to electronic and quantum materials. These techniques are addressing materials science problems with significant societal impact ranging from energy storage and production to neuromorphic computing.

Abe Stroock, Gordon Dibble '50 Professor of Chemical and Biomolecular Engineering, Smith School of Chemical and Biomolecular Engineering

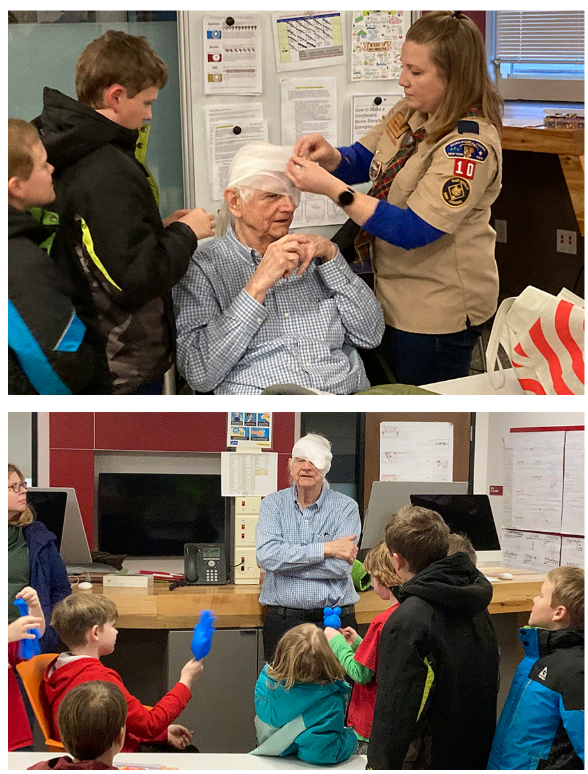
Stroock has become an international leader in the development of micro- and nano-scale technologies for the pursuit of scientific questions and applications in biological systems. Notably, his lab led the movement of microfluidic approaches into a new area of relevance for biophysics and bioengineering with the creation of methods to form microfluidic structures in soft, organic matrices; these systems opened opportunities to study and use vascular-like function of relevance to mammalian tissue engineering and plant physiology. Building on a breakthrough enabled by his new microfluidic approaches, Stroock has focused significant attention over the past 15 years on physical studies inspired by plant physiology and on applications of physicochemical ideas and approaches to plant science and agriculture.

Rong Yang, assistant professor, Smith School of Chemical and Biomolecular Engineering

Yang's research has had a tangible impact on the manufacturing science of soft nanomaterials by transforming chemical vapor deposition (CVD) into a versatile platform for the synthesis of a broad palette of soft polymeric materials. A first key research contribution that she made at Cornell is based on her original insight that vapor-phase solvation of monomers during CVD polymerization can enable rational tuning of a broad range of polymer film properties. And whereas prior demonstrations of CVD polymerization were limited to the synthesis of thin polymer films, she demonstrated that CVD can form the basis of approaches to shape-controlled polymer nanoparticles.


Cornell University
643,457 followers
1d · Edited

Michael Skvarla, part of the Cornell NanoScale Facility, expected to leave Cornell after finishing his degree. However, after growing fond of the Ithaca area and the quality of life in the Finger Lakes region, he decided to stay. Now, 50 years later, Michael is still happily rooted in the community he's come to love. Summing up his journey at Cornell in one simple phrase, he says, "It has been an enjoyable ride."



Aaron Windsor writes — Mike used his Army medic training to teach my cub scouts first aid!

Soctera, Inc. has been awarded $750,000 as one of seven winners in the DBX Microelectronics Challenge! This recognition validates Soctera's innovative AlN/GaN HEMT technology and is a testament to its commercial viability.

The momentum built through dedicated R&D and partnerships with crucial materials and device fabrication suppliers has given Soctera line-of-sight to production readiness for its power amplifier product. This PA will give radar and telecommunications applications 5x the thermal performance while utilizing only 5% of the gallium. This milestone marks the commencement of an exciting new phase of growth.

Dec 12, 2023

Soctera, Inc., research is performed in part at the Cornell NanoScale Facility (CNF), a member of the National Nanotechnology Coordinated Infrastructure (NNCI), which is supported by the National Science Foundation (Grant NNCI-2025233).

EFC Partners with Cornell NanoScale Facility to Develop Eco-Friendly Semiconductor Solutions

EFC Gases & Advanced Materials has launched a collaborative research program with the Cornell NanoScale Science and Technology Facility (CNF) to explore sustainable alternatives for the semiconductor industry. The focus of this partnership is to evaluate low global warming potential (low-GWP) fluorocarbons as eco-friendly replacements for the currently used fluorocarbons (FCs) and hydrofluorocarbons (HFCs) in critical etching applications. These incumbent gases, known for their negative environmental impact, are essential in semiconductor materials processing, yet there are no viable alternatives available.

This research program, funded exclusively by EFC, aims to investigate the effectiveness of several low-GWP etching candidates for high aspect ratio (HAR) etching of silicon-based materials.

Through a series of carefully designed experiments, the performance of these low-GWP candidates will be assessed against incumbent fluorocarbons such as octafluorocyclobutane (C_4F_8), and hydrofluorocarbons like HFC-23, trifluoromethane (CHF_3).

The ultimate goal of this initiative is to develop efficient and sustainable etching processes for critical semiconductor materials, aligning with EFC's commitment to providing high-quality, environmentally friendly products to the electronics industry. This initiative is part of EFC's broader effort to introduce sustainable solutions and reduce the environmental impact of the semiconductor manufacturing process.

With the collaboration of the CNF, EFC aims to advance the frontier of sustainable semiconductor processing.

2024 CNF REU + SUMMER UNDERGRADUATE RESEARCHERS

This past summer, the Summer Undergraduate Researchers we were working with at CNF were from the following programs; the 2024 Cornell NanoScale Science & Technology Facility Research Experience for Undergraduates (CNF REU) Program and the 2024 Cornell NanoScale Science & Technology Facility Research Experience for Undergraduates (CNF REU) Program with Morgan State University, the Butcher Funded Tuskegee University Summer Program, the 2024 Cornell Robert Frederick Smith School of Chemical and Biomolecular Engineering FMRG: Cyber (CBE FMRG: Cyber) Summer Program, the Cornell Center for Materials Research North Carolina Agricultural & Technical State University (CCMR NC A&T) Summer Program, and the Xing Army Educational Outreach Program (AEOP).

It was a great summer and we hope everyone stays in touch!

Melanie-Claire Mallison, CNF REU Program Coordinator

The 2024 CNF REU + SUMMER UNDERGRADUATE RESEARCHERS

MICHAEL BATAVIA

Computer Science, New York University
Program: 2024 CBE FMRG: Cyber (LC)
PIs: Profs. Allison Godwin, Fengqi You, Nicholas Abbott
Mentors: Guangyao Chen, Soumyamouli Pal
Project Title: Computer Vision Applied to Polymer Particles in LC to Enable On-the-Fly Characterization of Their Morphology and Size Distribution, Among Other Properties

RIVER CHEN

Materials Science and Engineering, UIUC
Program: 2024 CNF REU
Principal Investigator (PI): Prof. Zhiting Tian
Mentor: Joyce Christiansen-Salameh
Project Title: Fabrication of Superconducting Devices Integrating Phonon Traps

SIYI CATHY CHEN

Materials Science and Engineering, UIUC
Program: 2024 CNF REU
Principal Investigator: Prof. Yu Zhong
Mentor: Kaushik Chivukula
Project Title: Fabrication of 2D-Material-Based Ionic Transistors

KYLA CHRISTOPHER

Animal Science, Tuskegee University
Program: 2024 Butcher Funding
Principal Investigator: Prof. Jonathan Butcher
Mentors: Shuofei Sun, Alex Cruz
Project Title: Biofabricated Complex Cardiovascular Tissues

BROOKLYN JENKINS

Mechanical Engineering, North Carolina Agricultural and Technical State University
Program: 2024 CCMR NC A&T
Principal Investigator: Prof. Sadaf Sobhani
Mentor: Charlotte Albunio
Project Title: 3D Printing of Ceramics for Energy Reactors

GANNON LEMASTER

Electrical Engineering, Brown University
Program: 2024 CNF REU
Principal Investigator: Prof. James C. Hwang
Mentors: Lei Li, Xiaopeng Wang
Project Title: Millimeter-wave Electrical Permittivity of Semiconductors and Insulators

SARAH LEVINE

Civil Engineering, Worcester Polytechnic Institute
Program: 2024 Xing Army Educational Outreach Program (AEOP) Program
Principal Investigator: Prof. Huili Grace Xing
CNF Staff Mentor: Jeremy Clark
Xing's CNF User Mentors: Jimy Encomendero, Xianzhi Wei
Project Title: Atomic Layer Deposition of High-K Dielectrics on AlGaN and MOSCAP Characterization

FABIANA MAYOL LÓPEZ

Chemistry, Ana G. Méndez University, Gurabo Campus
Program: 2024 CNF REU
Principal Investigator: Prof. Huili Grace Xing
Mentors: Joseph Dill, Shivali Agrawal
Project Title: Ohmic Contacts to High Al-Content n-type AlGaN

ELIZABETH QUANSAH

Materials Science & Engineering, University of Illinois at Urbana-Champaign
Program: 2024 CNF REU
Principal Investigator: Prof. Sadaf Sobhani
Mentor: Giancarlo D'Orazio
Project Title: Micro-scale Ceramic Additive Manufacturing for Aerospace Applications

RICHARD REMIAS

Physics, University of Rhode Island
Program: 2024 CNF REU
Principal Investigator: Prof. Judy Cha
Mentors: Quynh Sam, Khoan Duong
Project Title: Nanomolding of Topological Materials for Interconnect Applications

IMRIE ROSS

Biochemical Engineering, University of Georgia
Program: 2024 CBE FMRG: Cyber (iCVD)
Principal Investigators: Prof. Allison Godwin, Prof. Nicholas Abbott, Prof. Rong Yang
Mentors: Apoorva Jain, Shiqi Li, Soumyamouli Pal
Project Title: Initiated Chemical Vapor Deposition (iCVD) Polymerization in the LC to Synthesize Polymer Particles in an Automated Fashion to Enable Cyber-Aided Synthesis

HUNTER SAYLOR

Electrical and Computer Engineering,
Morgan State University
Program: 2024 CNF REU (MSU)
Principal Investigator: Prof. Sadaf Sobhani
Mentor: Giancarlo D'Orazio
Project Title: Micro-Additive Manufacturing Processes for Electrochemical CO_2 Reduction

DANIEL TELESHEVSKY

Electrical and Computer Engineering, Cornell University
Program: 2024 Xing Army Educational Outreach Program (AEOP) Program
Principal Investigator: Prof. Huili Grace Xing
CNF Staff Mentor: Phil Infante
Xing's CNF User Mentors: Jimy Encomendero, Xianzhi Wei
Project Title: LPCVD Nitride Passivation of AlGaN/AlBN Devices

TIMOTHY WALSH

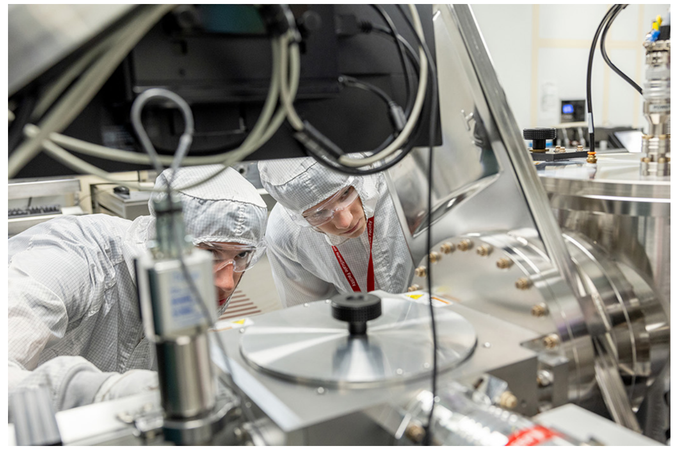
Chemical Engineering, Cornell University
Program: 2024 Xing Army Educational Outreach Program (AEOP) Program
Principal Investigator: Prof. Huili Grace Xing
CNF Staff Mentor: Aaron Windsor
Xing's CNF User Mentors: Jimy Encomendero, Xianzhi Wei
Project Title: Characterization and Optimization of Ohmic Contacts to Nitride Semiconductors

JADEN WATT

Mechanical Engineering, North Carolina Agricultural and Technical State University
Program: 2024 CCMR NC A&T
Principal Investigator: Prof. Richard Robinson
Mentor: Tom Ugras
Project Title: Multiscale Nanofilms with Emergent Chiral Properties

HAJO WISE

Mechanical Engineering, Rochester Institute of Technology
Program: 2024 Xing Army Educational Outreach Program (AEOP) Program
Principal Investigator: Prof. Huili Grace Xing
CNF Staff Mentor: Xinwei Wu
Xing's CNF User Mentors: Jimy Encomendero, Xianzhi Wei
Project Title: Characterization of AlGaN/AlBN HeterostS



Education and Outreach Coordinator's Column

By Tom Pennell

CNF had a great year in our education and outreach and workforce development initiatives. I just received the final tally from Melanie-Claire, and we hosted over 4,000 visitors last year! Adding to that, CNF facilitated the return of the NISE Net nano exhibition to the Ithaca ScienCenter which saw just under 100,000 visitors in 2023!

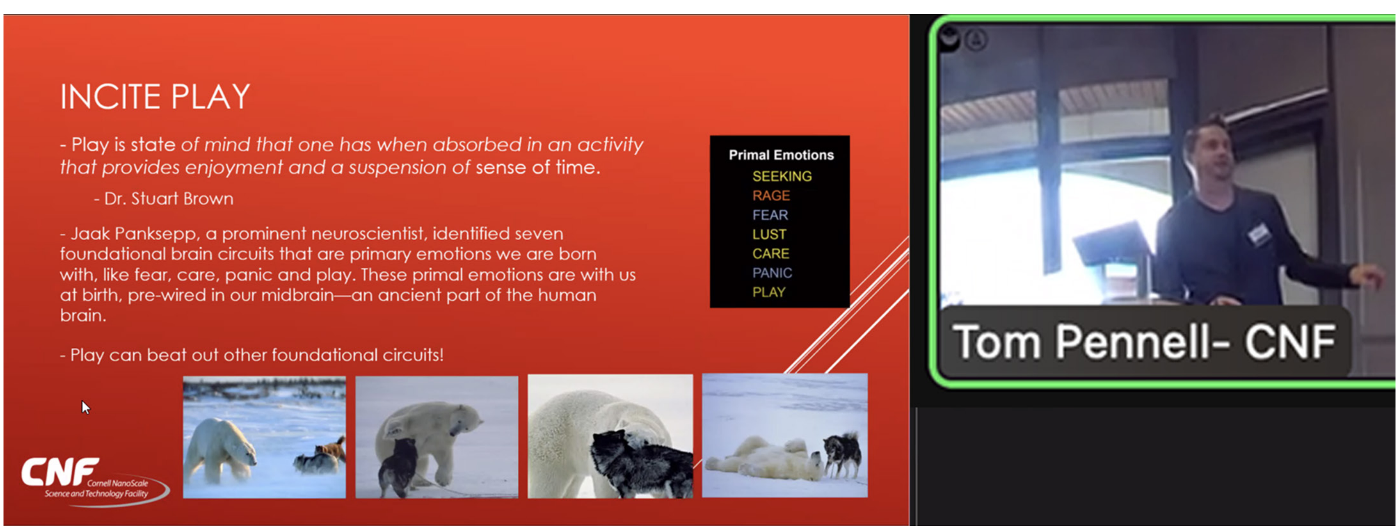
Of the over 4,000 CNF visitors last year, more than 25% were K-12 students. Group sizes ranged from small local science classes to the big unveiling of our VR cleanroom experience with our 4H partners at the New York State Fair. We took every opportunity to educate the public this year, and had a massive impact!

It was also a big year in the area of workforce development. The open and accessible nature of our facility makes us a prime resource for workforce development activities both regionally, and across the country. We continue to expand our partnerships with Tompkins Cortland Community College and Tompkins Seneca Tioga BOCES, with several exciting new programs on the near horizon.

We spend a lot of time focusing on the incredibly small, while making big plans to shape the future. Planets and moons are formed from dust in space mating with other dust in space and coalescing over time into a finite structure. Each particle of dust mating with another, forms an increased gravitational pull, drawing others in. 2023 has been a gravitational year for CNF's education and outreach and workforce development program. We are forming new and exciting partnerships almost daily. A year ago, these endeavors seemed very amorphous…disorganized.

CNF recognizes that Education and Outreach and Workforce Development are not independent activities. STEM education is a pathway toward a rewarding career; therefore, we aim to engage all age groups from "K-Gray" in nanoscience and show them the many opportunities this field has to offer. This mindset has allowed us to bring shape and form to these activities and move toward meeting the needs of the growing US semiconductor industry.

There are many great things to come in 2024. Stay tuned! For more information on CNF's education and workforce development programs, please contact me at pennell@cnf.cornell.edu



As Micron Builds, Cornell NanoScale Facility Develops a Workforce

By Caitlin Hayes
Cornell Chronicle
January 31, 2024

The ATLAS Program, Year Two

On a snowy morning over winter break, the only sound in Duffield Hall's large, empty atrium was a faint clanking. In a hallway across from the Cornell NanoScale Science and Technology Facility (CNF), the sound grew louder, and through an open classroom door: seven high school students were elbow deep, wrenches and screwdrivers in hand, in a machine worth more than a half-million dollars.

Students pulled out gauges, pistons, power sources, gas and water lines, devices within devices – they were taking the machine entirely apart, to learn how it was put together in the first place.

"It was fun, and it became very apparent how many companies and small parts and just engineering went into it," said Elyas Talda, a senior at Ithaca's Lehman Alternative Community School who participated in a new program run by CNF to provide public high school students with a foundation in nanoscale science.

Later that week, the students would use the same machine, a plasma deposition system, in CNF's cleanroom to reproduce the program's logo on a silicon wafer. Deposition is used to create the circuits and chips that run smartphones, cars, computers – that run our society, said Thomas Pennell, education and outreach coordinator and a process integration specialist at CNF, as well as lead instructor for the two-week ATLAS (Accelerated Training for Labor Advancement in Semiconductors) Program, that ran Jan. 8-19.

"The goal is to give the students, in a very compact format, a really good view of all the things you can do in the microfabrication environment as well as cleanroom career paths," Pennell said.

The program is part of a larger effort at CNF to help prepare a regional workforce for the opportunities ahead — as Micron Technology prepares to break ground in Clay, New York, on what may become the largest microchip fabrication facility in the country. Micron alone could bring an estimated 50,000 jobs to the region, but many of those jobs will require some degree of training.

"We want engineers and technicians who are ready to work in semiconductor technology or nanotech areas, and they need hands-on experience in fabrication from start to finish — there are not many schools that have the facilities and technical staff to deliver that," said Judy Cha, the Lester B. Knight Director of the CNF and professor of materials science and engineering in Cornell Engineering. "CNF really hits all the notes — it can fill this critical need."

For Pennell, workforce development is inseparable from education and outreach, and he's forged partnerships with multiple area schools, from colleges

to elementary schools. In 2023, CNF's outreach efforts engaged more than 4,000 people.

"My wanting to be a scientist didn't start when I got to college," Pennell said. "It probably started when I opened my first Lego set. So, I see education and outreach as a continuous pathway to workforce development. And the outreach is really rewarding. If I hear a kid say, 'That's so cool,' just once during the day, I got the win."

Broadening Perspectives

Now in its second year, the ATLAS Program works with students enrolled in the Tompkins-Seneca-Tioga Board of Cooperative Educational Services (TST-BOCES) New Visions Engineering Program, a yearlong program held on Cornell's campus that prepares high-achieving, college-bound high school seniors for majors in engineering,

In the ATLAS Program, the students receive extensive training for and unprecedented access to CNF's cleanroom, a lab space specially designed to reduce particulates that could interfere with research and the fabrication of nanoscale devices.

BOCES students tour the cleanroom, learn about safety protocols, and the many machines that help researchers make and study new materials and various devices, from microchips to nanoscale robots. They tour the elaborate infrastructure that supports the cleanroom as well, with miles of steel tubing, an HVAC system that never sleeps and four kinds of water for various uses.

The group then takes a three-day online course, Technology and Characterization at the Nanoscale, open to the public and offered online in January and in-person in June, that teaches participants the processes and techniques needed to create a nanoscale device. After deconstructing the plasma deposition system, purchased for a small fee from a facility that was no longer using it, the students head straight back into the cleanroom to put what they've learned into practice by making their own device.

"You don't have many experiences like that in high school, where you can learn about it and then actually do it and see the results," said Mckenna Crocker, a senior at Dryden High School. "I had this one idea of what nanoscience is, but now we've seen how complex it is and how many professions you can have."

Many students echoed Crocker, saying the program broadened their sense of engineering and possible careers, giving them a better sense of what research looks and feels like, and the sheer volume of engineering that goes into something as small as a smartphone.

"I think it made us less stubborn and more open-minded about the kinds of engineering we were interested in," said Zak Eshelman, a first-year student at Clarkson University who participated in the ATLAS program last year, with 14 other seniors. "We gained an appreciation for the other disciplines in engineering, and what fabrication is and what goes in to creating these devices. I think that's pretty important for young scientists and engineers to learn."

New Visions Engineering course instructor David Syracuse said the ATLAS Program both humbles students — by introducing them to something totally new — and empowers them. He noted how careful students were in preparing to go into the cleanroom, helping each other with the requisite full-body gowns, hoods and booties.

"They realized what a remarkable opportunity it was," he said. "It means a lot. When I say to a kid, 'I trust you to do this,' it gets them thinking, it gives them confidence and really has an impact."

Meeting the Moment

While Pennell works on ways to scale up the ATLAS Program to reach more students, he's actively pursuing numerous additional programs to fulfill CNF's potential as a leader in education and workforce development.

Julius Won, a senior at Lehman Alternative Community School, works to deconstruct a plasma deposition system during a two-week training in microfabrication, hosted by the Cornell NanoScale Facility.

CNF is launching a pilot with the TST-BOCES welding program in February to train students in the specific kind of welding needed for a cleanroom facility — ultra-high-purity gas line welding — with hopes to expand that program next year to other BOCES welding programs in the state. With Tompkins Cortland Community College, CNF is in the process of developing a credential program, with two trainings available already, where students can supplement their associate's degree in engineering with trainings in the CNF cleanroom – and enter directly into the workforce upon graduation.

These programs are in addition to workshops and demonstrations Pennell runs in schools, at museums and science centers, the New York State Fair, and more; last year, he coordinated and organized three Chip Camps for 120 middle schoolers with collaborators at Micron.

"A lot of partnerships are blooming," Pennell said. "We went big last year in our outreach, and we're hoping to make this year even bigger."

For CNF, the increased emphasis on outreach — and Cornell's increased engagement with the microchip industry — is in response to a need in the region, and in the country. The CHIPS and Science Act, signed into law in 2022, aims to establish microchip manufacturing in the U.S., reduce reliance on other countries, and secure supply chains for what has become an essential commodity.

"The CHIPS and Science Act really is historic, something I realized in the midst of so many initiatives and inquiries coming to CNF. It's a moment to rise up and ride this seismic shift," Cha said.

"People have always looked to CNF for leadership in nanoscale research, but now they're also doing it for workforce education and development. It's a big opportunity. We are excited, and we're ready."

Now in its second year, the ATLAS Program works with students enrolled in the New Visions Engineering Program, a yearlong program held on Cornell's campus that prepares high-achieving, college-bound high school seniors for majors in engineering.

A Few More Scenes of CNF Outreach with Tom Pennell!

CNF FLL Explore Expo 2024 Photos Now Online!

We extend our heartfelt appreciation for the dedicated participation and hard work of the 26 teams that joined the CNF LEGO Expo this year. Each team's unwavering enthusiasm and commitment were palpable throughout the event, serving as a source of inspiration for all involved. The positive guidance and encouragement from each coach undoubtedly ignited the aspirations of countless young minds.

We especially thank Dr. Xinwei Wu for organizing the Expo and Don Tennant for getting so many great photos!

We had too many fabulous volunteers to list them all — just know we appreciate you so much!

Enjoy the photograph album now on the main CNF LEGO EXPO website below.

https://www.cnf.cornell.edu/education/lego

Career and Technical Education
Innovative Program

Otsego Area Occupational Center
P.O. Box 57, Milford, New York 13807
607-286-7715
Cell: 607-287-0079

November 20, 2023

Cornell University
616 Thurston Aue
Ithaca, NY 14853

Dear Cornell University Faculty, Staff, and Students

I would like to thank you on behalf of the New Visions Engineering class of 2024 for taking the time to show us your engineering facilities. The tour of CESR was one of the most memorable parts of our time at your University. While we were in the tunnel, we were told how 200 pans were used to solve the problem of binding materials. It showed us how sometime the most complicated problems can have the simplest solutions.

The time we spent in your Biomedical Engineering and Nanoscale Science and Technology Facilities was an enlightening experience. The idea of the heart being referenced as mechanical engineering opened our minds to a whole new way of thinking about the human body. All of us were amazed by the various kinds of work being done in your clean room and consider ourselves lucky to have been able to see machines that create objects at the nanoscale level. Thank you for our very own clean suits.

Many of us were inspired by the accomplishments made by the students in the Combat Robotics, Autonomous Underwater Vehicle, and Baja teams. The robot Florence was one of our favorite robots because of its uniqueness. When we design robots later in our school year we hope strive for that level of creativity. We recently did a research paper on AI and seeing how a submarine can use AI to complete and obstacle course amazed us. At the present time we are working on 3D printing so when we learned that you can 3D print custom parts for the Baja team it sparked some new interests in us. Especially since several of us are interested in mechanical engineering.

Thank you again to everyone who took the time to make our trip to Cornell University unforgettable.

Sincerely,

Victoria E. Stevens and the New Visions Engineering Class of 2024

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