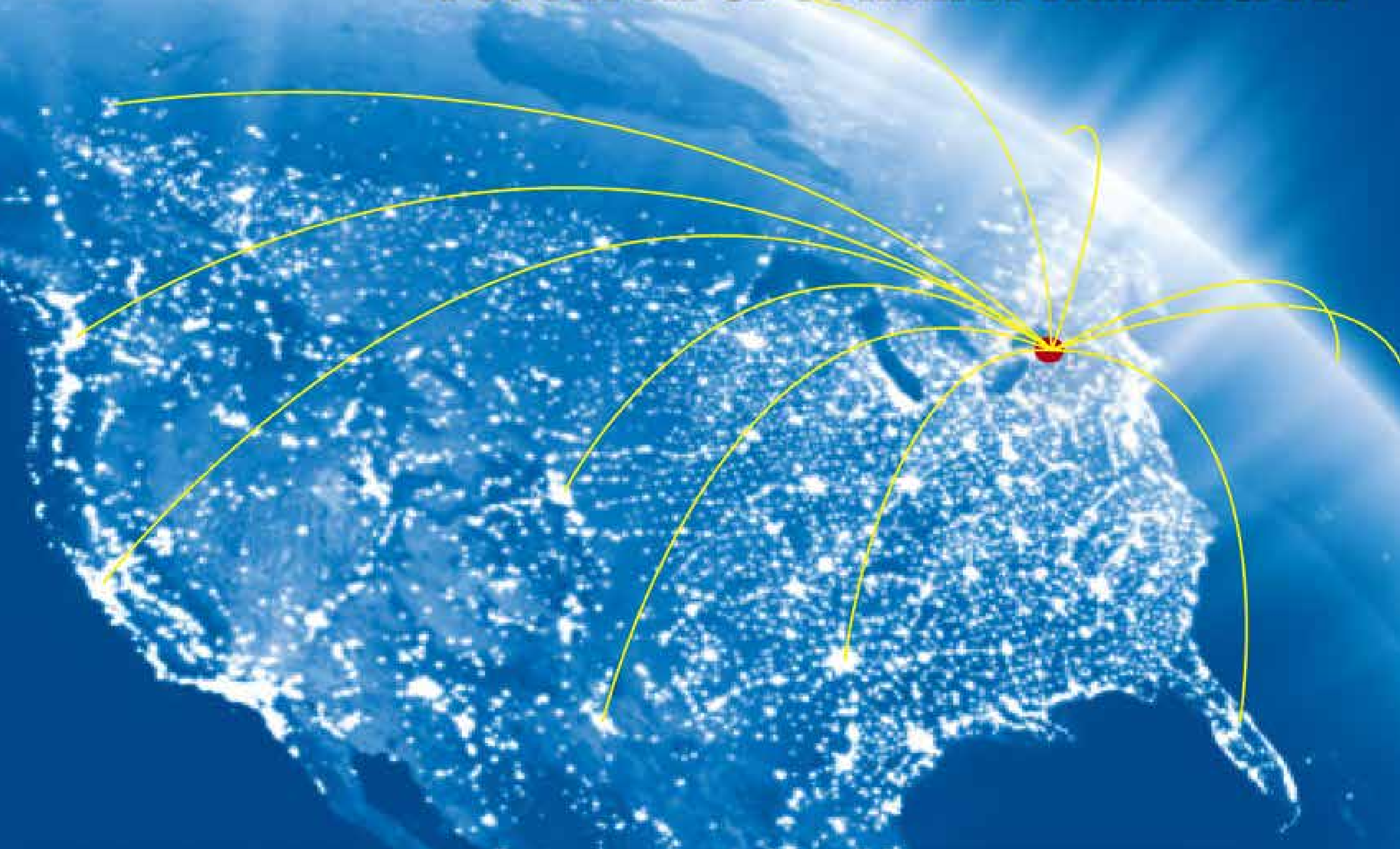
CNF
Cornell NanoScale Science and Technology Facility

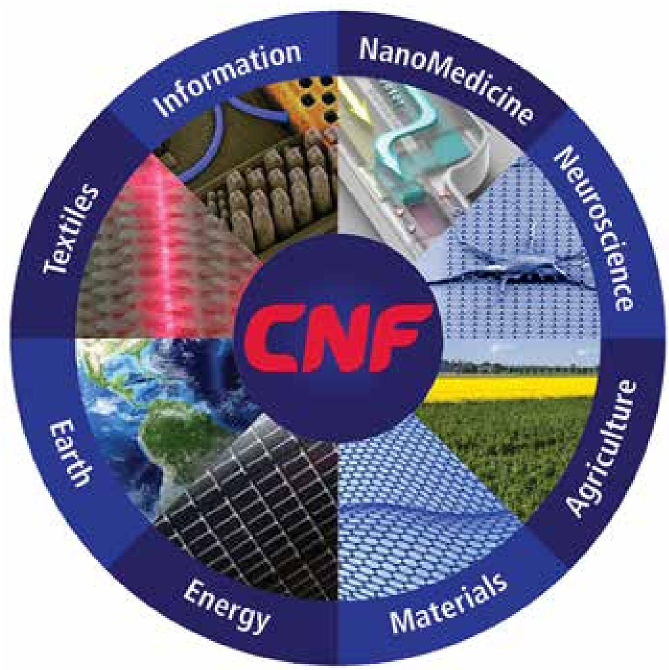
EQUIPMENT

PROCESSES

EXPERTISE

Enabling nanoscale research & commercialization





Open Access in Every Nanoscale Research Field

CNF Equipment Resources
include a tool set valued at over $160M, designed for 4-inch and 6-inch wafer sizes, and other variations.

CNF Staff Resources
include twenty scientific and technical staff, plus administrative staff, who together provide on-site user support, advice, training, and process support.

CNF Staff Backgrounds
include biology, chemical, electrical and mechanical engineering, materials science, and physics.

The Cornell NanoScale Science & Technology Facility (CNF)

is a national user facility that supports a broad range of nanoscale science and technology research projects by providing state-of-the-art resources coupled with expert staff support. We provide the interactive and exciting learning and practicing environment that is critical to completing successful cutting-edge research.

Since 1977, projects at CNF have encompassed physical sciences, engineering, and the life sciences, with a strong interdisciplinary emphasis. Currently, over 500 researchers per year (50% of whom come from outside of Cornell) use our fabrication, synthesis, characterization, and integration resources to build structures, devices, and systems from nanometer to micrometer length-scales.

On a regular basis, new researchers from academia, industry, and government laboratories partake in our New User Training and learn to use CNF tools to carry out their research projects — from development to commercial prototyping.

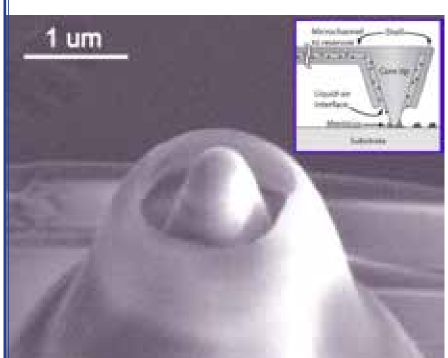
CNF combines materials & expertise to address research across disciplines.

Research Fields @ CNF

Find our research accomplishments online for summary reports of current research • http://www.cnf.cornell.edu/cnf5_research.html

Chemistry & Chemical Nanotechnology

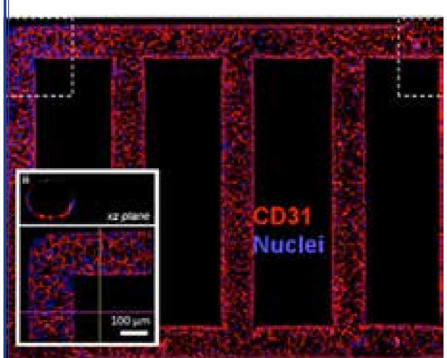
The most revolutionary part of nanotechnology comes from the manipulation of individual molecules and the building of functional nanostructures from the bottom up. Examples include self-assembled monolayers, dendrimers, functionalized nanotube structures, etc. Many of the applications in this realm of nanotechnology continue to be realized with a base of successful processes being formed. Within more traditional areas of chemistry, nanotechnology enables chemical sensor and chemical mixing systems using microfluidics. And in combination with optics and electronics, chemistry also drives the development of new materials and processes for nanostructure fabrication and synthesis.



Nanofountain probe for molecular inks. Espinosa group (Northwestern)

Life Sciences & Medicine

Nanoscale structures and devices can be used to simulate biological structures, sort or detect cells or molecules, manipulate fluids, or control cell growth, for example. Also, the power of microelectronics and micromechanical systems (MEMS) can be harnessed to fabricate specialized electrical probes for in vivo *studies. Next, surfaces can be modified by patterning or adsorption to change bioactivity, promoting cell growth, attachment, or specialization. When biological material must be deposited or patterned, processes raise materials compatibility issues. CNF has special facilities and staff expertise for addressing these compatibility issues.*



Living blood vessels* in vitro *for studies of angiogenesis and clotting. Stroock group (Cornell)

MEMS & NEMS

Micro- and nanomechanical systems make use of the full range of CNF-processing capabilities, including advanced lithography, thin film etching, and thin film deposition. Applications include both sensors and actuators, either stand-alone or integrated with electronics. Mechanical structures are routinely fabricated in single crystal silicon, oxide, nitride, and polysilicon, and less commonly in glass, silicon carbide, metal, and plastic. Microfluidics is a rapidly growing subfield, often bridging together MEMS, NEMS, biology, and chemistry.

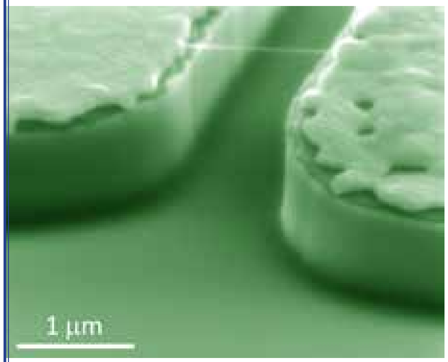
A single MEMS-based piezoelectric vibrational energy harvester cantilever; static position (inset) and vibrating at 58 Hz at 0.5 g. (Microgen)

Research Fields @ CNF

Find our research accomplishments online for summary reports of current research • http://www.cnf.cornell.edu/cnf5_research.html

Nanoscale Electronics

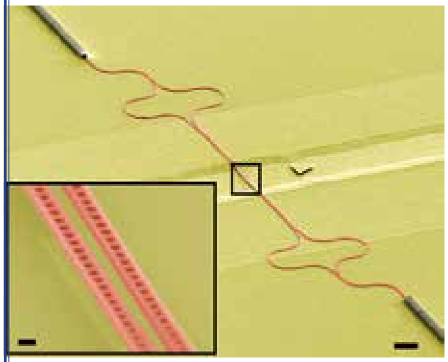
Microfabrication has enabled advances in electronics for almost sixty years. With advanced nanotechnology, even more advanced devices are possible. CNF supports silicon, carbon, compound semiconductors, and other two-dimensional materials — with patterning down to 10 nanometers (nm). In addition, novel structures including nanotube devices, spin-based devices, and single molecule devices have been explored. Integration of electronics with MEMS, optics, and microfluidic devices can result in powerful new functional nanostructure devices.



Suspended carbon nanotube device for biosensing. Minot group (Oregon State University).

Optics & Optoelectronics

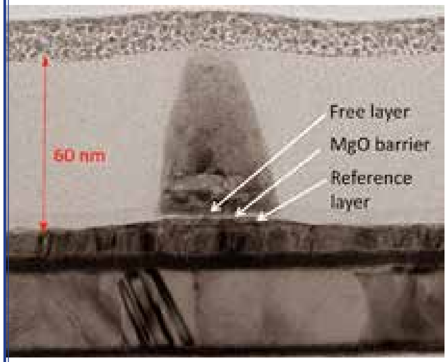
Nanotechnology makes possible a variety of new optical and optoelectronic structures, including lasers, waveguides, diffraction gratings, optical switches and modulators, photodetectors, and photonic crystals. CNF has extensive experience and appropriate technologies for fabrication of optical structures in materials including silicon, quartz, compound semiconductors, and plastic.



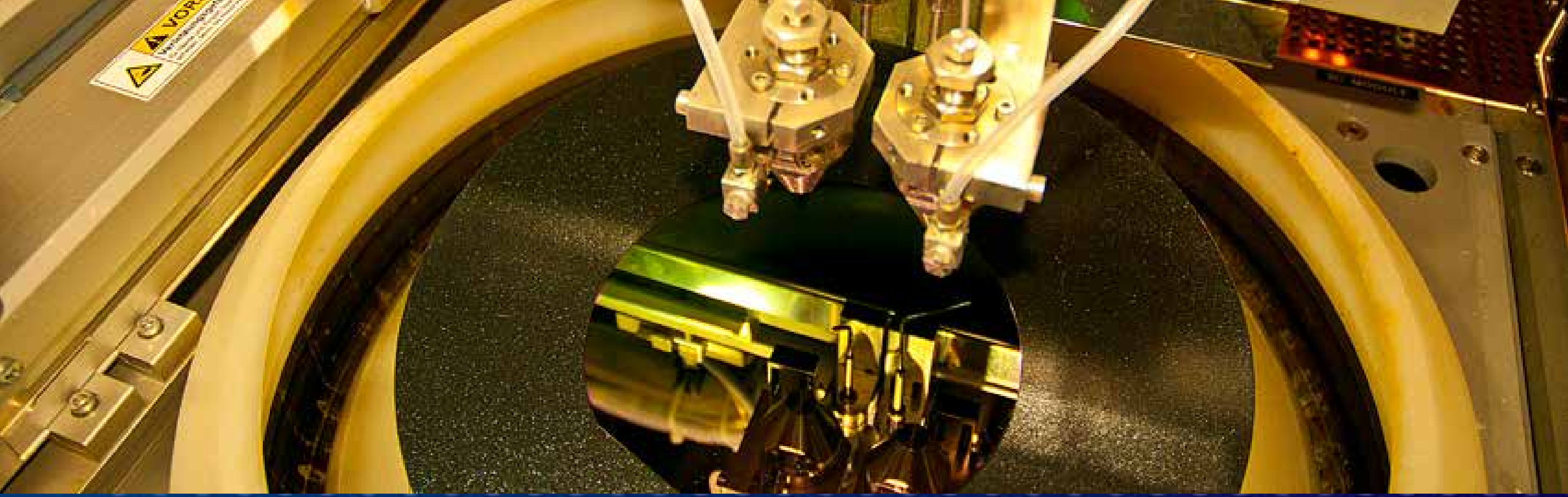
Suspended photonic crystal EBL nanobeams for optomechanical tuning of optical filters. Lončar group (Harvard).

Physics & Nanostructures

Because of the small dimensions, nanotechnology enables direct observation of many quantum phenomena that would not otherwise be possible. Measurements of conductivity of single molecules, conduction through small junctions with few defects, as well as observations of magnetic scattering of spin-polarized currents are possible. High resolution electron-beam lithography (EBL) and sensitive instrumentation, including scanned probe microscopes, enable many of these experiments. EBL systems can reproduce pattern features and gaps below 10 nm.



A 40 nm magnetic random access memory device. Kent group (NYU and Spin Transfer Technologies)



CNF Cleanroom

- Founded in 1977, current CNF cleanroom opened in 2004
- 17,000 square feet of Class 1000 space
- Available 24 hours a day, 7 days a week
- Hourly usage fees for equipment
- Accommodates primarily 100 mm and 150 mm wafers, plus variations (pieces, etc.) and limited 200 mm wafer capability

Lithography

- Contact photolithography
- Electron-beam lithography
- Nanoimprint lithography
- Projection photolithography
- Photomask fabrication

For contact photolithography, CNF offers three contact aligners, including an ABM, a SÜSS MA/BA 6, and a SÜSS MJB4, with options for a variety of near ultraviolet (UV) and deep UV exposure wavelengths, front and back side alignments, and aligned wafer bonding on wafers up to 150 millimeters (mm) in diameter.

CNF maintains a full complement of photolithography tools, including an ASML PAS 5500/300C Deep UV Stepper, and GCA i-line and g-line steppers. Together they provide users with a flexible tool set capable of performing exposures with feature sizes less than 200 nm on substrates ranging from 5 mm pieces to full 200 mm wafers. CNF lithography processes are supported by both manual resist processing systems and by a SÜSS Gamma Automated Resist Processing Platform with both spin and spray resist capabilities.

CNF excels in the application of electron-beam lithography (EBL) to research areas ranging from electronic devices and integrated optics to the emerging fields of NEMS, nanobiotechnology, and nano-magnetics. We currently meet user demand with two high-resolution direct write EBL tools: a JEOL JBX 9500FS and a JEOL JBX 6300FS. Together, these systems provide the most versatile and advanced EBL resources anywhere in the country, with unsurpassed resolution and alignment. Samples from small pieces to 300 mm wafers can be handled. These systems are available and accessible to researchers from around the world. Our qualified staff has a proven track record of guiding CNF users through complex projects using EBL and EBL-related processes, routinely integrating work at the sub-20-nm level.

Thin Film Deposition & Growth

- Plasma chemical vapor deposition (CVD)
- CVD of graphene, SiO_2, SiN, polysilicon
- Evaporation & oxidation
- Molecular monolayer vapor deposition
- Nanotube and nanowire growth
- Sputtering

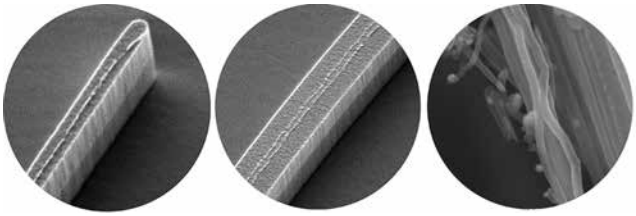
Thin Film Etching

- Reactive ion etching (RIE)
- Bosch™ deep RIE in silicon
- Deep RIE in silicon dioxide
- Ion milling
- Plasma etching
- Xenon difluoride release

CNF has over a dozen reactive ion etching (RIE) systems to meet the demands of different materials, gases, and excitation sources. The Oxford Cobra NGP100 shown here is configured for nanoscale etching using HBr for silicon photonics applications and methanol for magnetic materials. The system is an inductively coupled plasma (ICP)-based platform with a 380 mm plasma source. This large source, combined with the large 240 mm electrode diameter, allows for highly uniform etching over a 200 mm sized area. The ICP is powered with a 3 kw radio frequency (RF) generator operating at 2 megahertz (MHz) achieving plasma densities over $10^{12}/cm^{-3}$ enabling high etch rates and selectivities. Other RIE systems include tools for Bosch™ deep silicon etching and ICP tools for etching of silicon dioxide and III-V semiconductors.

The AJA Ion Mill provides pattern transfer, using argon ion sputtering, for materials not amenable to reactive ion etching. It features a 22 cm diameter Kaufman RF-ICP gridded ion source producing a collimated argon ion beam for uniform etching of samples up to six inches in diameter. The sample holder is water cooled at 20°C, has motorized tilt (0-180°), and continuous sample rotation up to 25 RPM. It is most commonly used for etching magnetic materials.

The FIRST Nano CVD Furnace is used to grow graphene and carbon nanotubes on samples up to 4-inch diameter using a variety of hydrocarbon gas sources. This tool is also used for hydrogen and vacuum annealing up to 1000°C.



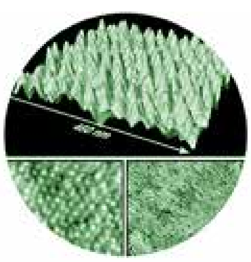
Inspection & Characterization

- Atomic force and scanning electron microscopy
- Confocal and fluorescence microscopy
- Electrical and optical characterization of films and coatings
- Focused ion beam
- Spectroscopic ellipsometry
- Other scanned probe characterization

Other Wafer Processing

- Chemical mechanical polishing
- Polymer ashing
- Potassium hydroxide (KOH) etching
- Rapid thermal anneal/oxidation
- Wafer bonding
- Wafer dicing

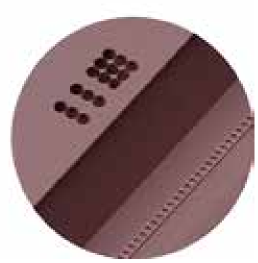
Since the beginning, the processing and characterization of silicon and III-V semiconductor materials have been a strength of the CNF. In recent years, nanostructured materials including nanotubes, nanowires, and nanocrystalline particles have become an integral part of the research conducted in the facility. Studying the fundamental make-up of these materials by fabricating structures to explore their chemical, mechanical, optical and electrical properties is currently an area of intense investigation. The design, analysis and application of soft materials — polymers and biologics — has also grown into a major body of ongoing work at CNF.









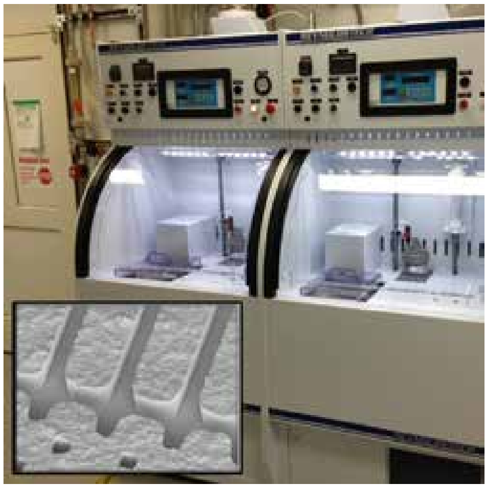
Nanomaterials

- Biological coatings and templates
- Nanotube and nanowire growth
- Nanocomposites and self-assembly
- Nanoparticle synthesis and coatings

Supporting Processes

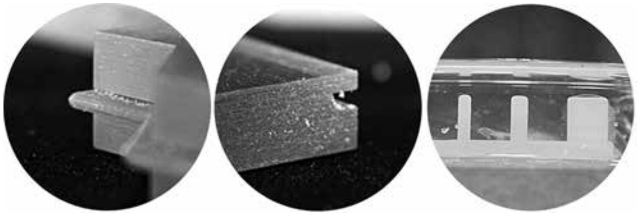
- Electroplating
- Microfluidics fabrication and probe station
- Nanomanipulation
- Three-dimensional and InkJet material printing

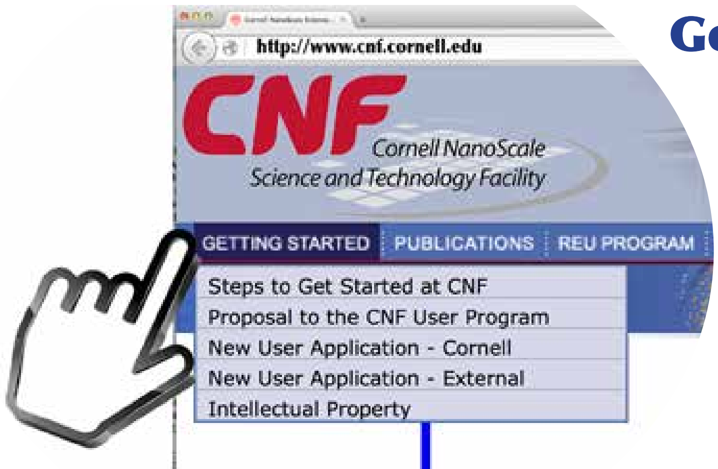
Using the ObJet 3D Printer, CNF researchers can print prototypes and working devices in a matter of hours. The printer accepts .STL files from a wide variety of 3D CAD software. The printer slices the CAD files into 16- or 28-µm-tall layers, then prints and cures each layer simultaneously. A freshly printed device can be handled immediately, and a gel support material that surrounds the edges and fills in overhangs can be removed by spraying with water or a dilute base. The system is most commonly used for fabrication of templates, jigs, and connectors for microfluidic devices.



CNF offers three custom electroplating stations for substrates up to 150 mm diameter. Dedicated systems are provided for copper and gold, with a third station most commonly used for nickel. Applications include electroplating copper for damascene wiring, electroplating into resist molds to form high aspect ratio structures, and deposition of thicker films (>5µm) on substrates. Inset: Over 2 µm of copper electroplated on a platinum seed layer using a photoresist mold.

Atomic Layer Deposition (ALD) offers the opportunity to create precisely controlled structures for advanced semiconductor and other nanotechnology applications, by creating ultra-thin films on nanometer and sub-nanometer scales. A unique property of the Oxford ALD FlexAL is its ability to deposit material conformally into high aspect ratio features. This technology is widely regarded as a key enabler of the next generation of smaller semiconductor devices.





Getting Started @ CNF!

Setting up a new project or user can take a week or two to ensure we have all the details and requirements necessary. Once we have your project particulars, we will arrange your three-part New User Training. Many users get started @ CNF within a few weeks of first contact!

Weekly technical discussions allow you to call in and discuss your project with staff, to organize your processes and trainings before arrival.

Project Support

Research projects require a complex interplay of constituent materials and processing techniques to achieve a desired outcome. The successful researcher must consider process flow and the influence of each procedure on the final device performance.

The CNF offers the depth and breadth of tools, well characterized processes, and extensive staff expertise to bring considerable capability and insight to the inevitable choices a researcher must make to complete a project.

CNF Annual Meeting

Our annual meeting is an excellent opportunity for the public and scientific communities to learn about exciting research carried out by CNF users.

If your company would like to sponsor our Annual Meeting, please contact us!

NNCI & CNF

To advance research in nanoscale science, engineering and technology, the National Science Foundation is providing funds for five years to support sixteen sites, including CNF, as part of the new National Nanotechnology Coordinated Infrastructure (NNCI).

CNF Short Course: Technology & Characterization at the Nanoscale (CNF TCN)

This 3.5 day intensive short course, typically held twice a year in January and June, combines lectures and laboratory demonstrations to impart a broad understanding of the science and technology required to undertake research in nanoscience.

The CNF TCN is an ideal way for faculty, graduate students, post docs and staff members to rapidly come up to speed in many of the technologies that CNF users to employ.

We encourage everyone expecting to become a CNF user to attend this course.

Learn more at http://www.cnf.cornell.edu/

CNF Programs for K-12, 4H, and Undergraduates

Some of our best days are spent introducing our nanoworld to young minds. While we cannot take K-12 groups into the cleanroom, we have a variety of resources to demonstrate nanotechnology concepts at an age-appropriate level. School groups visit for our hands-on experiments, nanotech discussions, and tours of the building.

For our summer internships, the CNF Research Experience for Undergraduates (REU) Program, we bring five or more undergraduate students from around the United States to work on a well-defined and independent ten-week research project. With over 25 years of programs, the CNF excels at training its REU interns to perform their own research.

Nanooze

We regularly publish **Nanooze**, a magazine specifically designed to interest and engage young people in nanotechnology and in science. Over 100,000 copies of each issue are distributed free to classrooms around the country. Visit the website below to have your school added to our mailing list.

http://www.nanooze.org/

Commercialization & Intellectual Property

CNF has partnered with New York State, local business incubators and foundry facilities to provide commercialization opportunities for our users. Researchers working at CNF on products of the future can now develop fabrication processes with an eye toward scaling from R&D to production by incorporating the tool maps into their planning at an early stage, and may be eligible for tax incentive programs from NYS.

Access to the CNF is open to all qualified researchers and projects on an equal basis. Researchers pay user fees based on actual tool time, so there are no high up-front costs. This makes CNF an attractive alternative to setting up one's own multi-million dollar nanofabrication lab. CNF is particularly well-suited to start up company and Small Business Innovation Research (SBIR) efforts. Dozens of small companies have taken advantage of our expertise and tool set to develop and test their first products prior to establishing their own facilities. Other companies have used CNF to successfully compete and complete SBIR Phase I and II projects. Because CNF operates as a user facility, companies can easily protect their intellectual property.

At CNF, your intellectual property remains yours.

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• The photographs and research images in this brochure were provided by CNF staff and users, and Cornell University Photography. •

• This brochure was printed on 10% post-consumer paper using soy-based inks. Please mind the environment and reduce, reuse, and recycle! •

Get Started @ http://www.cnf.cornell.edu/cnf5_steps.html

CNF Cornell NanoScale Science and Technology Facility

Cornell University

NYSTAR®

NSF

Three ways to follow us! @CornellCNF @CNFUsers @CNFComputing

The CNF is supported by the National Science Foundation, the Empire State Development's Division of Science, Technology and Innovation (NYSTAR), Cornell University, industry, & our users.
The CNF is a member of the National Nanotechnology Coordinated Infrastructure (NNCI).