Advanced E-beam Lithography

For several decades, electron beam lithography (EBL) has been the primary technique for defining, patterning and connecting experimental structures at the nanoscale. Since its inception in 1979, the Cornell NanoScale Science and Technology Facility (CNF) has remained at the forefront of nanofabrication research by providing state-of-the-art EBL tools to the academic and industrial research community. CNF has excelled in the application of EBL to research areas ranging from electronic devices and integrated optics to the emerging fields of nanoelectromechanical systems (NEMS), nanobiotechnology and nanomagnetics. Breakthroughs in these fields are a direct consequence of the unique lithographic processing capabilities developed at CNF over the past 25 years, which include:

- The ability to reproducibly achieve feature sizes below 30 nm.
- Multilayer EBL with less than 20 nm overlay.
- Mix and match EBL and photolithographic processing.
- Nanoimprint template fabrication.
- Patterning on thin silicon and silicon nitride membranes.
- Substrate handling from small pieces to 300 mm wafers and 3” to 9” photomasks.
- Writing at 25, 50 and 100 keV accelerating voltages.
- Minimum address grid of 1 nm.
- Writing currents from 50 pA to 100 nA at 100 KeV.
- Process integration through a complete suite of techniques encompassing silicon and compound semiconductors and other hard and soft materials.
- Multilayer resist processing for 3-D structures such as T-gates.
- Ultrahigh resolution patterning on thin film membranes.
- Flexible pattern generation including curves and algorithmically defined structures.

As with all CNF facilities, these advanced E-beam capabilities are available to all users from around the country. CNF provides open user access with staff support for accomplishing technical objectives in an efficient manner.
CNF currently meets the demands of scientists working in the broad field of nanoscale science and engineering by providing two high resolution direct write EBL tools: a Leica VB 6-HR and a JEOL JBX 9300FS. These systems are available 24 hours a day year round and are accessible to users from across the country through our user program. Our qualified staff has a proven track record of guiding users through complex processing using EBL and training them in all aspects of EBL related processing. Combined with a full suite of optical lithography, thin film growth and deposition, thin film patterning, advanced metrology equipment, modeling, and extensive integration capabilities, CNF is the right place to explore the world of nanoscale science.
2. Rectangular cantilever with a 50nm Au dot at the free end used for attogram detection of selective binding of self-assembled monolayers (Scale bar 5 micrometers). Inset shows a zoomed in portion of the 50nm dot.

3. Vertically aligned carbon nanofiber grown from 50 nm diameter Ni catalyst pattern, using plasma enhanced chemical vapor deposition.

4. Log periodic antenna coupled to Niobium microbolometer for use as an infrared photodetector.
LEICA VB 6-HR

- Accelerating Voltage: 100 kV, 50 kV
- 16-bit Pattern Generator
- Pattern Generator Speed 25 MHz
- Field Size 300 μm with a 5 nm address grid
- Field Size 500 μm with a 8 nm address grid
- Less than 20 nm minimum resolution
- Overlay: ± 40 nm mean plus 3σ
- Stitching: ± 30 nm mean plus 3σ
- Maximum wafer size: 8”
- Maximum write area: 6”

A biomimetic approach to color generation based on a butterfly wing: a multigap diffraction grating with high viewing angle.

Oblique angle electron micrograph of an AlGaAs ring resonator side-coupled to an optical waveguide.

Surrounding-gate depletion mode NMOS Si FinFET device fabricated to study low frequency noise in MOSFETs.
Advanced lithography by itself is only part of the story. In its new 16,000 sq. ft. clean room in Duffield Hall, CNF houses approximately 80 major fabrication and characterization tools, with a replacement cost in excess of $100 Million. These include contact lithography, g-line and i-line steppers, two 100 KeV electron beam lithography tools, evaporators, sputtering systems, CVD, furnace processes, and over a dozen different dry etching tools. Over 700 users from 200 institutions access CNF each year. With over 5 new users each week, our training schemes are well-developed. New users can expect to be working productively in the laboratory within a few days of arrival.

Access to CNF is open to all qualified projects on an equal basis; from Cornell, from other universities, and from large and small companies. All users pay user fees, but they are based on usage time so there are no large up front costs. Due to the large number of users, fees can be kept relatively low, making CNF an attractive alternative to setting up a nanoscale laboratory.

CNF is particularly well suited for start up companies and SBIR efforts. Dozens of small companies have developed their first products using our facilities, prior to establishing their own development and production facilities. Many other companies have used CNF facilities to successfully compete and complete SBIR phase I and II projects. The versatile tool set supports projects in all areas on nanoscale technology. Experienced process engineers can be particularly effective in the CNF environment.

Because CNF operates as a user facility, companies can easily protect their intellectual property. CNF staff instruct and assist, but under normal circumstances do not collaborate with users. Your intellectual property thus remains yours.

As a member of the National Nanotechnology Infrastructure Network (http://www.nnin.org/), CNF users have access to the facilities of other major nanotechnology laboratories, as necessary, to complete their projects.
Selected Recent Publications by CNF EBL Users

**Attogram detection using nanoelectromechanical oscillators**  

**Reduction of spin transfer by synthetic antiferromagnets**  

**Nanoscale thin single-crystal silicon and its application to electronics**  

**Vertically aligned carbon nanofiber-based field emission electron sources with an integrated focusing electrode**  

**Current-Induced Nanomagnet Dynamics for Magnetic Fields Perpendicular to the Sample Plane**  

**A tunable carbon nanotube electromechanical oscillator**  

**Determination of electron orbital magnetic moments in carbon nanotubes**  

**Microwave oscillations of a nanomagnet driven by a spin-polarized current**  

**Nanotaper for compact mode conversion**  

**Nanometer-scale scanning sensors fabricated using stencil lithography**  

**Magnetization reversal in arrays of Co rings**  

**Coulomb blockade and the Kondo effect in single-atom transistors**  

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For a virtual tour please go to:  
http://www.cnf.cornell.edu/cnf_virtualtour.html

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