A National Nanotechnology User Facility

Working with Industry, Academia, and Government
THE CENTER FOR NANOSCALE SCIENCE AND TECHNOLOGY

The Center for Nanoscale Science and Technology (CNST), part of the National Institute of Standards and Technology (NIST), is the Department of Commerce’s nanotechnology user facility. The CNST enables innovation by providing rapid access to the tools needed to make and measure nanostructures. These tools are available to all researchers, both inside and outside NIST, with a particular emphasis on supporting industry. Visit us at nist.gov/cnst.

In the **NanoFab**, work with commercial state-of-the-art tool sets at economical hourly rates, and get help from a dedicated, full-time technical support staff.

In the **NanoLab**, access the next generation of tools and processes through collaboration with CNST scientists who are developing new measurement and fabrication methods to meet national nanotechnology needs.

Robert Celotta, Director
James Kushmerick, Deputy Director
A NATIONAL NANOTECHNOLOGY USER FACILITY

The CNST serves researchers from industry, academia, NIST, and other government agencies.

Our state-of-the-art research NanoFab offers:

- A comprehensive tool set, including advanced capabilities for lithography, thin-film deposition, and nanostructure characterization
- Reliable, reproducible processes maintained by a professional staff
- Quick access at economical rates—submit the short application at any time; get started in a few weeks
- Training and advice provided by experts
- Fabrication and characterization support available—let us do the work

Our NanoLab with world-class researchers offers:

- Collaborative research with unique instruments and nanofabrication methods
- Exciting opportunities for postdoctoral researchers, visiting scientists, and engineers
- A broad research portfolio with emphasis on these thematic areas:
  - Nanofabrication and nanomanufacturing
  - Nanoscale imaging and spectroscopy
  - Future electronics
  - Nanobiomedicine

Resources (FY 2016): Budget: $38.2 million, Staff: 145 (133 Technical)
STATE-OF-THE-ART

The NanoFab provides researchers with rapid access to state-of-the-art, commercial nanoscale measurement and fabrication tools and methods, along with associated technical expertise, at economical hourly rates. It is well-equipped to process and characterize a wide range of nanoscale materials, structures, and devices. Through its shared operating environment and close coupling with experts in the NanoLab, the NanoFab promotes collaboration in nanotechnology both across NIST’s laboratories and among researchers nationwide.

To get started, contact NanoFab Manager Vincent Luciani, nanofab@nist.gov

- **RAPID ACCESS** – Applications are accepted continuously, with a streamlined application process designed to get projects started in just a few weeks.

- **SHARED-USE OPERATION** – Economical hourly rates, based on operating costs, with tools reserved through an online system accessible from mobile devices.

- **RESEARCHERS MAY APPLY FOR REDUCED RATES** – If a nonproprietary project advances the CNST mission, reduced rates may be available.

- **FLEXIBLE HOURS** – The NanoFab is open and staffed weekdays from 7 a.m. to midnight, with access possible 24 hours a day, 7 days a week.

- **TRAINING** – The NanoFab can train researchers in tool use.

- **EXPERT STAFF DEDICATED TO TECHNICAL SUPPORT AND PROCESS DEVELOPMENT** – The NanoFab is operated by a dedicated support staff of process engineers and technicians who train and assist users, operate and maintain the tools, and develop and control the processes. The support staff is available for expert consultation for all tools and processes.

- **REMOTE JOBS** – Researchers can specify the work they need done and have it performed by the NanoFab staff.

- **INTELLECTUAL PROPERTY RIGHTS ARE PROTECTED** – NIST does not claim any rights to intellectual property used or developed in the NanoFab unless a NIST federal employee is a co-inventor.
TOOLS AND PROCESSES

Over 100 commercial tools are available within the NanoFab’s 5,600 m² (60,000 ft²) of advanced laboratory space, which includes 1,900 m² (20,000 ft²) of cleanroom. Most tools are located in the 780 m² (8,400 ft²) class 100 cleanroom. Our key capabilities, tools, and processes are summarized below. Visit nist.gov/cnst for a complete list and user rates.

**LITHOGRAPHY** – Patterning of features from less than 10 nm to micrometers in size on wafers up to 200 mm in diameter.

- Two Direct Write Electron Beam Lithography Systems (JEOL JBX 6300-FS)
- Laser Pattern Generator (Heidelberg DWL 2000)
- Nanoimprint Lithography Tool (Nanonex NX-2000)
- Maskless Aligner (Heidelberg MLA-150)
- i-Line 5x Reduction Stepper (ASML PAS 5500/275)
- Contact Aligners (Suss Microtec MA8)
- Automated Resist Spin/Spray Coater (Suss Microtec ASC200 Gen 3)

**SOFT LITHOGRAPHY** – A soft lithography lab allows replication of master molds by spin and drop casting elastomeric polymers.

- PDMS Casting Station with a Spinner (Smart Coater 100) and Assembly Hood (Envirco)
- PDMS mixing tool (FlackTek DAC 250.1 FVZ-K) and PDMS Port Creator (CorSolutions)
- Plasma bonder (Harrick PDC-32) and forced convection curing oven (Jeio Tech OF-12G)
- Soft Lithography cleanroom features a hood (Supreme Air), Microfluidic test station (CorSolutions), and Salinization/Bonding Chamber (Yield Engineering Systems) to facilitate device manufacture and testing

**DRY ETCH** – Etching for processing silicon, oxides, nitrides, polymers, metals, III-V compounds, alloys, ceramics, and multilayer structures.

- Four ICP Etchers (2 Oxford Plasmalab 100s) with sample heating and cryogenic cooling and 2 Unaxis Shuttleline ICP Etch Systems, including “Bosch” process deep silicon etching
- Two Reactive Ion Etch Systems (Unaxis 790)
- XeF₂ Etch System (Xactix Xetch E1 series)
- Ion Milling System (4Wave IBE-20B) with end point detection
- Downstream Plasma Asher (ULVAC Solutions ENVIRO-1Xa) for resist stripping
- Deep Silicon Etcher (SPTS Omega c2L Rapier)

**METROLOGY AND CHARACTERIZATION** – Nanoscale imaging, structural and chemical characterization using a wide range of electron, X-ray, and optical techniques.

- Two Dual Beam SEM/FIB systems (FEI Helios NanoLab 660) for imaging, patterned material ablation, chemical analysis using X-ray energy dispersive spectroscopy (EDS), and crystallographic studies using an electron backscatter diffraction (EBSD) system
- Scanning/Transmission Electron Microscope (FEI Titan) with a 16-Megapixel Camera (Gatan Oneview), cryotransfer holder, and EDS and electron energy-loss analytical capabilities for chemical analysis
- Two Field Emission Scanning Electron Microscopes, a FESEM (JEOL 7800F) and a FESEM (Zeiss Ultra-60) with EDS for chemical analysis
- Two Atomic Force Microscopes (AFM) - Wafer-scale AFM (Bruker Fast Scan) and a research-grade AFM (Asylum Research Cypher) with high-resolution fast scanning capability
- X-Ray Diffraction System (Rigaku SmartLab) with 9 kW rotating anode X-ray generator for fast data collection
- Dynamic Light Scattering with Field Flow Fractionation (Wyatt Technologies Dawn Heleos II)
- Tools for ellipsometry, profilometry, reflectometry, and film stress measurements

**THIN-FILM DEPOSITION AND PROCESSING** – Depositing and annealing a wide variety of materials with sub-nanometer precision.

- Cluster Sputter Deposition System (4Wave) with biased target chamber to produce atomically sharp interfaces
- Two Dual Gun Electron Beam Evaporator Systems (Denton Infinity 22)
- Two Sputter Deposition Systems (Denton Discovery 550)
- Furnaces for low-pressure chemical vapor deposition, thermal oxidation, and diffusion processes
- Rapid Thermal Annealer (AnnealSys AS-Master 2000 HT)
- Plasma-Enhanced Chemical Vapor Deposition System (Plasma-Therm Versaline)
- Atomic Layer Deposition System (Oxford FlexALRPT)
- Parylene Deposition System (Specialty Coating Systems PDS-2010)
NANOFABRICATION AND NANOMANUFACTURING
The CNST is advancing the state of the art in nanomanufacturing by developing measurement and fabrication tools for both lithographic (“top-down”) and directed (“bottom-up”) assembly approaches.

NANOSCALE IMAGING AND SPECTROSCOPY
The CNST is developing instruments to reveal the nanoscale properties critical to light-matter interactions, charge and energy transfer processes, catalytic activity, and interfacial structure in energy-related devices.

FUTURE ELECTRONICS
The CNST is developing new methods to create and characterize devices, architectures, and interconnects for graphene, nanophotonic, nanoplasmonic, spintronic, and other future computation and communication systems.

NANOBIO MEDICINE
The CNST is expanding its expertise and capabilities to support users working at the nexus of nanotech, biology, and medicine.

CUTTING-EDGE COLLABORATIVE RESEARCH
The NanoLab offers opportunities for researchers to collaborate on creating and using the next generation of nanoscale measurement instruments and fabrication methods. Agile and highly collaborative by design, the NanoLab embraces collaborations among a rotating cadre of postdoctoral researchers, NIST scientists, and researchers from across the U.S. and abroad. Researchers are invited to gain expertise by working directly with the NanoLab’s multidisciplinary scientists and engineers, who are developing cutting-edge tools in these broad thematic areas:

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NANOFABRICATION RESEARCH GROUP
The Nanofabrication Research Group (NRG) creates new measurement methods to enable the development and effective use of nanomanufacturing and nanofabrication processes.

J. ALEXANDER LIDDLE, GROUP LEADER – Custom-built super-resolution fluorescence microscopy instrumentation combined with advanced statistical analysis techniques to provide information on the nanoscale structure and chemistry of materials; methods to direct the self-assembly of heterogeneous nanostructures such as quantum dots and gold nanoparticles with one nanometer precision.

VLADIMIR AKSYUK – Unique, nanofabricated opto-mechanical devices enabling high-precision, high-band width force measurements at the nanoscale, and the ability to structure and tune electromagnetic fields using mechanical actuation of plasmonic nanodevices.

B. ROBERT ILIC – Methods to simulate and fabricate devices for linear and nonlinear dynamics measurements of suspended microscale and nanoscale electro(opto)-mechanical structures with applications in chemical and biological sensing.

HENRI LEZEC – Sophisticated instrumentation, including focused ion beam systems, femtosecond lasers, and a multi-probe scanning near-field optical microscope that use surface plasmons to study and exploit the physical properties of light and light-matter interactions at deep sub-wavelength dimensions and in metamaterials.

RENU SHARMA – Instrumentation that can measure in situ the dynamic, atomic-scale physical and chemical changes occurring during gas-solid interactions at elevated temperatures, including a unique environmental transmission electron microscope that incorporates Raman spectroscopy.
KARTIK SRINIVASAN – Methods to simulate, fabricate, and probe (via near-field and far-field techniques) novel nanoscale photonic systems, including single-photon sources, signal transducers, and frequency-conversion devices for applications in communications, sensing, and future electronics.

SAMUEL M. STAVIS – Nanofabricated fluidic devices and advanced fluorescence microscopy systems created and customized to control and measure nanoparticles and biomolecules.

MICHAEL ZWOLAK – Computational and theoretical techniques to predict the properties of molecular nanostructures and nanofluidic devices, and to guide the development of pioneering approaches for sensing and measurement.

NANOSCALE IMAGING AND SPECTROSCOPY GROUP

The Nanoscale Imaging and Spectroscopy Group (NSG) develops instruments that reveal the nanoscale physical and chemical processes and properties critical to advances in energy conversion, transport, storage, transmission and signaling in energy-related and biomedical applications and technologies.

NIKOLAI ZHITENEV, GROUP LEADER – A multifaceted toolset for correlating the nanoscale structure and composition of solar cell materials and devices with their functional performance, including near-field optical, electron beam induced current, cathodoluminescence, and photoconductive atomic force microscopies.

AMIT AGRAWAL – Optical and optoelectronic techniques, including multicolor pump-probe, differential absorption, and terahertz spectroscopy, to study light-matter interactions in nanoscale photonic systems with femtosecond resolution.

ANDREA CENTRONE – Innovative measurement methods that combine infrared and visible spectroscopy with atomic force microscopy to determine chemical composition, optical and thermal properties with nanoscale resolution.

MANDY ESCH – Micro- and nanofabrication, microfluidics, and measurement techniques to integrate tissues-on-a-chip devices with tissue sensors.

PAUL HANEY – Theory and modeling expertise for interpreting next-generation measurements on materials for energy applications, including photovoltaics and lithium-ion batteries.

ANDREI KOLMAKOV – Methods and instrumentation for in situ (photo-)electron and X-ray microscopies and electrical measurements of interfaces and of nanodevices functioning in realistic operating environments, including liquid or dense gaseous media.

VERONIKA SZALAI – Improved measurement tools for in operando imaging of chemical reactivity and surface topography of catalyst solid-liquid interfaces; advanced electron paramagnetic resonance spectroscopic measurement and instrumentation development to probe bionanomaterial structure and function.

ELECTRON PHYSICS GROUP

The Electron Physics Group (EPG) develops and provides innovative measurement instrumentation supporting nanotechnology development with an emphasis on applications for future electronics.

JABEZ McCLELLAND, GROUP LEADER – One-of-a-kind instrumentation for the study and manipulation of materials at the nanoscale using focused ion beams created by a magneto-optical trap ion source, with capabilities including low-energy, light-ion microscopy and nanoscale-precision ion implantation.

ROBERT McMICHAEL – Microwave, optical, and, quantum tools for measuring the magnetization dynamics in individual magnetic nanostructures.

MARK STILES – Fundamental theoretical methods for calculating and elucidating measurements of nanostructures and devices, including ferromagnets, graphene, and neuromorphic systems.

JOSEPH STROSCIO – Unique, low-temperature scanning probe microscopy systems integrated with comprehensive sample preparation and thin-film growth capabilities, enabling the atomic and electronic structure of nanostructures and novel materials for future electronics to be determined with unprecedented spatial and energy resolution.

JOHN UNGURIS – Scanning electron microscopy with polarization analysis, a NIST-developed, spin-sensitive microscopy method that reveals the magnetic structure within materials or devices with nanoscale-resolution and without disturbing sample magnetization, with notable applications in emerging magnetic media and magneto-electronic device development.
NIST

Founded in 1901, the National Institute of Standards and Technology (NIST) is a non-regulatory federal agency within the U.S. Department of Commerce. NIST’s mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards and technology in ways that enhance economic security and improve our quality of life. The agency operates primarily in two locations: Gaithersburg, Maryland (headquarters) and Boulder, Colorado. NIST employs about 3,400 scientists, engineers, technicians, and support and administrative personnel, and hosts about 2,500 associates from academia, industry, and other government agencies, who collaborate with NIST staff and access user facilities.

CNST

The NIST Center for Nanoscale Science and Technology (CNST) supports the development of nanotechnology by providing industry, academia, NIST, and other government agencies access to world-class nanoscale measurement and fabrication methods and tools.

- The CNST’s NanoFab provides economical access to and training on a commercial state-of-the-art tool set.
- The CNST’s NanoLab offers opportunities for researchers to collaborate on creating and using the next generation of nanoscale measurements, fabrication tools and methods.

Contact information for CNST staff available at https://www.nist.gov/cnst/staff-directory

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