EQUIPMENT

PROCESSES

EXPERTISE

NNIN

National Nanotechnology Infrastructure Network

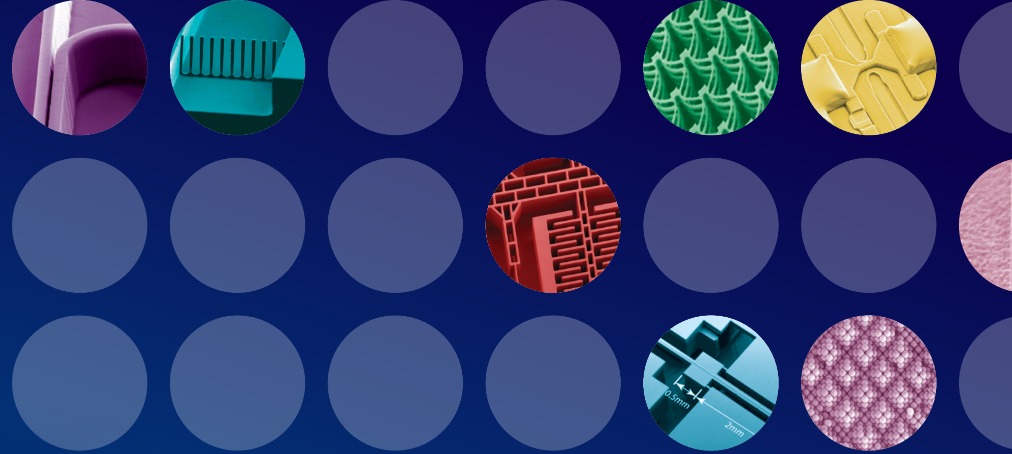
The National Resource for **Nanoscale Science and Technology**

- Electronics
- Optics
- MEMS and Microfluidics
- Biology
- Nanomaterials
- Chemistry and Chemical Nanotechnology
- Microsystem Integration
- Computation
- Nanoscale Devices and Systems
- Geosciences
- Physical Sciences
- Manufacturing Research
- Education
- Social and Ethical Issues in Nanotechnology
- Nanomedicine
- Health and Safety

NSF

NNIN

Nanoscale Science, Engineering & Technology



Arizona State University
Cornell University
Georgia Tech
Harvard University
Howard University
Penn State
Stanford University
University of California at Santa Barbara
University of Colorado at Boulder
University of Michigan
University of Minnesota
University of Texas at Austin
University of Washington
Washington University in St. Louis

NNIN

The **National Nanotechnology Infrastructure Network (NNIN)** is an integrated networked partnership of user facilities, supported by the National Science Foundation, serving the resource needs of the nanoscale science, engineering, and technology communities. NNIN provides users across the nation in academia, small and large industry, and government with open access, both on-site and remotely, to leading-edge tools, instrumentation, and capabilities for fabrication, synthesis, characterization, design, simulation, and integration, to help enable their individual nanoscience research projects. The NNIN also has extensive education, training, and outreach activities as well as activities related to the social and ethical issues associated with nanotechnology. NNIN, which came into being on March 1, 2004, builds upon the base of activities and user support provided by the former National Nanofabrication Users Network, expanding to broadly support research and technology development in all areas of nanoscience. Upon entering its 2nd 5-year funding period in March 2009, NNIN added several new sites with an expanded research focus.

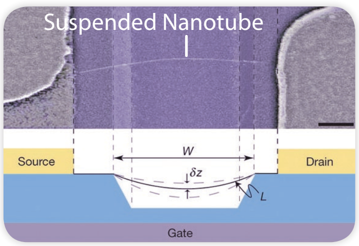
NNIN is not a funding or a research organization. No research is directly funded by the Network. The NNIN nodes themselves do not have a specific research mission, although they may be affiliated with a sponsored research center (NSEC, ERC, etc.) Rather, NNIN is a research facilitator, providing the high technology equipment resources, staff expertise, and training to enable effective and high quality nanoscale research.

We invite researchers from academia, industry, and government to explore how NNIN can help them achieve their nanotechnology research and development goals.

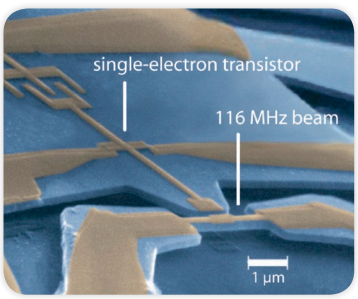
Capabilities

NNIN capabilities span the full spectrum of nanoscale science, engineering, and technology. NNIN actively supports projects in Physics, Optics, Materials, Life Sciences, MEMS, Electronics, and Chemistry. Each of the fourteen network sites is different, offering a specialized set of technologies and services to the network.

Physics



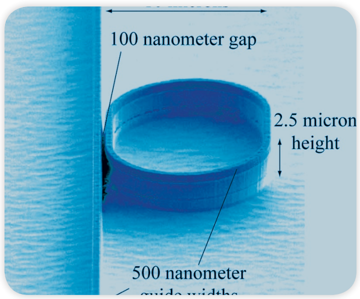
P. MCEUEN, CORNELL UNIVERSITY



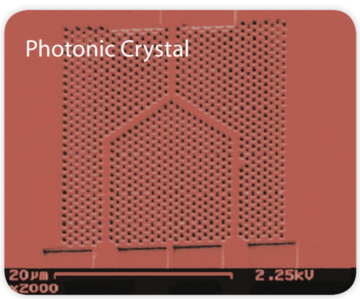
A. CLELAND, UCSB

Because of the small dimensions, nanotechnology enables direct observation of many quantum phenomena which 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 and sensitive instrumentation including scanned probe microscopies enable many of these experiments. NNIN e-beam lithography systems can reproduce pattern features and gaps as small as 10 nm.

Optics



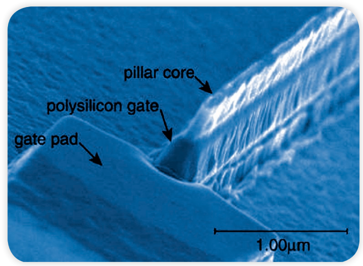
R. BOYD, UNIVERSITY OF ROCHESTER



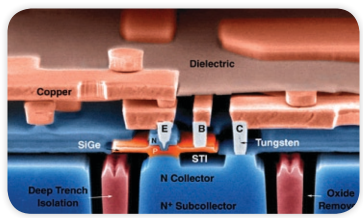
M. LIPSON, CORNELL UNIVERSITY

Nanotechnology makes possible a variety of new optical and opto-electronic structures. These include lasers and waveguides, diffraction gratings, optical switches and modulators, photodetectors, and photonic crystals. NNIN facilities have extensive experience and appropriate technologies for fabrication of optical structures in materials including silicon, quartz, compound semiconductors, and plastic.

Electronics



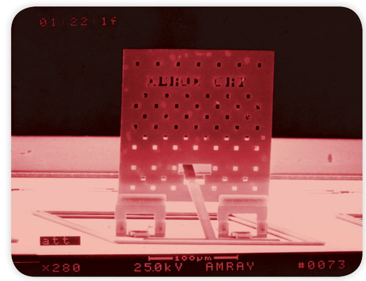
F. PEASE, STANFORD UNIVERSITY



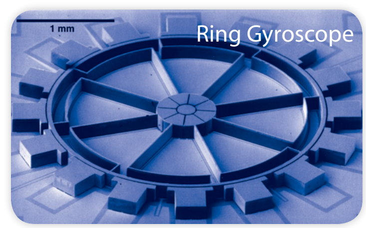
J. CRESSLER, GEORGIA TECH

Microfabrication has enabled advances in electronics for almost 50 years. With advanced nanotechnology, even more advanced devices are possible. NNIN facilities support both silicon and compound semiconductor systems with feature sizes as small as 10 nm. In addition, novel structures including nanotube devices, spin based devices, and single molecule devices have been explored at NNIN sites. Integration of electronics with MEMS, Optics, and microfluidic devices can result in powerful new functional nanostructure devices.

MEMS/NEMS



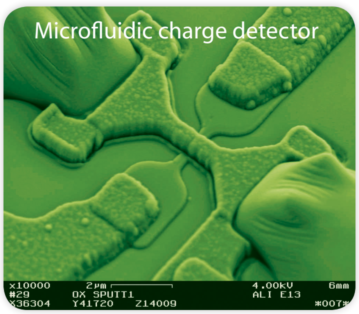
J. KUBBY, XEROX



K. NAJAFI, UNIVERSITY OF MICHIGAN

Micro- and nanomechanical Systems make use of the full range of NNIN 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. The material and process demands of MEMS are often different than for microelectronics. Many NNIN sites, however, have a critical mass of MEMS users and are well positioned to support this technology. Mechanical structures are routinely fabricated in single crystal silicon, oxide, nitride, and polysilicon, and less commonly glass in silicon carbide, metal, and plastic. Microfluidics is a rapidly growing subfield, often bridging together MEMS, biology, and chemistry.

Life Sciences

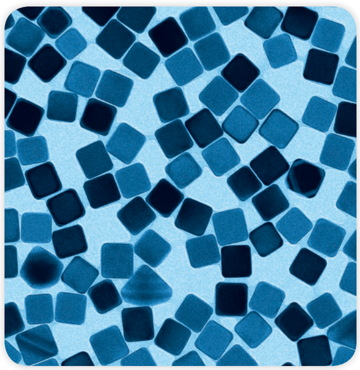


S. TIWARI, CORNELL UNIVERSITY

Applications of nanotechnology to the life sciences continue to multiply at a rapid rate. 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. On the other hand, the power of microelectronics and MEMS can be harnessed to fabricate specialized electrical probes for in-vivo studies. Also, surfaces can be modified by patterning or adsorption to change bioactivity, promoting cell growth, attachment, or specialization.

Many nanostructures for biology are fabricated in common silicon and silicon dioxide substrates, while others use plastic and glass substrates. At other times, actual biological material must be deposited or patterned, processes which raise materials compatibility issues. Some NNIN nodes have special facilities and staff expertise for addressing these compatibility issues.

Chemistry and Chemical Nanotechnology



WASHINGTON UNIVERSITY

The most revolutionary part of nanotechnology comes from the manipulation of individual molecules and the building up of functional nanostructures from the bottom up. Examples include self-assembled monolayers, dendrimers, functionalized nanotube structures, etc. Many of the imagined applications in this realm of nanotechnology are far from realization, but a base of technology is forming. Several NNIN facilities are equipped to assist users in this area, and the sites employ several technical liaisons, experienced Ph.D. scientists, to assist users in this area.

Within more traditional areas of chemistry, nanotechnology enables chemical sensors and chemical mixing systems using microfluidics. Chemistry also drives the development of new materials and processes for nanostructure fabrication and synthesis.

Computation

NNIN is developing and deploying computational resources for the user community in support of nanoscale science. Capabilities include support for state-of-the-art computational chemistry and materials science simulations, as well as tools for device and process simulation. For example, codes exist for ab initio simulation of solids and molecules, molecular dynamics of atoms and molecules, electronic structure of semiconductor devices and transport through nanodevices including single molecule junctions. Since many of these techniques are highly specialized, NNIN has on staff several Ph.D. scientific computation associates to develop the software base and assist the user in applying the right simulation tool, even, where necessary, extending the capabilities of existing simulations for specific experimental situations. Resources and support facilities are located at the Harvard, Cornell, Stanford, and Michigan sites, primarily, but are accessed remotely by users across the country.

Equipment and Processes

Traditional Lithography
- Electron beam lithography
- Contact photolithography
- Projection photolithography (G-line, I-line, DUV)

Thin film deposition and growth
- Evaporation
- Plasma CVD
- Sputtering
- Oxidation
- CVD of silicon dioxide, silicon nitride, polysilicon
- MBE
- Nanotube and nanowire growth
- CVD of graphene
- Molecular monolayer vapor deposition

Thin film etching
- Ion mill
- Reactive ion etching
- Plasma etching
- Bosch™ deep RIE in silicon
- Deep RIE in silicon dioxide
- Xenon difluoride release

Other wafer processing
- Wafer bonding
- Ion implantation
- Chemical mechanical polishing
- Rapid thermal annealing/ oxidation

Inspection and characterization
- Scanning electron microscopy
- AFM
- Other scanned probe characterization
- Fluorescence microscopy
- Confocal microscopy
- Focused Ion Beam
- Spectroscopic Ellipsometery
- Electrical and optical characterization of films and coatings

Synthesis, nanomaterials, nanostructured coatings, and molecular assembly
- Nanotube and nanowire growth
- Nanoparticle synthesis and characterization
- Molecular synthesis
- Electrophoretic particle deposition
- Zeta potential
- Porous materials
- Polymer synthesis and coatings
- Nanocomposites
- Self assembly
- Cell culture/biological coatings/ templates
- Particle growth
- Particle depositon
- Particle synthesis
- Particle characterization
- Nanotoxicology

Novel patterning, structuring, manipulation, and mesosopic/ microscopic assembly
- Nanoimprint lithography
- Microcontact printing
- Nanopore formation
- Scanned probe lithography/ direct manipulation/Dip Pen™
- Quantum dot growth/patterning
- Nanosphere assembly
- Electrofluidic/microfluidic assembly of particles
- Chemically directed assembly of particles/devices

NNIN Facilities

Cornell NanoScale Science and Technology Facility (CNF)

Cornell University
http://www.cnf.cornell.edu

Site Focus: Broad scope in Nanotechnology, Biology, Chemistry, MEMS, Characterization, Materials, Electronics, Life Sciences, Computation

Since its founding in 1977, the **Cornell NanoScale Science and Technology Facility (CNF)** has been a national user facility, where researchers from universities and companies across the country can access state-of-the-art fabrication and characterization tools, and learn to use them with the help of a knowledgeable technical staff. Over the years, the CNF user community has expanded steadily, typically serving 700 users per year.

CNF currently has a staff of 20 technical personnel devoted to hands-on research service, outreach, and to new and growing disciplines. The lab maintains a comprehensive set of more than 90 major tools with a replacement value of ~$125M, including two JEOL state-of-the-art field emission 100kV electron beam lithography systems.

Other tools include a broad range of lithography systems (including DUV stepper and nanoimprint tools) , furnaces, plasma etchers , and thin film deposition tools, as well as extensive characterization and computation resources.

Stanford Nanofabrication Facility (SNF)

Stanford University
http://snf.stanford.edu/

Site Focus: Broad scope in Nanotechnology, Biology, Chemistry, MEMS, Characterization, Materials, Electronics, Life Sciences, Computation

The **Stanford Nanofabrication Facility (SNF)** is a state-of-the-art, shared-equipment, open-use resource, providing capabilities to NNIN across the entire range of nanotechnology. Research areas include optics, MEMS, biology, and chemistry, as well as process characterization and fabrication of more traditional electronics devices. SNF is especially committed to supporting use of micro- and nanofabrication technologies in non-traditional research applications. This laboratory serves academic, industrial, and governmental researchers across the country and around the globe. Capabilities include conventional optical lithography, e-beam lithography, nanoimprint lithography, a wide range of physical and chemical vapor deposition techniques, and extensive wet and dry etch capabilities.

Stanford also provides access to the Stanford Nanocharacterization Laboratory (SNL). SNL provides a wide range of high quality characterization tools including SEM, TEM, FIB, and Xray diffraction.

Lurie Nanofabrication Facility (LNF)

University of Michigan
http://www.LNF.umich.edu

Site Focus: MEMS, Electronics, System Integration, Biology, Computation, Geosciences

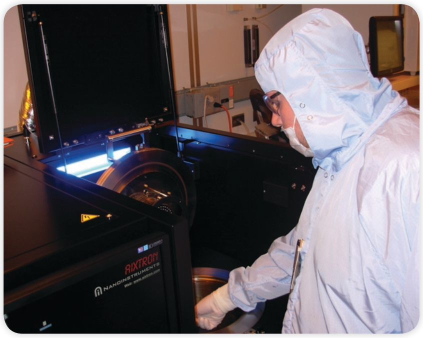
The University of Michigan Lurie Nanofabrication Facility (LNF) now consists of over 12,000 sq. ft of clean-room space, with a recent expansion that provide enhanced capabilities for 6″ wafer processing. It offers complete capabilities for the fabrication of solid-state materials, devices, circuits, and microsystems using silicon, compound semiconductors, and organic materials. It hosts one of the leading research centers worlwide on MEMS and microsystems, with applications for integrated sensors/actuators, microsystems, biology, medical microsystems, chemistry, and environmental monitoring. The LNF has established technologies for bulk and surface micromachining, MEMS fabrication, and MEMS-CMOS integration. Equipment is available for thin film deposition and growth, optical and e-beam lithography, nanoimprinting, wet and dry etch, electrochemical deposition, chemical mechanical planarization, wafer bonding, wafer dicing, wire bonding, metrology, and more, including two new state-of-the-art STS Pegasus DRIE tools.

The LNF also provides expertise in environmental and geological sciences, including sensors for underwater observatories, and in computation and modeling of MEMS and microfluidic devices and structures.

Nanotechnology Research Center

Georgia Institute of Technology
http://www.nrc.gatech.edu/

Site Focus: Biology, Integrated Systems, Electronics



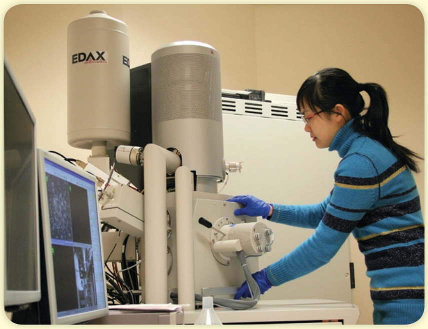
Fabrication and characterization activities of the **Nanotechnology Research Center (NRC)** are carried out in both the Pettit Microelectronics Building and the new Marcus Nanotechnology Building. Although a broad range of technologies is available at these facilities, Georgia Tech especially emphasizes the application of nanofabrication to bioengineering and biomedicine, aided by a dedicated bio-cleanroom. NRC technical staff members assist more than 500 users yearly (35% external) with both on-site and remote processing.

The NRC has historically supported research on a wide variety of materials, structures, and processes. The scope of projects includes: nanostructures, nanoelectronics, photonics, MEMS, NEMS and BioMEMS, materials growth, process chemistry, and biological and chemical sensors. Major tools at Georgia Tech include optical and electron beam lithography (JEOL JBX 9300FS), thin film deposition, atomic layer deposition, graphene growth, carbon nanotube PECVD, plasma processing, thermal processing, ink-jet printing, electroplating, packaging, and metrology.

NanoTech User Facility-Microfabrication Laboratory (NTUF/ MFL)

University of Washington
https://depts.washington.edu/ntuf/

Site Focus: Biology and Life Sciences, Nanotechnology for Ocean Observatories, Societal and Ethical Impacts of Nanotechnology

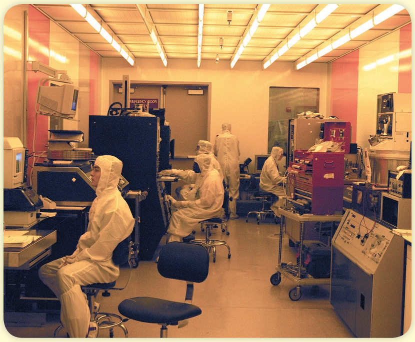


The **NanoTech User Facility (NTUF)** and adjacent **Microfabrication Laboratory (MFL)** provide access to leading-edge instruments for characterization and fabrication at the micro- and nanoscales with an emphasis on the investigative and educational needs of biological, life, and aquatic sciences users. NTUF houses two SPMs, an AFM-interfaced Zeiss confocal microscope, a Renishaw Raman confocal microscope, an FEI Sirion SEM, an FEI Tecnai F20 TEM/STEM, and a Biacore SPR. Fabrication tools include a Nabity electron-beam lithography system on the SEM, a fully equipped soft lithography shop, a Heidelberg desktop pattern generator, and an Oxford atomic layer deposition system. The MFL provides 8,000 sq ft of cleanroom space offering complementary capabilities for thin film deposition, photolithography, plasma and chemical etching, electron-beam writing, Dip Pen™ and nanoimprint lithography.

Minnesota Nano Fabrication Center

University of Minnesota
http://www.nfc.umn.edu

Site Focus: Nanofabrication, particularly as related to energy

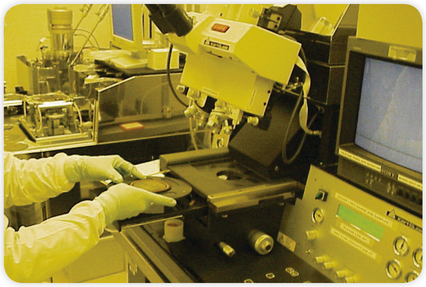


The **Minnesota Nano Fabrication Center (NFC)** provides a full suite of process tools for work in micro- and nanotechnologies. More than a dozen professional staff members ensure that the equipment is available for your use and that process expertise is available to assist you in fabricating your devices. Particular areas of expertise include magnetic structures, MEMS, and nano structures. The process tool inventory includes a wide range of etch and physical film deposition, thermal annealing and oxidation, chemical deposition approaches including atomic layer deposition, and various lithography capabilities including optical contact, optical stepper, direct write e-beam, nano imprint, and focused ion beam. As an NNIN support for alternative energy, the facility provides access to an ultra high vacuum thin film deposition capability for copper-indium-gallium-selenide (CIGS), the material with the highest photovoltaic conversion efficiencies ever reported.

Penn State Nanofabrication Laboratory

Penn State University
http://www.mri.psu.edu/facilities/nnin

Site Focus: Chemical nanotechnology, materials integration, complex oxides



The **Penn State Nanofabrication Laboratory** supports fundamental and applied research in nanoscience and nanotechnology with world renowned strengths in materials for heterogeneous device and microsystem integration by combining top-down and bottom-up nanofabrication methods. Specific areas of emphasis include chemical and molecular-scale nanofabrication, nanomaterials growth and directed assembly, amorphous semiconductor materials, and complex ferroelectric oxide materials and devices. In addition to a comprehensive set of traditional fabrication instruments and processes, the laboratory provides users with new self assembled monolayer based chemical patterning methods and nanowire integration processes that extend the limits of nanolithography. Molecular assembly techniques are available for derivatizing surfaces with specific chemical and biological functionality. Advanced electron beam lithography, nanoimprint, novel liquid precursor chemical vapor and atomic layer deposition instruments give specialized capabilities in top-down fabrication. The laboratory also offers fully integrated materials deposition, patterning, and dry etching processes to support CMOS compatible complex ferroelectric oxide device fabrication, including lead-based compounds with excellent ferroelectric response.

NNIN Facilities

Nanotech

University of California, Santa Barbara
http://www.nanotech.ucsb.edu/

Site Focus: Optics, Electronics, Physics, Materials

Nanotech at UCSB has extensive facilities that support research in nanotechnology. Specific UCSB strengths include leading expertise in compound semiconductors, photonics, quantum structures, and expertise with nonstandard materials and fabrication processes. Research within the UCSB research community is highly collaborative. Areas of excellence include: compound semiconductor electronic and optoelectronic devices in arsenides (AlInGaAs), phosphides (InGaAsP), and nitrides (AlInGaN); polymer and organic electronic and photonic devices; quantized electron structures and THz physics; spintronics, single electronics, and quantum computation; quantum optics; MEMS/NEMS, bio-instruments, and microfluidics. Nanotech houses a full range of thin film processes including optical lithography to <500nm, e-beam lithography to <10nm in a state-of-the-art JEOL 6300FS system, various PVD and CVD systems, and advanced ICP etching systems. The UCSB facility also offers Ph.D. level process support and guidance, and highly experienced engineering staff.

Microelectronics Research Center (MRC)

University of Texas, Austin
http://www.mrc.utexas.edu/

Site Focus: Electronics, Chemical Nanotechnology, Instrumentation for Manufacturing

The **Microelectronics Research Center** at The University of Texas at Austin **(MRC)** provides opportunities to perform research and education in novel materials of interest to Silicon nanoelectronics, III-V optoelectronics and nanophotonics, novel sensors and nanostructures, and interconnects and packaging. MRC particularly contributes expertise in electronics, chemical nanotechnology, and instrumentation for manufacturing to NNIN.

The facilities include a JEOL-6000FS/E-based electron beam lithography system capable of 20nm resolution on masks, small substrates, and 8″ wafers. This e-beam is utilized to generate templates for the Step and Flash Imprint Lithography tool. The S-FIL IMPRIO100 is a nanoimprint scheme for patterning of features in sub-20nm regime with ability to perform layer-to-layer alignment through a transparent template to sub micron accuracy.

The Arizona State University NanoFab (ANF)

Arizona State University
http://nanofab.asu.edu

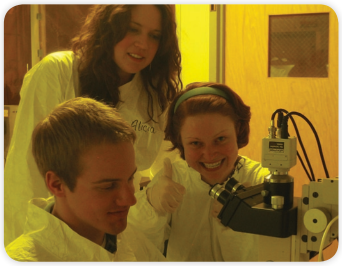
Site Focus: Inorganic-organic interfaces, Si and III-V processing, MEMS, Microfluidics, BioMEMS

The **ASU NanoFab** has been managed as a multi-user facility since it was established in 1983. A staff of seven cleanroom engineers is available to train users and to assist in process development in a 4,000 sq. ft. Class 100 cleanroom and associated laboratories. Two domain experts are available to help users with Si MOS and MEMS/BioMEMS process development, with particular emphasis on the interface between biological systems and inorganic materials. The ASU NanoFab has broad expertise in micro and nanoscale fabrication with a toolset that can handle small pieces up to 8″ wafers. Fabrication tools include electron beam lithography (JEOL 6000F S/E), deep-silicon etching (STS ASE), wafer aligning/bonding (EVG620/520HE), thick-oxide growth (>1 μm) , LPCVD and PECVD of oxide, poly-Si and low-stress nitride. A variety of optical and electrical measurement & characterization tools are available including wide temperature range wafer probing (-60∞C to +400∞C). A cell culturing capability is available along with a glove box and surface contact angle goniometer for surface modification studies.

Colorado Nanofabrication Laboratory

University of Colorado at Boulder
http://cnl.colorado.edu

Site Focus: Electronics, Optoelectronics, MEMS, Precision Measurements, and Energy



The **Colorado Nanofabrication Laboratory (CNL)** at the University of Colorado is a recent addition to the NNIN network, centrally located in the Rocky Mountain region. CNL provides easy access to a wide range of nanofabrication equipment and is specifically set up for device and materials research that requires flexibility in terms of sample size and materials.

Research performed in the facility includes basic nanoscale science, electronic and optoelectronic devices, as well as MEMS for medical and metrology applications. Examples include silicon MOSFETs, GaAs MESFETs, III-V photodetectors and laser diodes, SiC BJTs, quantum dot arrays, microthrusters, and microactuators.

The CNL facility is staffed with three professionals who are responsible for maintaining the facility, assisting users and developing fabrication processes. Capabilities include optical lithography, mask making, e-beam writing, several thin film deposition processes (evaporators, RF and DC sputter systems, PECVD), dry etching (RIE, ICP), and a wide range of thermal processes. The CNL also has in-house characterization including SEM, profilometers, ellipsometers, and AFM/STM. On-wafer electrical testing is available too, as is basic device packaging.

Center for Nanoscale Systems (CNS)

Harvard University
http://www.cns.fas.harvard.edu

Site Focus: Chemical Nanotechnology and Computation

The NNIN effort at Harvard University through the **Center for Nanoscale Systems (CNS)** provides interdisciplinary nanotechnology research support in several critical areas such as soft lithography, and nanoparticle and molecular electronic device fabrication. Harvard's pioneering efforts in soft lithography continue with the addition of NNIN facilities for extending and improving the biological, physical and chemical capabilities of the technique. As part of the NNIN computational program, a core scientific computational resource center has been established. The NNIN/C resource center provides NNIN users easy Internet access to computing hardware, simulation tools, and software programs for computational nanoscience. The software consists of a suite of robust programs that address critical issues in the areas of physical, chemical, and biological nanostructure and nanodevices. Finally, CNS provides strong technical support and thorough training of users from the NNIN community. NNIN users will have full access to the capabilities of the Center for Nanoscale Systems' nanofabrication, imaging and analysis, and computational facilities.

Howard Nanoscale Science and Engineering Facility (HNF)

Howard University
http://www.msrce.howard.edu/

Site Focus: Materials

The **Howard Nanoscale Science and Engineering Facility (HNF)** supports nanotechnology research and development in diverse areas such as electronics, materials science, optics, polymer science, membrane technology, medicine, physics and chemistry. The three technical areas of particular emphasis for NNIN are electronics and materials (wide band gap devices and applications to nanotechnology), chemistry (characterization science), and materials (nanofiltration membranes and technology).

The Howard facility also has strong education and outreach programs within the K-12 and public community in the capital area.

Nano Research Facility (NRF)

Washington University in St. Louis
http://www.nano.wustl.edu

Site Focus:Nanostructured Materials, Nanoparticles, Nanotoxicology

The **Nano Research Facility (NRF)** at Washington University in St. Louis provides technical expertise at the intersection of nanotechnology, public health, and the environment, providing open access for both academic and industrial users. The core labs include a micro- and nanofabrication lab with Class 100, Class 1,000 and Class 10,000 clean rooms, a surface characterization lab, particle technology lab, and bio-imaging lab. NRF offers photolithography, soft lithography, material deposition, and top-down etching for micro- and nanofabrication. Alternatively, NRF provides knowledge-based synthesis – the bottom up approach – to make metallic nanomaterials (Ag, Au, Pd, Pt) with well-defined sizes and shapes. The NRF tool inventory includes a Veeco NanoMan™ VS scanning probe microscope, FEI Nova™ 230 SEM integrated with EDAX, FEI Spirit™ 230 TEM, Karl Suss MJB3 Mask Aligner, Perkin Elmer Elan DRC II™ ICP-MS and Optima 7300 DV™ ICP-OES systems, Malvern Nano ZS dynamic light scatting system, and TSI Particle Imaging Velocimetry (2D-PIV and 3D-PIV). NRL staff are collaborating with faculty at Washington University to develop a photoacoustic microscope that has non-invasive imaging modalities for nano and biological applications.

How Does NNIN Work?

Social and Ethical Impacts of Nanotechnology

Experience indicates that both the positive and negative impacts of new technology on society must be fully explored and understood. The landscape is full of promising technologies which failed due to social rather than scientific issues. Nanotechnology is both an evolutionary and revolutionary technology, creating many social and ethical issues that must be considered carefully. Among these are workforce, resource, economic, energy, educational, health, and safety issues.

NNIN is devoting a portion of its effort to the study of these important issues. As part of this effort, NNIN is collecting and archiving important information on the evolution of nanotechnology to build an infrastructure to facilitate SEI research both now and in the future. NNIN researchers will act as a resource for scientists, journalists, and government. Lastly, NNIN is actively communicating these issues to the public through forums, seminars, workshops, and multimedia. These resources are available through the NNIN web site.

Facilities

NNIN facilities are operated as true user facilities where everyone has open full access to the same high level technology. NNIN builds upon the successful model established by the National Nanofabrication Users Network which served many thousands of users during 1994–2003. Critical to this model are:

1) An extensive state-of-the-art equipment set at each site;
2) An intellectual and technological focus at each site in at least one nanotechnology area, fully supported by adequately developed processes, staff, and facilities;
3) Complementarity and cooperation between sites to cover the breadth of nanotechnology;
4) Skilled and knowledgeable staff at each site, who are dedicated to serving the needs of the user community;
5) Refined training and support mechanisms; and lastly,
6) A culture of open support with equal access to all.

NNIN sites were chosen specifically with these criteria in mind.

Over five thousand users visit or work at the fourteen NNIN sites each year. Some visit for only a week or two, periodically; others are resident for a longer time. Some postdocs and scientists take up permanent residence near the NNIN facility to have continuous access to the site while telecommuting to their home institution.

Users are supported by over 150 experienced technical staff for instruction and assistance while maintaining full intellectual control of their own project.

NNIN is set up to allow laboratory access within a few weeks of initial contact. Training regimens are streamlined so that even an inexperienced user can be working somewhat independently in a few days. Becoming an experienced nanotechnologist is obviously a longer process, but the staff and the support structure at the NNIN sites facilitate this as much as possible. Our goal is to eventually train most users to be independent, while providing instruction and close support to those who need it.

For the most part, NNIN facilities do not act as contract houses which can be hired to fabricate a specific structure for you as a deliverable. Some simple process sequences, however, can be executed remotely by NNIN staff.

Types of NNIN Users

Academic Users

A majority of NNIN users are academic users, both from our home NNIN institutions but also from literally hundreds of large and small academic institutions. In some cases, students come for access to only a few specialized instruments and then return home. In other cases, the entire spectrum of resources is used. Because of the extensive staff support, even new graduate students can be rapidly productive. User fees for academic use are designed to be affordable and some sites offer subsidized housing to facilitate use.

Industrial and Government Users

NNIN facilities are open for research and development activities for scientists from small and large companies as well as government. Again, projects and interactions can take many forms.

NNIN facilities are ideal for start up companies and companies pursuing SBIRs. Projects can begin quickly with little upfront investment in time or money. Many hundreds of start up companies have developed their first products within NNIN facilities, and NNIN has been a critical part of many SBIR projects.

Intellectual Property and Technology Access

Intellectual property is always a concern for users, but it is handled in an efficient and transparent manner at NNIN sites. Operating as a user facility with your staff doing the work, there is little need for you to reveal your intellectual property to NNIN staff. And you are in fact encouraged not to. The universities make no claim on your intellectual property based solely on equipment use. Unless instructed otherwise, NNIN staff will stick to generic equipment instruction without exposure to your intellectual property. Only minimal disclosure to cover safety and materials compatibility is required. If you wish to enter into a joint development agreement with the university, that can be done, but it is neither required or common. This simplicity allows projects to start quickly as there is little if anything to negotiate. The relationship is a mere purchase of equipment services rather than a research agreement.

That being said, much of the power of the user facility concept comes from the open exchange of ideas. All users may take advantage of the technology that was developed and shared by previous users but no one is required to share.

It is important to distinguish the user facility, its staff, and its embedded technology, on the one hand, from that of the individual faculty research groups. At each university there is significant technology and intellectual property within the research groups. Users do not automatically have access to this any more than other users do to yours. Users do, however, benefit from the processes and techniques developed by the local user community. Collaboration with faculty and staff is possible, but not required. Each facility does, however, completely control its own equipment and laboratory, and users have unfettered access to that technology.

Education and Outreach

Education is an important part of NNIN activities. The focus of our programs is to encourage STEM involvement and assist in workforce development. We have a multi-faceted E&O program that reaches school age children through adults. To meet the educational needs of this diverse community, NNIN has developed both local activities as well as a nationally coordinated program in nanotechnology education and awareness. Our programs include: activities to encourage K-12 students to STEM education and careers; programs and resources for K-12 teachers; activities, resources, and tools for undergraduates and graduate students; workforce development (workshops, symposia); and programs for the general public.

As part of our national programs, we offer one of the largest Research Experience for Undergraduates programs in the country, hosting approximately 75 undergraduates each summer. A Research Experience for Teachers program is also offered at five sites and supports approximately 15 teachers per summer. Graduate students from across the country can participate in our International Winter School for Graduate Students which is a two week course that occurs in a country of the developing world. Visit our web site to learn more about our programs http://www.education.nnin.org.

www.nnin.org

How do I begin?

The NNIN web site at http://www.nnin.org acts as a portal to additional NNIN process information, site capabilities, training, educational media, and documentation. Once you have a project idea, pick a site that seems to match, based on expertise or geography. You may contact one or more NNIN sites to discuss your application. NNIN site staff will work through your project description and provide an evaluation and process plan if possible. If a site is unable to help you for technical reasons, you will be referred to a more appropriate site. If you have an application that does not seem to fit any of the NNIN sites, please contact NNIN management via phone or email.

To contact the NNIN directly, please call or write to:

National Nanotechnology Infrastructure Network (NNIN) c/o CNF

Prof. Sandip Tiwari, Director

Dr. Lynn Rathbun, Program Manager

250 Duffield Hall
Cornell University
Ithaca, New York 14853
(607) 255-2329
http://www.nnin.org
rathbun@cnf.cornell.edu

14 NNIN Facilities

Cornell NanoScale Science and Technology Facility (CNF)
Cornell University
http://www.cnf.cornell.edu

Stanford Nanofabrication Facility (SNF)
Stanford University
http://snf.stanford.edu/

Nanotechnology Research Center
Georgia Institute of Technology
http://www.nrc.gatech.edu/

Lurie Nanofabrication Facility
University of Michigan
http://www.eecs.umich.edu/ssel/

Nanofabrication Center
University of Minnesota
http://www.nfc.umn.edu

Penn State Nanofabrication Laboratory
Penn State University
http://www.mri.psu.edu/facilities/nnin

Nanotech
University of California, Santa Barbara
http://www.nanotech.ucsb.edu/

Microelectronics Research Center (MRC)
University of Texas, Austin
http://www.mrc.utexas.edu/

Center for Nanoscale Systems (CNS)
Harvard University
http://www.cns.fas.harvard.edu

The Arizona State University NanoFab (ANF)
Arizona State University
http://nanofab.asu.edu

Colorado Nanofabrication Laboratory
University of Colorado at Boulder
http://cnl.colorado.edu

Nano Research Facility (NRF)
Washington University at St.Louis
http://www.nano.wustl.edu

Howard Nanoscale Science and Technology Facility (HNF)
Howard University
http://www.msrce.howard.edu/

NanoTech User Facility-Microfabrication Laboratory (NTUF/MFL)
University of Washington
https://depts.washington.edu/ntuf/

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