

The National Nanofabrication Users Network (NNUN)

ECS-9731293 and ECS-9731294

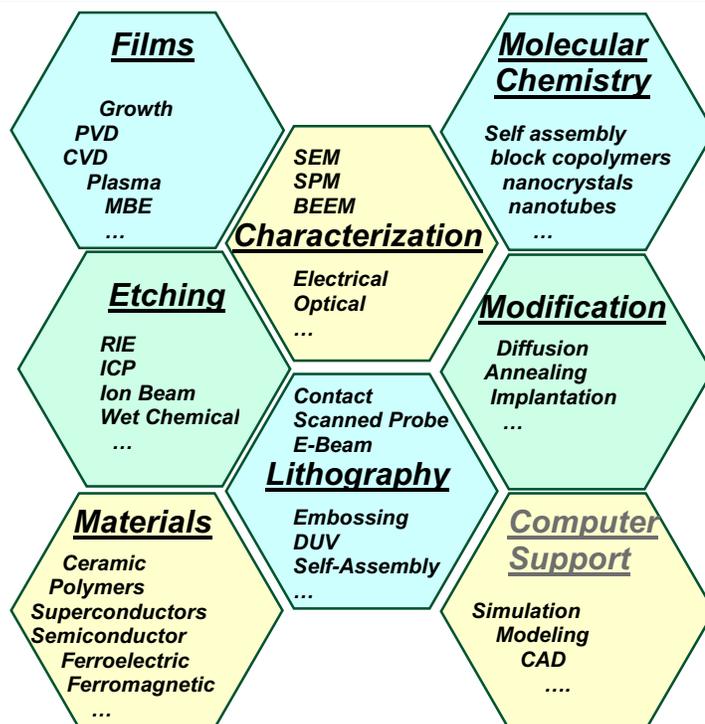
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Cornell University, Howard University, Penn-State University, Stanford University, and University of California at Santa Barbara

In nearly all of the interdisciplinary areas where nanotechnology has had a significant role, synthesis and patterning at the nano-scale needs to be coupled to active control at a larger scale. Examples vary from the use of nanotubes as probes for sensing, nanocrystals as chip-based fluorescent tags or low power embedded electronic memory elements, spin-valves as magnetic memory elements, electronic transport in molecules for the study of storage or transport phenomena, to those where systems are built using the unique effects of the nano-scale. The key contribution of National Nanofabrication Users Network (NNUN) to nanotechnology is in providing effective and efficient access to advanced integrated nanofabrication and synthesis equipment and expertise to make the research experiments and applications possible. Research work conducted in NNUN typically depends on the integration of complex chemical and physical nanotechnology processes conducted over a large number of tools. So, nano-embossing or chemical synthesis accompany electron-beam lithography and more traditional tools such as stepper lithography or high density plasma etching, or implantation or chemical-mechanical polishing in order to make projects successful on a larger scale.

During 2002, NNUN enabled the research of nearly 2000 academic and industrial users from across the nation. Of these nearly 1450 were graduate and undergraduate students, and more than 300 PhDs awarded depended on NNUN resources. More than 120 small companies were also supported by NNUN facilities, and over the last many years research from NNUN has spawned nearly 25 companies. NNUN is a service network, and its success depends critically on providing networked resources; education through workshops and courses; web-based information and tools for project preparation; integrated tools and instruments for synthesis and fabrication; strong on-site training; and strong project support and technical assistance through a highly skilled staff. NNUN consists of two hub facilities on the east and west coasts at Cornell University and Stanford University, and three additional sites at Howard University, the Pennsylvania State University and the University of California at Santa Barbara, each offering expertise in overlapping general purpose and

Figure 1: Integrated nanotechnology resources from NNUN.



specialized complementary areas.

Research and Usage at NNUN: NNUN evaluates its research and usage through a variety of measures. A sampling of research conducted at NNUN is published annually in the first quarter of the year¹ and is available on the web. Individual sites also provide information related to projects conducted². with representative projects from across various disciplines. For quantitative purposes, we separate these categories as biology; chemistry; electronics; materials, physics, processes and characterization; mechanics and microelectromechanical systems (MEMS); and optics. The usage across these disciplines is broad and a number of significant accomplishments in research employed NNUN resources. We invite you to visit our web-site <http://www.nnun.org> to see our latest reports and to watch technical events.

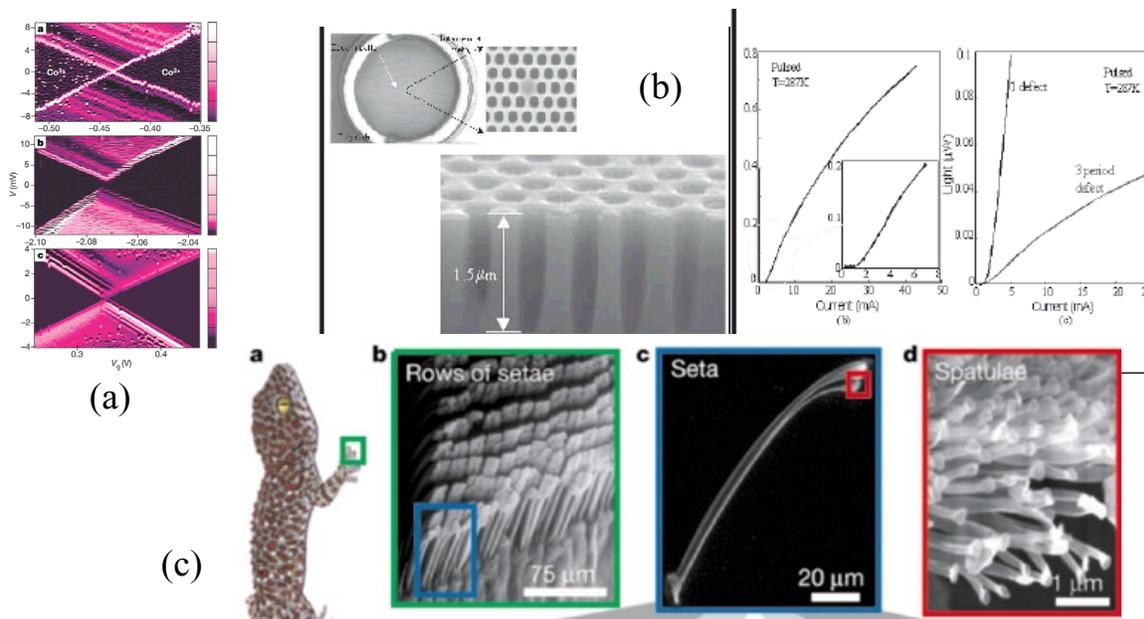
Figure 2: Number of users across disciplines during 2002, and their zip-code locations.

Biology	227
Chemistry	101
Electronics	285
Materials	285
MEMS	378
Optics	268
Physics	134
Processes & Charact.	323
Total	1985



Three examples of work conducted by researchers during

Figure 3: Some recent examples of experimental results at the nano-scale that utilized the resources of NNUN. (a) Single atom single electron transistor (J. Park et al., Nature, p.722(2002)), (b) Photonic crystal microcavity long wavelength light source (J. Sabarinathan et al., 14th InP & Related Materials Conference, p.425(2002)), and (c) Geckos setae: a nanostructured surface with vander Waals adhesion (K. Autumn et al., Proc. Natl. Acad. Sci., p.12252 (2002)).



¹ Available at <http://www.cnf.cornell.edu/nnun/2002nnunreports.html>

² For example, <http://www.cnf.cornell.edu/2002cnfra/2002cnfra.html>, <http://www.msce.howard.edu/%7Eananonet/PROJECT.HTM>, <http://www.nanofab.psu.edu/research/default.htm>, <http://snf.stanford.edu/About/Research/Research.html>, <http://www.nanotech.ucsb.edu/research/research.html>,

the year 2002 across these disciplines at the nano-scale are provided in Figure 3. Multiple publications are also available from <http://www.nnun.org>.

Education and Outreach: Technical training, encouragement of careers in science and engineering, and broad dissemination of information are also important directions of NNUN's efforts. Our web-site³ provides important links to these activities and resources. Some examples of these are:

Introduction to NNUN:⁴ An introduction to the network and its resources. Available as a CD and as a movie on the web.

Nanotechnology courses:⁵ Available since 1999 on the web and updated yearly from the on-site courses that are offered at Cornell Nanofabrication Facility, these courses introduce the practice of nanotechnology and its usage across disciplines.

Process Libraries:⁶ Available since 1998, the search engine provides a wide variety of information on tools and techniques for specific technical steps across disciplines as practiced in NNUN.

Live Technical Sessions:⁷ A recent addition has been live broadcasting of web-sessions that are lively interchanges of specific projects and possible methods of implementations.

Workshops: NNUN organizes workshops throughout the year which emphasize detailed practice of specific techniques, or provide a broader forum for discussing advances in a field. During this year, a workshop on electron-beam lithography on Cornell Campus was attended by nearly 85 people from across the country. Additional workshops were held at Penn-State and Howard University, and a US-Japan Symposium will be held in January, 2003.

High-School and Community Colleges: NNUN hosts a variety of events that specifically address technical training and educational needs. These include chip-camps organized at Penn-State, visits to our laboratories for a day by community colleges, and visits to local schools, etc.

Research Experience for Undergraduates: NNUN hosts 42 undergraduate students that focuses on carefully screened faculty and staff-sponsored hands-on research that can be completed in 10 weeks with a real-world experience of publications⁸ and conference.

Major Conferences: NNUN has multiple booths, posters, CDs, and other material that it continuously develops and deploys in order to broaden the accessibility of nanotechnology to researchers. During 2002, NNUN has been present at APS, AVS, ECS, MRS, and numerous other meetings.

Summary: NNUN is a network that helps users implement ideas requiring fabrication, synthesis and integration of nano-scale and larger structures, devices, and systems. We are convenient to use because of our focus on user's success, and productive because of extensive equipment, staff, and knowledge resource. A large variety of information from us is also conveniently available over the web. So, even those who do not need to access hands-on NNUN resources may find useful practical information by visiting us remotely.

³ <http://www.nnun.org>

⁴ <http://www.nnun.org/Multimedia/Multimedia.html>

⁵ <http://www.cnf.cornell.edu/nanocourses/nanocourse.html>

⁶ accessed via <http://www.nnun.org> and see for example, <http://snf.stanford.edu/SiteMap/SiteSearch.html> and <http://www.cnf.cornell.edu/>

⁷ <http://www.cnf.cornell.edu/live.html>

⁸ <http://www.nnun.org/Reu/REU.html>