

## APPENDIX 3: HARVARD UNIVERSITY/NANOSCALE SCIENCE AND ENGINEERING CENTER PROFILE

### I. Description

**Institution:** Harvard University

**PI:** Robert M. Westervelt

**Co-PIs:** Bertrand I. Halperin

**Title:** Nanoscale Systems and their Device Applications

**Proposal:** 0117795

**Program Officers:** Denise Caldwell, Ulrich Strom

**Education Outreach Director:** Kathryn Hollar, ofhollar@deas.harvard.edu

### II. Research Agenda

**Research Focus:** The Center has overlapping interdisciplinary research areas in

#### Cluster I: Tools for Integrated Nanobiology

Aims to build bridges between the physical and biological sciences. The physical sciences offer powerful new tools for manipulating and testing biological cells and tissues. In turn, biology offers an enormous range of engaging problems in functional biological systems, and the opportunity to think about “hybrid” systems that combine biological and non-biological components.

#### Cluster II: Nanoscale Building Blocks

Addresses the synthesis of new classes of nanostructures that exhibit size-dependent properties, with an emphasis on structures with unconventional shapes, as well as on zero-, one- and two-dimensional nanostructures based on metal chalcogenides, and the incorporation of nanostructures into novel devices.

#### Cluster III: Imaging Electrons

Imaging Electrons at the Nanoscale explores new ways to image the quantum behavior of electrons inside nanostructures using custom-made scanning probe microscopes (SPMs). Semiconductor heterostructures with novel properties are grown using Molecular Beam Epitaxy (MBE).

The Nanoscale Science and Engineering Center (NSEC) is a research collaboration with Harvard University, the Massachusetts Institute of Technology, the University of California-Santa Barbara, and the Museum of Science-Boston with participation by Delft University of Technology (Netherlands), the University of Basel (Switzerland), the University of Tokyo (Japan), and the Brookhaven National Laboratory, the Oak Ridge National Laboratory, and the Sandia National Laboratory.

### III. Education Activities within the University

#### Research Experience for Undergraduates (REU)

- ◆ **Description:** NSEC-supported REU students work closely with faculty, graduate students, staff, and postdoctoral researchers on individual research projects for 10 weeks.
- ◆ **Staff/Expertise:** The REU Program is coordinated by Dr. Kathryn Hollar, Director of Educational

Programs for the Division of Engineering and Applied Sciences. She holds a PhD in Chemical Engineering, and has taught chemical and general engineering courses, as well as preparatory programs for graduate teaching assistants.

◆ **Goals and Objectives:**

- ◇ To encourage a diverse group of future scientists and engineers to pursue careers in nanoscale science & engineering
- ◇ To increase awareness of research areas available for graduate studies
- ◇ To give graduate students and postdoctoral researchers preparation and experience in project management

◆ **Target Audience:**

- ◇ In 2005, a total of 49 students were funded through our joint programs, which span various science and engineering disciplines. Of these students, 17 students were mentored by 11 NSEC-supported faculty, and additional 4 interns were funded by NNIN.
- ◇ Students were recruited from a variety of institutions, and ranged from rising sophomores to rising seniors. 27% of the students were from underrepresented groups in science and engineering, and over 50% were female.

◆ **Current Activities:** The REU interns also participate in a structured program of professional development seminars and workshops, from presentation skills to faculty-led research talks as part of our larger joint REU program that funded 49 students in summer 2005.

◆ **Nano S&E Content Focus:** Students supported by NSEC funds participated in projects that were within NSEC cluster themes.

### **Applied Physics 298r: Interdisciplinary Chemistry, Physics, and Engineering**

◆ **Description:** Graduate and advanced undergraduate students participate in AP298r, *Interdisciplinary Chemistry, Engineering and Physics*, an interdisciplinary graduate survey course of ongoing research at the Center.

◆ **Staff/Expertise:** The course is taught by Professor Robert M. Westervelt. Faculty from the NSEC gave 20 lectures during the spring semester.

◆ **Goals and Objectives:** To give graduate students and advanced undergraduates the opportunity to explore the research areas within the NSEC.

◆ **Target Audience:** Graduate students and advanced undergraduates Over 25 students enrolled in the course in Spring 2005.

◆ **Current Activities:** Students enrolled in the course prepare a presentation and paper on a selected topic, in addition to attending all seminars.

◆ **Nano S&E Content Focus:** Course requirements include a paper and oral presentation on one of the topics. Course handouts and faculty presentations can be downloaded at [www.nsec.harvard.edu/AP298.htm](http://www.nsec.harvard.edu/AP298.htm).

### Research Exchange Seminar

- ◆ **Description:** This postdoctoral and graduate student researcher-led seminar was held biweekly on Tuesday at lunchtime during the academic year (2004-05).
- ◆ **Goals and Objectives:** To encourage NSEC postdoctoral fellows and graduate students to learn about each other's research. The Exchange seminar blossomed into a venue where graduate students could get the advice of the postdoctoral fellows on preparation for oral presentation and then give their talk at the Exchange.
- ◆ **Target Audience:** Graduate students and postdoctoral researchers
- ◆ **Current Activities:** Speakers and topics have been suggested for next fall and many of the presentations during the past year have been presented in shortened form at professional society meetings.
- ◆ **Nano S&E Content Focus:** Presentations are based on NSEC-funded research.

### Postdoctoral Fellowship Program for Members of Underrepresented Groups

- ◆ **Description:** We have established Center fellowships to encourage the participation of women and members of underrepresented groups in science and engineering.
- ◆ **Goals and Objectives:** To provide support and professional development for members of underrepresented groups in science and engineering so that they may become leaders in their fields.
- ◆ **Target Audience:** Members from underrepresented groups in science and engineering. Thus far, 5 Fellows have been funded.
- ◆ **Current Activities:** These Fellows are integrated into the research and educational community of the NSEC, and connections with faculty and institutes across the university are facilitated through this program. Access to research facilities and educational and professional development opportunities helps develop a strong pool of well-prepared researchers for faculty positions and the scientific community.
- ◆ **Nano S&E Content focus:** Fellows participate in many NSEC educational and outreach activities.

## IV. Education Activities Outside the University

### Activities at the Museum of Science, Boston

- ◆ **Description:** The participants and their colleagues develop innovative science communication strategies for enhancing public understanding of research in nanoscale science and engineering, engaging a broad range of audiences at the Museum of Science and elsewhere.
- ◆ Program Staff & Expertise:
  - ◇ **Carol Lynn Alpert**, NSEC Director for Public Engagement and Director of Strategic Projects at the Museum of Science
  - ◇ **Daniel Davis**, Education Associate for Nanoscale Science & Engineering
  - ◇ **Adam Weiss** and **Greg Murray**, Education Associates for Current Science & Technology, Museum of Science, Boston

- ◆ **Goals and Objectives:** To enhance public understanding of nanoscale science and engineering, and to provide communications expertise and resources to scientists and engineers in nanoscale science & engineering.
- ◆ **Target Audience:** K-12; public audiences
- ◆ **Current Activities**
  - ◇ Monthly Live New England Cable News Cablecasts have informed an audience of over 1.6 million viewers
  - ◇ Reaching a national audience via Cable TV
  - ◇ Live presentations on the Current Science & Technology (CS&T) stage at the Museum of Science, Boston; over 160 presentations have reached more than 5400 museum visitors
  - ◇ Guest Researcher Appearances on the CS&T Stage, featuring NSEC researchers, have engaged over 400 museum visitors
  - ◇ Nanotech Consumer Products Display
  - ◇ Communicating Science workshop with REU and RET participants impacted over 45 undergraduates and teachers.
  - ◇ Multimedia Research Updates for Touchscreens and Web
  - ◇ Nanotech Symposium for Teachers and Guidance Counselors scheduled for November 2005
  - ◇ For more information, see [www.mos.org/nano](http://www.mos.org/nano) and [http://www.nsec.harvard.edu/pages/education\\_mos.htm](http://www.nsec.harvard.edu/pages/education_mos.htm).
- ◆ **Nano S&E Content Focus:** Broadly focused, highlighted by ongoing research in the NSEC based at Harvard University

### Research Experience for Teachers

- ◆ **Description:** The NSEC, in collaboration with an REU/RET Site in Materials Research and Engineering, hosted 7 teachers in 2004 and 5 teachers in 2005. These teachers work side-by-side with faculty, postdoctoral researchers, graduate students, and REU participants on research or science curriculum projects at Harvard University. **Program Staff and Expertise:** The RET program is coordinated by Dr. Kathryn Hollar, Director of Educational Programs for the Division of Engineering and Applied Sciences.
- ◆ **Goals and Objectives:** Teachers commit to 6–8 weeks during the summer, and are invited for a second summer to refine educational modules that are developed as a result of their research experience. Goals of the program are to develop long-term relationships with these teachers and their home school systems and infuse the high school science curriculum with tested examples of nanotech applications that can be widely disseminated to impact many students and teachers.
- ◆ **Target Audience:** High school teachers in the Eastern Massachusetts, New Hampshire and Rhode Island area, with a focus on recruiting from urban school districts, including the Cambridge Public Schools.
- ◆ **Current Activities:** This program has resulted in educational modules and several initiatives and partnerships that extend beyond the summer experience, including planning for the Nanotech Symposium for teachers at the Museum of Science, Boston.

- ◆ Nano S&E Content Focus: Teachers have developed projects in soft lithography, laboratories in current and voltage, and developing high school ConceptTests in chemistry, physics, and biology.

### **Small Scale Science Seminar for Teachers in the Cambridge Public Schools**

- ◆ Description: Faculty and postdoctoral researchers funded by the NSEC developed lectures on ongoing research for teachers in the Cambridge Public Schools as part of the teachers' professional development requirement.
- ◆ Goals and Objectives: To provide teachers with ideas for incorporating nano-focused research and concepts into their curriculum, and to encourage teachers to participate in the RET program.
- ◆ Program Staff and Expertise: The seminar series was coordinated by Dr. Kathryn Hollar, Director of Educational Programs for the Division of Engineering & Applied Sciences, in collaboration with Dr. Melanie Barron, Science Curriculum Coordinator for Cambridge Public Schools, and Maureen Havern, teacher liaison for the NSF GK12 collaboration between Harvard and Cambridge Public Schools.
- ◆ Current Activities: Faculty and researchers in the NSEC will continue to deliver presentations for teachers in the 2005-2006 school year that are focused on the tools for integrated nanobiology. These presentations will also be available for students enrolled in the new course, *Research Internships*, at Cambridge Rindge and Latin School.
- ◆ Nano S&E Content Focus: Faculty, postdoctoral researchers, RETs, and graduate students presented topics in nano- and small-scale research, including nanowires, microfluidics, and soft lithography.
- ◆ Nano S&E Content Consultants: The program also featured presentations and discussions with Nanotech Education Associates Dr. Daniel Davis and Joel Rosenberg of the Museum of Science, Boston.

### **V. Education Outreach Materials**

#### **Describe and provide examples of materials, outlines, demonstrations, etc. developed for outreach activities for the K-12 and/or informal audiences**

- ◆ **Soft Lithography: Fabrication on the Micrometer and Nanometer Scale.** Developed by Colleen O'Shell (Chemistry, Cambridge Public Schools, MA), Christina Talbot (Physical Sciences, Memorial High School, Manchester, NH), Logan McCarty (Graduate Student advised by Prof. George Whitesides). The concept of fabricating micro- and nanostructures using soft lithography is tailored in a straightforward experiment for high school students using polymers, metal deposition, and chemical etching. This experiment applies the two most common methods of pattern transfer known as molding and printing. Students create a polymer stamp of a master pattern. Through a chemical deposition process a glass slide is coated with a silver film. The stamp is swabbed with hexadecanethiol and printed on the glass slide. The print creates a self-assembled monolayer, a molecule thick, that acts as a resist on the silver surface. The printed glass slide is then passed through an etching solution that removes the silver that has not been printed. The polymer stamp is also placed on another polymer substrate where a solvent can be applied. The solvent, through capillarity, draws the polymer into the crevices of the stamp. After evaporation of the solvent occurs the stamp is removed leaving the polymer substrate with a pattern that is the reverse of the stamp and a copy of the master. The adaptability of this process to recreating most small scale patterns allows students to envision the applications of this process beyond the laboratory into every day use. This experiment promotes comprehension of soft lithography, nanotechnology, polymerization, polymers, redox equations, covalent bonding, solubility and chemical and physical properties. This experiment was piloted at Harvard University during the summer of 2005 with high school students with varied chemistry knowledge.

- ◆ **Dissemination format:** This module will be available on the [www.eduprograms.deas.harvard.edu](http://www.eduprograms.deas.harvard.edu) website, and will be disseminated through the Nanotechnology Symposium for Teachers and Guidance Counselors at the Museum of Science, Boston in November 2005. Conference presentations are also planned.

### **Describe a recent successful education outreach activity**

In July 13 and August 3, 2005, the joint REU programs and NSEC researchers hosted over 25 Junior Scholars from the Crimson Summer Academy, as part of their Career Explorations program. The Crimson Summer Academy is a Harvard-funded program that brings economically-disadvantaged students of high potential to Harvard in 3 consecutive summers in a rigorous college and career preparation program. During their visit to the Division of Engineering and Applied Sciences, Junior scholars had a lunch-time discussion with REU students from diverse institutions and backgrounds, graduate students, and postdoctoral researchers. Topics covered included selecting a college, why panel members chose science as a career, and financial aid options. Junior Scholars then participated in brief presentations and lab tours on nanobiology and femtosecond laser research. The day culminated in a lecture by an NSEC faculty member and a reception.

Benefits of this collaboration include increasing awareness of science and engineering career paths for underrepresented groups in S&E. The program also engaged visiting undergraduates (many of them from underrepresented groups), graduate students, postdoctoral researchers, and faculty in the broader educational programs of the NSEC in a format that emphasized the community present in the NSEC and in DEAS.

## **VI. Education Outreach Evaluation**

### **Summarize outreach evaluation plan**

REU and RET programs involve on-line exit surveys of program participants, including undergraduates, teachers, graduate students, postdoctoral researchers, staff, and faculty. These surveys are adapted from existing models, including those developed by Dr. Fiona Goodchild (RET) and Dr. Mari Goldman (REU). Teachers who attend workshops are asked to fill out an evaluation at the end of each workshop.

### **Summarize outreach evaluation results**

The REU and RET programs are rated highly successful by participants in the areas of the mentor relationship, professional development activities, social interaction, and diversity of participants. Mentor evaluations in 2004 indicated a need for more pre-program training, which we addressed in early 2005, and plan to strengthen in 2006.

Teachers rated workshops as high quality, but requested more hands-on modules and assistance in implementing concepts into the curriculum.

## **VII. Lessons Learned**

### **List 2-3 lessons learned to share with others embarking on a nano education outreach effort.**

- ◆ Develop long-term relationships and collaborations with school systems and teachers, and follow up regularly.
- ◆ Listen to collaborators and respond to needs by providing the right resources and connections.

### **Describe what you might do differently in the future**

- ◆ More front-end formal evaluation so that impacts can be assessed more accurately.
- ◆ More training of researchers in public engagement skills.

