Appendix 6: Ohio State University/NSEC Profile

I. Description

Institution: Ohio State University
PI : Ly James Lee
Co-PIs: Jeffrey J. Chalmers, Albert T. Conlisk, M. Ferrari, Robert J. Lee
Title: NSEC for Affordable Nanoengineering of Polymer Biomedical Devices
Proposal: 0425626
Program Officer: Bruce Kramer
Education Outreach Director: Paula Stephenson, Ph.D., nsec.ohio-state.edu

II. Research Agenda

Research Focus: The primary goal of the center is to develop polymer based, low cost nanoengineering technology that can be used to produce nanofluidic devices and multifunctional poly-nanoparticle-biomolecule nanostructures for next generation medical diagnostics and therapeutic applications. The research plan is comprised of three thrust areas. In the *Nanomanufacturing Thrust Area*, we combine affordable and environmentally and biologically-benign 'top-down' fabrication and 'bottom-up' molecular self-assembly techniques to produce well-defined passive and active nanoparticles and nanostructures. In the *Transport Phenomena Thrust Area*, the research aim is to achieve design capabilities at the nanoscale, and multiphase transport structures. In the *Biocompatibility Thrust Area*, our current effort focuses on 3D tissue engineering designs for advanced cytotoxicity testing.

III. Education Activities for Undergraduates and Graduate Students

Long-range plans for education and human resource development for undergraduate and graduate students are integrating the latest research developments into a practical student curriculum leading to a nanobiotechnology minor for undergraduate students and a professional certificate for graduate students. The multidisciplinary program summarized in the following table will: (1) develop and offer at least 5 entirely new courses (of which 3 are core courses covering aspects of the Center's research theme); (2) modify at least 8 recently-introduced courses to better align with the center's research theme; (3) expand 3 IGERT courses to NSEC students; and (4) use existing relevant courses from the participating departments. In the current environment, courses at OSU tend to be offered by departments for their own students in relative isolation. The center's new focus provides the incentive and structure for developing an integrated curriculum across disciplines, beginning at the freshman level. At least two new NSEC courses will be phased in every year to maintain a reasonable faculty and administrative workload. Guest lecturers will be drawn from faculty of partner universities, industry, national laboratory partners, and international collaborators. In addition to technical courses that target upper division science and engineering students, we will develop the course *Size Matters: Nanotechnology in Human Life and Society* to bring the center's activities to a general undergraduate student population, as well as to the general public via videotape or CDs. A new *lab module on Design of Nanoscale Biodevices* will be developed and introduced through a design-and-build experience to nearly 1000 freshman engineering students at OSU each year.

Courses will be cross-listed in participating departments. The first two courses listed in the following table are new undergraduate courses/lab modules that target freshmen students to draw them into further studies and careers in nanobiotechnology. The next three courses emphasize fundamentals of nanofluidic device fabrication and will be required core courses in the minor and certificate. The following four courses are electives based upon particular research interests. The last three courses emphasize modeling and provide the foundation for the design and execution of advanced research. Our preliminary curriculum design calls for the minor and certificate to include the 3 core courses supplemented by 4 elective courses chosen from other new and established courses in participating units at OSU.

Related courses are available at OSU for designing a specialized program of study in topics of polymers (processing fundamentals/membranes, polymer science and engineering, rheology, particle technology, colloids and surfaces, conducting polymer devices); nanostructures (quantum chemistry, electronic spectra, structure of molecules, high precision machining, thermodynamics, fluid dynamics/mechanics, heat/mass transfer, tribology; quantum mechanics, and atomic molecular physics); and biomedicine (micro/nanodevices biological transport, biomaterials, biochemistry, drug delivery).

Nanobiotechnology Curriculum for Undergraduate (U) and Graduate (G) Students

Blue = New NSEC courses, Green = Modified courses, Black= IGERT/other courses for NSEC students

Existing and New Courses	Level	Participating NSEC Faculty
----------Freshman Courses----------		
SIZE MATTERS: Nanotechnology in Human Life and Society	U	*Koelling*, Tomasko, Agarwal
Fundamentals of Engineering: ***(add lab module on Design of Nanoscale Biodevices)***	U	*Tomasko*, Rathman, Hansford
----------Introduction to Nanobiotechnology----------		
Nanobiotechnology Seminar (core course)	U G	LJ Lee, Conlisk,Olesik,R Lee,Chalmers
Principles of Biomedical Devices (core course)	U G	*Hansford*, Agarwal, Desai (BU)
Nanofabrication (core course)	U G	*Lu*, LJ Lee, Hansford, Yi
----------Specialization Courses----------		

Molecular Nanotechnology	U G	*Rathman*, Frechet (UCB), new OES in Chem E
Measurement at the Nanoscale	U G	*Menq,* Koelling
Nanotechnology in Medical Diagnosis	U G	*Chalmers*, LJ Lee, Bashir (PUR)
Nanotechnology in Advanced Therapy	U G	*Kniss*, B Lee, Lannutti, Yang
----------Fundamentals at the Nanoscale for Graduate Students----------		
Interfacial Phenomena and Biological Functionalization	G	*Agarwal*, Cooper, Rathman,
Micro/Nano-Fluidics: Design and Modeling	G	*Conlisk*, Hansford, LJ Lee, Fan
Molecular Modeling and Simulation of Materials	G	*Singer*, Ghosh, Peters (FAMU/FSU), OES Mech Eng
----------IGERT Courses Extended to NSEC Fellows and Other Students ----------		
Introduction: Molecular Engineering of Microdevices (MEMD)	U G	Lannutti, *LJ Lee*
Seminar: Future trends in MEMD, mgt. skills, globalization	U G	LJ Lee
MEMD course on Membrane Science and Technology	U G	*Ho*, Tomasko

Additional educational elements will enhance the center's education objectives:

- *SEC Fellow Advisory Teams.* A primary advisor, one or more co-advisors, and an external mentor will jointly advise each fellow in research in one of the thrust areas.
- *Undergraduate Mentoring and Outreach*. Under faculty oversight, NSEC Fellows will mentor/supervise undergraduate students in the freshman design course's new nanobiotech module, in REU research, and in senior honors research theses. Undergraduate students will also participate in supervised K-12 outreach.
- *Undergraduate Summer Research Internships*. Five non-OSU honors undergraduate students will be selected each summer to carry out fulltime research at OSU under center supervision, for a total of 25 students over the five-year period of the center. These students will be supported by related REU awards.
- *Fellow Teaching/Outreach*. To gain teaching and leadership experience, under faculty supervision center Fellows will serve one quarter assisting NSEC courses and working with undergraduate students on research.

- *Web and CD-based Courses.* Teaching modules will be developed for NSEC undergraduate instruction and promoted for use by academicians worldwide, based on the two freshman courses. The modules will integrate class Powerpoint presentations with edited transcripts following the model successfully implemented by OSU Welding Engineering and distributed to industry. Modules will also be distributed through relevant professional associations.
- *Additional Fellow Support*. To increase the number of graduate fellows supported by the Center, doctoral students will only be supported for 4 years using a phase-in plan, with the other 1-2 years funded from other sources. Partial cost-sharing for center masters-level students will also be requested.

Project Staff: NSEC Education Committee, Paula Stevenson, Education and Outreach Director, Professor David Tomasko, Professor Susan Olesik, Professor Terry Conlisk

Goals and Objectives: To provide a various levels of understanding of nanoscience and engineering to undergraduate and graduate students in addition to professional scientists.

Target Audience: Undergraduate and Graduate Students and Professional Scientists.

Current Activities:
Curriculum Planning. In autumn quarter 2004, existing courses at OSU were inventoried and the requirements for establishing a new minor were reviewed. A draft structure for a minor in nanoscience and technology was prepared in winter quarter 2005 by the Education and Outreach Committee, incorporating new, revised, and existing courses. The Committee is currently planning an additional, new anchor course to help undergraduate students bridge the gap between traditional departmental courses and other courses in the NSEC curriculum. A syllabus is under development for the junior-level course "Fundamentals of Molecular Nanotechnology," currently envisioned to include four modules taught from the perspectives of Chemical Engineering, Chemistry, Electrical Engineering, and Physics. A proposal will be prepared and submitted this summer to curriculum committees in the College of Engineering and the College of Math and Physical Sciences. Following submission of the minor proposal, a similar proposal will be prepared to establish a Graduate Certificate or Graduate Specialization in nanobiotechnology.

Course Development. Four related new courses and one revised/expanded course have been offered to date, exceeding our proposed plans as outlined above.

The new nanobiotechnology core seminar course (LJ Lee/ChBE) was offered in Winter Quarter 2005. Topics included molecular self-assembly, nanotechnology, biotechnology, sensor technology, and bio/nanoethics. A majority of the speakers were NSEC thrust area leaders discussing the Center's long-range research goals, and faculty from the participating universities (PUR, BU, UCB, JHU, and UA). Thirty students from 8 departments (4 colleges) formally enrolled in the course, and an additional 10 or so students attended the course each week. NSEC, NIRT, and relevant IGERT students participated. Students formed research subgroups around topics of common interest and delivered presentations on the joint projects. The research subgroup meetings are expected to continue throughout the year to enhance communication and collaboration. Over 95% of the students gave the course an *overall rating* of "agree strongly" or "agree" (in summary) that the course was well-organized, intellectually stimulating, encouraged students to think for themselves, and other measures.

A second new course was developed and offered in winter quarter 05, Fundamentals of Biomedical Microscopic Imaging (Agarwal/BME). Offered to senior undergraduate students and graduate students, several NSEC students and some non-NSEC students enrolled. The course taught principles and described various microscopy techniques (light, electron and atomic force microscopy) for application to biomedical

research. Students were required to carry out "virtual microscopy" sessions available via internet.

The third new course, also offered in Winter Quarter 2005, is Polymer-Based Electronic and Magnetic Materials (Epstein/Chem/Physics). Registration was open to graduate students in Physics, Chemistry, and Engineering; advanced undergraduate students could also register with the instructor's permission. Approximately 15 students from 5 departments took the course for credit. In addition, several postdocs from different departments sat in on the class. This introductory course discusses the basics of physics and chemistry of organic and polymer-based electronic and magnetic materials and devices. This includes the electronic structure of molecules, polymers and solids, and their relation to electrical conductivity and magnetism of conventional metals and materials.

The fourth new course, Molecular Simulation of Materials (Singer/CHEM), is being offered in spring quarter 2005 to advanced undergraduate students and graduate students. Over twenty students are enrolled in the course and additional students are auditing. The course provides an introduction to the use of molecular simulations to predict static and dynamic properties of interest to physical scientists and engineers. Because students are from a wide variety of backgrounds, little prior knowledge is required other than a working knowledge of multivariate calculus and what is taught in introductory undergraduate physics and chemistry classes.

The freshman engineering design-and-build course (Tomasko/ChBE) is being revised and expanded. The Center is supporting the development of special "nanotechnology" laboratory sections of Engineering 183 and H193. These courses include quarter long design-build projects based around lab-on-a-chip technology that students work on in teams. Engineering 183 is a continuation of a successful pilot from an NUE grant to Tomasko last year and the Center is providing logistical and equipment support to scale it up as a full-time complement to the regular projects in this course. In academic year 2004-05, we expect an enrollment of 210 students in the nano sections of 183. Engineering H193 is the honors version of the freshman engineering sequence and the Center is providing equipment, supplies, and logistical support to the development of an advanced lab-on-a-chip experiment to study cell adhesion on nanostructured surfaces. This course will be offered for the first time in Spring quarter 2005 with an enrollment of 30 students.

IV. Education Activities Outside the University

Description of Education and Outreach Activities
The major goals of the outreach program are to use the center's research output to train and increase the technical literacy of K-12 students and teachers, members of the industrial workforce, and the general public; and to develop international collaborations. Tomasko (faculty) and Stevenson (Education Director) will coordinate an integrated, broad collaboration among university faculty and constituency groups as part of a Nanotechnology Literacy Initiative. Long-range plans and progress to date are reported below. All center faculty, graduate Fellows, and staff will participate in aspects of the education and/or outreach programs.

Outreach for grades K-12 focuses on the development and delivery of nanotechnology content and age-appropriate materials that promote hands-on learning. Our current primary strategy is to build on existing, successful programs in the OSU Colleges of Engineering and Math and Physical Sciences. A series of new 1-3 hour hands-on training modules will be developed and offered as part of the College of Engineering's on-campus outreach and recruiting activities, starting in summer 2005. These activities include the *Women in Engineering Summer Workshop*; the *High School Co-op Program*; the *Summer Experience*; and the Minority Engineering Program's *Camp Engineer.*

A. Outreach to High School Students

Description of Activities
Engineers in Motion, Women in Engineering Summer Workshop (Offered Twice Summer 2005)

Program Staff and Expertise
These programs are managed through the Women in Engineering office in the College of Engineering at Ohio State University. NSEC faculty prepared and delivered a 3-hour module for each of these programs.

Goals and Objectives
Learn about engineering fundamentals and disciplines. Explore engineering through hands-on activities, lab tours, and industry visits.

Target audience (educational levels, number of students at each level, etc.)
Engineers in Motion – Students finishing 9th or 10th grade, 35 students
Women in Engineering Summer Workshop – Female students finishing 12th grade and planning to enter College of Engineering, 35 students at each of 2 sessions.

Current Activities
The students participate in about 6-7 activities from different disciplines throughout the week. Activities include making LED bracelets (Electrical Eng), touring Honda of America in Marysville, DNA Extraction (Chemical & Biomolecular Eng.) among many others. NSEC faculty hosted one activity in which the students were divided into small groups (4-5 each) and accompanied to various NSEC laboratories where they worked on a hands-on activity and reported their work back to the larger group via a short presentation.

Nano S&E Content Focus
Activities included in the NSEC program were as follows:

- Femtosecond pulsed-laser fabrication (Prof. Farson, Welding Eng) – Micro and nanochannel fabrication in soft materials. Produced a CD with a channel tracing an image of an eagle.
- Liposome preparation and characterization (Prof. Lee, Pharmacy) – Prepared self-assembled liposomes in solution.
- Atomic Force Microscopy (Prof. Agarwal, Biomed. Eng) – Scanned surfaces and cells attached to those surfaces.
- Micromachining of Optic Components (Prof. Yi, Industrial Eng) – Explored high-precision machining for top-down fabrication approaches.
- Biomedical device micro- and nano-fabrication (Prof. Hansford, Biomed Eng) – Suited up and toured clean room to see photolithography and other nanofabrication methods.
- Ultrasonic micro- and nanoembossing (Prof. Benatar, Welding Eng.) – learned how to use sound waves to create and control nanofeatures in soft materials.
- Electrospinning of polymer nanofibers (Prof. Lannutti, Materials Science & Eng.) – prepared electrospun polymer fibers of a biodegradable polymer for use in tissue engineering applications.
- Thermal characterization and analysis (Prof. Ho, Chemical & Biom. Eng) – Students performed TGA analysis on biopolymers.
- Biochips (Prof. Yang, Chemical & Biom. Eng.) – Students worked with newly designed chips for high throughput ELISA.

B. Outreach and Education to Middle School Students.

Description
NSEC Faculty members visit local middle schools and later interact with the same students when they visit OSU.

Project Staff
All members of NSEC Education Committee and Other NSEC Faculty

Goals and Objectives
We expect to teach the students a basic understanding of nanoscience and technology and fabrication methods (microfabrication and nanofabrication). In addition, we want to interest minority middle-school students in science and technology through these efforts.

Current Activities
In March 2005, members of the NSEC Education and Outreach Committee met with the staff of the Columbus Public Science Office to begin planning presentations and events for academic year 2005-2006.

We have designed a nanoscience and technology unit for middle-school students that involves a visit to the school from an NSEC faculty member followed by a visit by the middle school student to OSU to do experiments and tour the NSEC labs.

In April 2005 Olesik made a presentation to the 8th grade science classes (60 students) of The Wellington School in Upper Arlington on Nanoscience and Technology. This presentation including a discussion of what the term nano means and how nature has used nanoscience for some time and now scientists and technologist are learning how to better understand and engineering nanomaterials. The students were also given a general description of what they would be doing during their visit to OSU.

In May 2005, the middle school students did laboratory experiments on micro-fabrication techniques and also visited numerous NSEC laboratories, including the operating fabrication lab.

A. Outreach to Middle-School and High School Teachers

Description of Activities
Professional Development Workshops for Middle School and High School Teachers

Program Staff and Expertise
NSEC Education Committee and Selected-NSEC Faculty

Goals and Objectives
Teach about grades 6-12 science teachers basic concepts of nanoscience and technology

Target audience (educational levels, number of students at each level, etc.)
Grades 6-12 science teachers

Current Activities
As a prelude to this, we showed Grades 3-5 teachers basic concepts on nanotechnology during the OSU Science Fellows Supporting Teachers Workshop, SFST (OSU's GK-12 program), which was held on June 21-

23, 2005. These teachers also visited the NSEC labs. We plan to offer professional development workshops Nanoscience and Technology during the winter and spring Professional Workshop Days for the Columbus Public School teachers.

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

These were described above and will be illustrated at the conference.

Evaluation
We are in the midst of getting external evaluation of the Outreach Program configured.