

## **NANOSCIENCE AND NANOTECHNOLOGY**

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### **Summary of Research**

As we enter the 21st century, nanoscience and nanotechnology are becoming increasingly important and changing the way we live on a daily basis. In addition, nanotechnology presents a new range of opportunities to build device components and systems, embodying entirely new technology architectures. With diameters frequently less than 10 nanometers (nm), carbon nanotubes (CNTs) and other nanomaterials have different properties than their bulk counterparts due to quantum effects. Theoretical calculations have predicted that the electrical properties of single-walled carbon nanotubes can rival, or even exceed, the best metals or semi-conductors currently known. Experimental efforts have demonstrated that CNTs have the potential to act as building blocks for flat-panel displays, nano-field effect transistors, nano-Schottky diodes, ion storage for batteries, etc. Dr. Jiao's research effort includes the development of nanofabrication techniques for the property controlled growth of nanotubes and nanowires and the investigation of these nanomaterials as building blocks for nanoelectronics. The funded cutting-edge research Dr. Jiao is leading not only benefits the scientific community, but involves students and local industry, as well. One of her funded projects is a Research Experience for Undergraduates (REU) site, the first of its kind at PSU. This program is funded by the National Science Foundation and recruits undergraduate women and minority students to do real-world research in faculty labs at PSU. This program is in its fifth year of operation and gives participants an opportunity to gain valuable skills, present their research at regional and national conferences, and co-author scientific papers for publication in peer-reviewed journals. In the last five years, more than fifty undergraduate students recruited national wide were trained in this program. At the local industrial level, Dr. Jiao is involved in a number of collaborative research projects, some of which are mentioned below.

### **Potential for Commercialization and Job Creation**

At the local level, Dr. Jiao has several collaborative research projects with local companies such as Intel, FEI Co., LSI Logic and Sharp Laboratories of America. These companies are a part of Oregon's key industry sector. As such, these projects bring financial support for Dr. Jiao's research and enhance research infrastructure while providing internship opportunities for students. In addition, PSU's Center for Electron Microscopy and Microanalysis serves to train students not only from PSU but also from Oregon's other institutions including OSU and UofO and technical personnel from local companies. The state-of-the-art instruments at the Center provide a unique opportunity for training and research. In addition to a number of modern microscopes, PSU's Center houses the only FEI Tecnai F-20 field emission high resolution transmission electron microscope (HRTEM) at a university in the Pacific Northwest. The research and training

students undertake through collaborative projects and the Center gives them valuable experience and Oregon a future workforce.

### **Total Research Funding**

Dr. Jiao is currently in charge of a number of research projects, the funding of which totals **\$4,777,787**. Some of these projects are summarized below.

1. **(\$1,300,000)**: “Whole-Cell Biosynthesis of Nanostructured Metal Oxide Semiconductors,” awarded by the National Science Foundation: August 2004 - July 2008. Serves as a co-PI in collaboration with colleagues from Oregon State University.
2. **(\$1,000,000)**: “NIRT: Nanotube based structures for high resolution control of thermal transport,” awarded by the National Science Foundation: June 2004 – May 2008. Serves as a co-principal investigator in collaboration with colleagues from Washington State University.
3. **(\$207,000)**: “REU Site: Application of Microscopy and Microanalysis to Multidisciplinary Research,” awarded by the National Science Foundation: February 2004– January 2007. Serves as a principal investigator (This is a renew grant).
4. **(\$400,000)**: “CAREER: A Novel Approach for Controlled Fabrication of Micro-Gated Carbon Nanotube Field Emitter Arrays and Their Electrical Property Characterizations,” awarded by the National Science Foundation: December 2003 – June 2008. Serves as a principal investigator.
5. **(\$300,000)**: “Systematic Investigation of Single-Walled Carbon Nanotubes Properties, Structure, Composition and Resistivity,” awarded by Intel Corporation: July 2003 – June 2006. Serves as a principal investigator.
6. **(\$80,000)**: “Sharp Fellowship Award to Support the Nanostructural Research for Electronic Devices,” awarded by the Sharp Lab of America: October 2004 – September 2005. Serves as a principal investigator.
7. **(\$30,000)**: “A Collaborative Effort on High Resolution TEM Investigation of Semiconductor Materials,” awarded by the LSI Logic: October 2003 – June 2004. Serves as a principal investigator.
8. **(\$475,000)**: “The Advancement of Portland State University’s Multi-Disciplinary Materials Research,” awarded by the M.J. Murdock Charitable Trust: August 2002 – July 2003. Served as a principal investigator.
9. **(\$180,000)**: “Integration of Nanoscience, Research, and Outreach –Systematic Tailoring of Carbon Nanotubes to Designed Electronic Properties,” awarded by the National Science Foundation: August 2002 – July 2005. Serves as a principal investigator.
10. **(\$35,000)**: “A Novel Method for Position-Controlled Growth of Carbon Nanotubes: Investigation of the Field Emission Properties of Carbon Nanotubes,” awarded by the Petroleum Research Foundation – American Chemical Society: June 2002 – May 2004. Served as a principal investigator.
11. **(\$485,741)**: “Matching Fund for Purchasing a Tecnai F-20 Field Emission High Resolution Transmission Electron Microscope,” awarded by the FEI Company: July 2001 – June 2002. Served as a principal investigator.
12. **(\$376,366)**: “Fund for Purchasing a FEI Sirion Field Emission High Resolution Scanning Electron Microscope,” awarded by the FEI Company: June 2002 – May 2003. Served as a principal investigator.
13. **(\$4,000)**: “High Resolution TEM Investigation of Nanostructures at the National Center for Electron Microscopy (NCEM),” awarded by the NCEM at Lawrence Berkeley National Laboratory: July 2000 – June 2002. Served as a principal investigator.

**Student Involvement**

Dr. Jiao involves high school students, undergraduate, and graduate students in her research. Currently, she oversees 1 post-doc, 4 PhD, 4 Master's, and 6 undergraduate students who conduct research in her laboratory. Each summer, she accepts 16 students from various colleges and universities into the NSF funded REU Program. These students undertake specific research projects with a PSU research faculty member. During the academic year, Dr. Jiao retains 2 or 3 of these students to continue their research. Dr. Jiao also mentors 1 or 2 high school students each summer through the Saturday Academy's Apprenticeships in Science and Engineering Program. All of these students participate in either campus, regional or national scientific conferences. Several of them have received national and international awards for their work. For example, one of her PhD students received the Distinguished Scholar Award from the Microbeam Analysis Society of America and the PSU President's Award for Outstanding University Service, and the Physics Department's Patty Jeanne Semura Outstanding Graduate Student Award. One of her Master's students received a fellowship award from Japanese Ministry of Education to work at the University of Tokyo. Two undergraduate students who attended the Pacific Northwest Microscopy Society conference in October, 2004, have been honored with awards in a poster session competition. More than two graduate students and three undergraduate students received awards from the Pacific Northwest Chapter of the AVS Science and Technology Society. Three high school students who worked at Dr. Jiao's lab won top awards from Intel Northwest Science Expo. In the last five years, Dr. Jiao's group has published more than three-dozen peer reviewed papers with graduates, undergraduates and high school students as co-authors.

**Website**

<http://www.physics.pdx.edu/~jiaoj>