PORTLAND STATE UNIVERSITY

TESTIMONY OF JUN JIAO, PH.D.
ASSISTANT PROFESSOR OF PHYSICS
PORTLAND STATE UNIVERSITY

BEFORE THE U.S. SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION ON S. 189, THE 21ST CENTURY NANOTECHNOLOGY RESEARCH AND DEVELOPMENT ACT

MAY 1, 2003

Good afternoon, Chairman Allen and members of the Senate Committee on Commerce, Science, and Transportation. I am Jun Jiao, Assistant Professor of Physics at Portland State University. I have been working in the field of nanotechnology for more than 10 years and have made significant research advances in this area. My original contributions in the area of nanomaterials growth and characterizations have been documented in more than 60 publications. My carbon nanotube work has been granted patent protection. In 1993, I was selected as a Presidential Scholar of the Microscopy Society of America. I serve as co-director of the Center for Nanoscience and Nanotechnology, and director of the Electron Microscopy and Microanalysis Facility both at Portland State University. I have received funding from the National Science Foundation, Petroleum Research Foundation, FEI Company, and Intel Corporation for research including the development of nanofabrication techniques for nanotubes and nanowires and the investigation of carbon nanotubes and semiconductor nanowires as the new generation of electron emitters.

I am pleased to appear before you today to discuss nanotechnology and S. 189. I want to thank Senator Wyden and members of the Committee for introducing this landmark legislation. There is great excitement about nanotechnology on college campuses and before I could confirm that I would appear today, I asked my students if they would give me their permission to reschedule a class that meets today. They said yes – because they wanted to make sure I told you how important this legislation is to their future. They are excited about the possibilities S. 189 presents and want you to know that they stand ready and willing to be a part of this important national initiative.

PORTLAND STATE UNIVERSITY'S CENTER FOR NANOSCIENCE AND NANOTECHNOLOGY IS KEY TO OREGON'S ECONOMY

Portland State University, Oregon's only urban university, located in the heart of the silicon forest and Oregon's largest economic center, has made a commitment to building a world-class program in nanotechnology. Portland State University has formed an interdisciplinary research center on nanoscience and nanotechnology. The Center involves faculty from Physics, Chemistry, Geology, Biology, Engineering, and Environmental Science. Funding and

DEPARTMENT OF PHYSICS
POST OFFICE BOX 751 ▪ PORTLAND, OREGON 97207-0751 ▪ (503) 725-3812 ▪ FAX (503) 725-3888 ▪ physics.pdx.edu

equipment for the Center has come from the University, industry partners, government, and private foundations. The support PSU has received has allowed it to establish a first class, state-of-the-art electron microscopy and microanalysis facility including an ultra high-resolution transmission electron microscope equipped with various analytical capabilities and a high-resolution scanning electron microscope capable of nano-characterization and electron beam lithography nano-fabrication. Both microscopes were made by the FEI Company, which is located in Hillsboro, OR. Portland State University is the only educational institution in the Pacific Northwest having such comprehensive nanostructural characterization and nanofabrication capabilities. This enables researchers to study the materials' properties at the atomic level and to create novel materials as well as nano-devices.

Portland State University has made a tremendous commitment to this area of research in part because it is essential not only to the future of the economy of the Pacific Northwest but to the global economy. The University faculty's research in the areas of carbon nanotubes, quantum dots, ultra high-resolution near-field microscopy, bio-physics, nano-imprinting, and fabrication of nano-devices is strong and carries national and international reputation. Many faculty research groups have engaged in collaborative research endeavors with local high tech industries such as Intel Corporation, FEI Company, LSI Logic, and Boeing Company, to mention just a few.

Academic and industrial research teams know that joint academic-industry partnerships on nanotechnology will make our economy stronger. Nanotechnology as currently practiced by scientists and engineers in the academic sector is not just an exercise in pursuing sophisticated science, it will have a significant impact on industry and society as a whole. The research in these areas allows us to characterize and structure new materials with precision at the level of atoms and to have unprecedented control of their electronic, magnetic, optical, and thermal properties – in fact, any property that we want to enhance. Consequently, the resulting nanomaterials have stronger, lighter, and better quality than conventional materials. This will have innumerable beneficial effects on our lives in the future -- from safer airplanes and cars to low-power consumption and higher application efficiency of miniaturized electronic products, such as cell phones, computers, and other instruments.

Additionally, Portland State University is part of a collaborative request to the Oregon State Legislature by the Oregon University System to support a signature research center in multi-scale materials and devices development. This proposal involves Oregon State University, the University of Oregon, the Oregon Health and Science University, and Portland State University. It has received favorable support from Oregon's Governor and key legislative committees and is awaiting final approval and funding.

All of this demonstrates that Portland State University and Oregon recognize that the impact nanotechnology currently has on new and existing industries is significant, but the potential for the future will be even greater. Therefore, significant investment in research and development in nanotechnology is essential and especially needed in the academic sector.

NANOSCALE RESEARCH IS THE FOUNDATION FOR THE NEXT GENERATION OF NEW SCIENTIFIC DISCOVERIES AND ENGINEERING DEVELOPMENTS

Nanotechnology is concerned with materials and systems whose structures and components show significantly improved physical, chemical and biological properties because of their nanoscale size. Structural features in the range of a nanometer dimension, which is 10,000 times smaller than the diameter of a human hair, exhibit remarkable novel phenomena as compared to the behavior of bulk materials. We can exploit the novel properties and phenomena of nano-based entities as we learn to manipulate structures and devices at the atomic, molecular and supramolecular levels, and as we develop techniques to efficiently manufacture and use them. Important changes in their behavior are caused not only by the order of magnitude size reduction, but also by new phenomena such as size confinement, predominance of interfacial interaction, and quantum effects. Such new forms of materials and devices herald a revolutionary age for science and technology provided that we can discover and fully utilize the underlying principles.

As a materials scientist, my research focus is on the development of carbon nanotubes and nanowires as new generation of electron field emitters as well as building blocks for nano-electronic devices. As individual nanoscale molecules, carbon nanotubes are unique. They have been shown to be true molecular wires, and have already been assembled into the first single-molecule transistor ever built. In the future, we will see our current silicon-based microelectronics supplanted by a carbon-based nanoelectronics of vastly greater power and scope. I have developed strong partnerships with local high tech companies such as Intel, FEI Company, and LSI Logic because of their interest in the research developments in these areas. Some midsize and small size companies are initiating active conversations with Portland State University's Center for Nanoscience and Nanotechnology and exploring partnerships with us for some specific nanotechnology investigations. Portland State University's President Daniel Bernstine has made business development and job creation a key element in our mission. The University is a hub for faculty expertise, specialized facilities, and highly-talented students who become leaders in the workforce.

I believe that current estimates suggesting that nanotechnology will have a one trillion dollar impact on the global economy throughout this century are reasonable. I have tremendous excitement about the possibilities of discoveries and innovations that can happen. For example, existing industries including those not typically characterized as 'high tech', will see their product lines and the way they manufacture influenced by our growing capabilities in nanotechnology. Moreover, aspects of nanotechnology will help small companies whose products are developed for niche markets including sensors, bio- and chemical-analytical devices and chemical ingredients expand. These small businesses are not likely to require the multi-billion dollar investments that 'chip' manufacturers must face in re-tooling their plants to the new advances in technology. The progress will be even more rapid as the relative risk from investing in nanotechnology becomes lower. I want to emphasize that the research now being done in nanotechnology is producing exciting results, but the cost of production of innovations is beyond the reach of today's consumers. Therefore, research has to be done to optimize those processes.

THE 21ST CENTURY NANOTECHNOLOGY RESEARCH AND DEVELOPMENT ACT WILL ENSURE THAT THE NATION'S WORK IN THIS AREA IS FUNDED, COORDINATED, AND FOCUSED.

As an active researcher in the area of nanotechnology, I am very pleased by the findings, goals, and programs outlined in the "21st Century Nanotechnology Research and Development Act." This Act will enable our nation to establish a comprehensive, intelligently coordinated program for addressing the full spectrum of challenges confronting a successful national science and technology effort. In particular, those related to funding, coordination, infrastructure development, technology transfer, and social issues. Currently the funding available through government agencies and private foundations and companies is limited. As a scientist who has received significant support for my work, I know that funding from federal programs is highly competitive. At the same time, researchers in this area are compelled to present proposals that are by their nature high-risk – but have the potential for high-gains. The result is that few proposals are funded, thereby limiting the work that can be done in universities throughout America. S. 189 will ensure that U.S. scientists receive reasonable funding for research to compete with their Asian and European counterparts, which have been strongly supported by their nations both financially and politically.

I want to address two specific issues emphasized in the Act. First, S. 189 supports long-term nanoscale research and development leading to potential breakthroughs in areas such as materials and manufacturing, nanoelectronics, medicine and healthcare, environment, energy, chemicals, biotechnology, agriculture, information technology, and national and homeland security. I support this approach because nanotechnology offers great promise in diverse fields and cannot advance without federal support. The foundation of knowledge in this area is incomplete, and significant fundamental research is needed. Particularly, in the current competitive and economically-challenged climate, private sector investment will fall far short of what is needed. Therefore, a strong federal role will be necessary for the field to realize its full potential. Also, history has shown us that each of the critical breakthroughs in science and technology has been based on years of sustained federal funding for research. The breakthroughs funded by the federal government are the foundation that enables subsequent efforts by the business sector to translate that research into products for the marketplace. Without the federal government underwriting the long-term funding, there will be fewer breakthroughs to translate into products and economic prosperity.

The Act also requires the Director of the National Science Foundation to collect data about the growth of the workforce that is anticipated as a result of expanded research in nanotechnology. This initiative will provide important information to workforce policy planners about the investment of key economic development and job training funding. I want to speak to this issue because I believe that nanotechnology has strong implications for high-wage jobs and will pay big dividends to communities that make this area of research and development a priority. By this I mean, we need to provide professional development and continuing education for those already working in this field, and make it a priority area of education for tomorrow's workforce. Among three classes I teach each year, two of them are concerning transmission electron microscopy and scanning electron microscopy of nanomaterials. These

classes attract students not only from our campus but also from local industry. The classes are full each time they are offered. Most importantly, through these classes as well as the hands-on laboratory experience, students are able to learn state-of-the-art materials characterization skills and are actively involved in the latest nanomaterials research. The students who are already working in the field leave the class prepared to tackle more challenging technical jobs.

A FEDERAL INVESTMENT IN INTERDISCIPLINARY RESEARCH CENTERS WILL LEVERAGE LOCAL, STATE, AND INDUSTRY SUPPORT

S. 189 authorizes $50,000,000 for Interdisciplinary Research Centers and provides grants of up to $5,000,000 to support geographically diverse centers that support the initiative priorities including those addressing the fundamental research, grand challenges, education, development and utilization of specific research tools, and promoting partnerships with industry identified in the legislation. These are exactly the missions that the Center for Nanoscience and Nanotechnology at Portland State University is pursuing. It is our long-term goal to secure additional federal funds and attract foundation and private contributions to expand the work we are doing and to build an internationally recognized multidisciplinary nanoscience and nanotechnology research center.

Additional support from the federal government for research in this area will help programs like mine, and those around the country, lead the way for innovations and discoveries. I support the calls for interdisciplinary work and collaboration outlined in the legislation because most of today's challenging problems in science and engineering are complex and will not be solved by investigators working within the borders of their own chosen fields. That is the philosophy that guides the work we do at Portland State University. Federal funding for nanotechnology will assist important interdisciplinary research efforts which may lead to curing cancer and AIDS, reducing reliance on fossil fuels, or building the next-generation of sensors to help safeguard our homeland.

S. 189 IS LEGISLATION THAT WILL RESONATE WITH YOUNG PEOPLE TODAY – TOMORROW'S SCIENTISTS AND ENGINEERS KNOW THAT INVESTMENT IN NANOSCALE RESEARCH IS KEY TO OUR NATION'S FUTURE

My research laboratory is one of the areas of excellence at Portland State University. As a result, I host many visiting dignitaries to campus who are interested in learning about ways the University is addressing the workforce and research needs of the future. Many of those visiting truly understand the research area. Others don't understand the specifics of the work we do, but have enthusiasm for its possibilities. For example, they may have grown up when the nation focused on the imperative of getting man to the moon. Or they have experienced the sophistication and evolution of computers from those that took up whole rooms to the pocket personal computer they carry. So, people of our generation typically have a general appreciation of why this area of research is important.

I want to assure you though that young people today – those in middle school and high school – are truly excited about this area of research. Let me give you two examples. In the past several years, I have been involved in an outreach program called apprenticeship of science and engineering organized by the Saturday Academy of Oregon. This program aims at promoting high school students to pursue higher education in science and engineering. Each

summer, I host one or two high school students selected among the high schools in Oregon and Washington to work with me on my nanomaterials research. For one position there are usually more than 40 applicants. In reading their application essays, I was amazed by the depth of the knowledge that young people have about nanotechnology. I was touched by their strong desire to participate in nanomaterials research. In my spare time, I also serve as a judge for the Intel Northwest Science Expo. This is an annual event designed to encourage middle and high school students to apply their interest in science and engineering to real world innovations. Each year, more than 500 students from Oregon and Washington participate in this event. The students present their own research at this event and every year I am encouraged by these young people who I know will become great scientists. These students are excited about nanotechnology, however we need an imperative such as S. 189 to ensure that our scientists of the future will have a firm training ground with consistent financial support.

In closing, I would like to thank the Committee for the invitation to testify today. It is an honor to be asked to participate in this crucial national discussion. My colleagues and I strongly believe that nanotechnology will lead to a new and improved technological revolution. S. 189 is the commitment we need to continue American leadership and innovation in the latest technological frontier. I urge the Committee to pass this bill.