January 5th, 2004

Dr. William H. Feyerherm,
Vice Provost for Graduate Studies and Research
Portland State University

Dear Dr. William H. Feyerherm:

Please find in the attached file an electronic copy of our proposal “Initiation of Basic Infrastructure for the Development of Nanotechnology at PSU. Instrumentation and Technical Support for Fabrication, Characterization and Packaging of Nano Polymer/Fluidic/Optical Devices and Nanostructures.” A hard copy was personally delivered to your office, in a timely manner, on Monday January 5th, 2004.

In our proposal we outline the benefits for creating a nanotechnology center at PSU (arguable the only way to implement NEMS technology, as described in our initial 5-page proposal), its gradual implementation, and the much-needed commitment from the PSU administration to provide laboratory space for the center in a mediate-future (we understand the hurdles behind this request). We also emphasize our request in the amount of $410K to acquire critical pieces of instrumentation and support personnel, which represent a crucial first step in building the infrastructure of a nanotechnology center; this total reflects an order of magnitude of budget figures your Office has provided for the current competition.

We attach to the proposal the strong support letters we have received from our Chairs. They have been very sincere in their support, provided suggestions to make our proposal stronger, and they appear very willingly to work closer with us in the future. We are very happy that one of our Chairs, Professor James Morris, is a member of our team in this proposal. Similarly, our Deans from CLAS and CECS also managed their schedule to learn the details contained in the proposal. One of us had the opportunity to describe to both of them the rich working atmosphere our multidisciplinary team (composed by engineers and scientists) has created, how intense interchange of ideas our weekly meetings became, and how all of us have agreed to work as a team.

We understand our task toward the creation of a nanotechnology center at PSU is challenging but, at the same time, exciting. This proposal has united us and we have been able (we hope) to elaborate a first substantive proposal that represent just a first stone in our planned future activities as a group. We hope to be funded in this our first enterprise, which will spark an even greater interest in each of us to participate in this endeavor, and provide an incentive to keep us working together (scientist and engineers) and perfection our strategies.

With our best regards

Sincerely

The team:  S. Benight   A. La Rosa   P. Moeck   M. Weislogel
           J. Jiao       C. Li       J. Morris   M. Yan
           R. Koenenkamp L. Meekisho S. Reed M.     S. Yi
Office of Research and Sponsored Projects

Title: Initiation of Basic Infrastructure for the Development of Nanotechnology at PSU. Instrumentation and Technical Support for Fabrication, Characterization and Packaging of Nano-Polymer/Fluidic/Optical Devices and Nanostructures.

The team:

S. Benight __________________ P. Moeck __________________
J. Jiao __________________ J. Morris __________________
R. Koenenkamp ____________ S. Reed _________________
A. La Rosa ________________ M. Weislogel _______________
C. Li _____________________ M. Yan _________________
L. Meekisho ________________ S. Yi __________________

Signatures of the relevant Department Chairs

Electrical & Computer Engineering,
Professor James E. Morris __________________________________________

Mechanical Engineering,
Professor Graig Spolek ___________________________________________

Physics,
Professor Erik Bodegom ____________________________________________

Chemistry,
Professor David W. McClure _________________________________________

Signatures of the relevant Deans

College of Engineering and Computer Science,
Dr. Dean Dryden ___________________________________________________

College of Liberal Arts and Sciences,
Dr. Marvin Kaiser __________________________________________________
Initiation of Basic Infrastructure for the Development of Nanotechnology at PSU. Instrumentation and Technical Support for Fabrication, Characterization and Packaging of Nano-Polymer/Fluidic/Optical Devices and Nanostructures.

ABSTRACT

Nanotechnology—a vision to build devices at nanometer-sized scales—is expected to revolutionize science, industry and the global economy in the 21st century. It will impact diverse areas such as materials science, biotechnology, manufacturing, electronics, medicine, and information technology. Current approaches such as Nano-Electro Mechanical Systems (NEMS) technology (a top-down approach to shrink devices dimensions down to nanometer scales by cleverly extending the application of existent micro-fabrication techniques) and ingenious Self Assembly Techniques (the bottom-up approach that builds nanostructures starting from their molecular constituents) are making great progress on the quest to fabricate materials and devices at the nanometer length scale. Progress in nanotechnology is challenging and demands substantial research infrastructure. This proposal—aiming at the acquisition of critical instrumentation and technical support—represents a crucial first step in building the infrastructure for a prospective NanoTechnology Center (NTC) at Portland State University. Acquisition of this instrumentation and support will provide a firm foundation in nanotechnology infrastructure required to build a productive and competitive NTC. This proposal also outlines the general scope and vision of the NTC. The research areas that will be supported are described with particular focus on how the requested instrumentation and personnel will benefit and enhance ongoing research projects, as well as how it will enable the formulation and execution of new developments in nanoscience and nanoengineering.

Building a nanotechnology center at PSU fits both the research expertise and departmental priorities of the Chemistry, Electrical Engineering, Mechanical Engineering and Physics departments. In addition to building interfaces between traditional disciplines of science and engineering, the NTC will also provide a forum for fostering partnerships with the industrial community in the Portland metropolitan area. Further, the NTC will benefit the students of PSU by providing broad exposure to modern problems and issues in nanotechnology, and training future researchers in the methods, instrumentation and theory underlying the broad field of nanotechnology. The implementation of the NTC can be facilitated through the collaboration with the numerous semiconductor industries in the Portland area, become a place where the surrounding companies can pursue new techniques without interrupting their production facilities, provide PSU with a distinct regional, national and international visibility as a nanotechnology development center, and become the seed for PSU’s future attempts to attract state, government and private external funding for the creation of an international nanotechnology center.
Initiation of Basic Infrastructure for the Development of Nanotechnology at PSU. Instrumentation and Technical Support for Fabrication, Characterization and Packaging of Nano-Polymer/Fluidic/Optical Devices and Nanostructures

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DESCRIPTION

I. PSU as a NANOТЕХНОLOGY DEVELOPMENT CENTER

I.1 Why a nanotechnology center?

With a prospective future of $1 trillion in products worldwide (antibiotics, the integrated
circuit, and manmade polymers) affected by nanotechnology and the projected need of 2 million
nanotechnologist workers in ten to fifteen years, a plan to initiate the implementation of the PSU
NanoTechnology Center (NTC) is presented here. The center will help reinforce technologies
already under development at PSU and foment the creation of new ones; it is expected to have a
long-term strong impact in many disciplines:

a) In Biotechnology, for example, new fabrication methods of micro- and nano-structure arrays
offer the potential to implement high-throughput bioassays analysis in the search for new
therapeutic drugs. Microarrays offer researchers a tantalizing way to harvest the bounty of
genome sequencing and proteomics, and the associated microarray industry is projected to
generate revenues in the tens of billions of dollars in a few years. (S. Benight, M. Yan).
b) In the creation of new materials and new characterization methods, including metallic
nanoparticles (S. Reed, J. Morris), carbon nanotubes, nanowires and nanodevices, such as
transistors on flexible substrates (J. Jiao, R. Koenenkamp), and characterization of
semiconductor quantum dots (P. Moeck, J. Morris, C. Li), which hold very promising
prospects for applications in medicine and electronics. Gold nanoparticles, for example, are being
explored as antennae to enhance the optical properties of adjacent chromophores or, when
regularly ordered in polymer templates, as potential single-electron transistor devices; carbon
nanotubes have a great prospective as field emitter sources for display applications; nanowires are
being used to fabricate novel field-effect transistors; and new techniques in Transmission
Electron Microscopy (TEM) are being developed to better characterize structural compositions of
quantum dots, with a prospective of effectively participate in the development of future
“Aberration Corrected TEM” for characterizing materials with genuine atomic resolution.
c) In exploiting the intrinsic higher capillary mass-flow rate efficiencies of micro-porous
structures, which have direct application in spacecraft thermal control systems and in terrestrial
micro-chip cooling industry (M. Weislogel).
d) Manufacturing, Stress Analysis and Packaging of mechanical micro- and nano-structures,
using top-down MEMS/NEMS approaches to significantly reduce the size of currently micronized
structures (S. Yi, L. Meekisho, J. Morris and A. La Rosa).
e) In fostering new methods to manufacture nanostructures, including molecular imprinting
techniques that combine unique surface chemistry and self-assembly methods to create, for
example, polymer wells of nanometer dimensions where single molecules can be accommodated
and studied at will. (M. Yan, S. Benight).
f) In optics, where clever design of sub-wavelength aperture arrays, or ordered apertures in thin
metal films, will allow to take the realm of optical applications into the mesoscopic regime,
something believed impossible just a few years ago (A. La Rosa).
g) In data storage, where new devices are being designed to exploit the quantum mechanical 'spin'
of the electron, in addition to its charge, to create a remarkable new generation of 'spintronic'
(spin electronics) devices\textsuperscript{20,21} which will be smaller, more versatile and more robust than current silicon chips.\textsuperscript{22} Characterization of the structural metastability of spintronics materials\textsuperscript{23} is one focus of Dr. P. Moeck’ and Dr. C. Li’s work.

The degree of urgency in our proposal for the creation of a nanotechnology center at PSU can be appreciated by considering the major initiatives on nanotechnology currently taking place all over the world.\textsuperscript{24,25} Indeed, the promissory future of nanotechnology, as described above, has prompted the formation of over a dozen major well-funded nanotech research centers at U.S. universities; the European Community runs several nanotechnology programs,\textsuperscript{26} including the Nano Network, which contains 18 member research centers working in nanomaterials synthesis. The U.S. government has enacted the National Nanotechnology Initiative—the Federal government's investment in the future of nanotechnology\textsuperscript{27}—and, in December 2003, Congress passed a law that authorizes $3.7 billion over the next four years for funding of federal government nanotechnology programs. We believe the NTC can be instrumental in capitalizing on such national investment in nanotechnology. The existence of the NTC will also help to exploit PSU’s strategic geographic location to establish a business partnership and research collaboration with the surrounding industrial companies.

1.2 The Vision of the NTC

The NTC envisions becoming an institutional foundation that helps PSU faculty to accomplish major research, educational and commercial initiatives in cutting edge nanotechnologies. By targeting the acquisition of major analytical and fabrication equipment, which otherwise would be out of reach of single researcher’s, the multi-user equipment policy of the NTC will optimize PSU’s economical resources devoted for research. The NTC also plans to create of a Post-doctoral Fund aimed at attracting recently-graduated professionals to work under the guidance of PSU researchers, which will allow a more rapid engagement of PSU in cutting edge research and subsequent publications in prestigious journals, thus placing the NTC at the international spot. Furthermore, a center offering both equipment and human resources, will improve recruiting of new faculty that find attractive the outlook of being able to implement immediately their research agendas at the NTC. This is a situation we can capitalize upon to attract major players in the nanotechnology field to the PSU campus.
On the **research** aspect, the NTC aims to enable every individual researcher with the proper tools and human resources to effectively contribute to the development of new nanotechnologies. Due to the expected multidisciplinary aspect involved in the development of nanotechnology, the NTC will support both the top-down and bottom-up approaches (detailed below) to build nanodevices and nanostructures, thus welcoming and capitalizing upon the diverse background of PSU faculties in nanoengineering and nanoscience. The NTC will also devote resources to enable structural characterization and packaging methods aimed at future device commercialization. This last aspect, which frequently goes unnoticed in major technology initiatives, is as important as the device fabrication itself. Indeed, in addition to being able to manipulate atoms and nanostructures, the challenge of nanotechnology consists of finding ways to mass-produce nanometer-sized objects and integrate them with human scale systems, which will facilitate their impact on the market place. The NTC therefore will nurture the much-needed new levels of cooperation among colleagues of different specialties to face the different challenges involved in the development of nanotechnology.

On the **educational** aspect, the impact of the NTC will be reflected in its capability to offer PSU students better hands-on technical training, particularly in technologies that are at the verge of commercialization, which will substantially elevate PSU students’ competitiveness in the job market. In addition, the existence of a nanotechnology center will also help PSU to more effectively compete with other major universities in recruiting new talented graduate students. As part of its goal of achieving a regional impact, the NTC also envisions becoming a useful resource for the surrounding companies (wanting to have the technical skills of their personnel updated with the latest technologies) through the offering of PSU’s NanoCourses (with syllabus including nanomaterials and nanofabrication methods, nanotechnology instrumentation, and theory). At the internal PSU level, the NTC can help building bridges among traditional fields of science and engineering, and become the seed to develop new curricula to train future researcher in the field of nanotechnology.

On the **commercial** aspect, the NTC will serve as a catalytic center for establishing closer collaboration with the private sector and bridging commercial partnerships. Initially, we will focus on major industrial partners in the region as potential customers of our services and facilities. Annual fees for NTC services, complemented with

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**Fig. 2** Research, Education and Commercialization constitute the major thrusts of the NanoTechnology Center (NTC). While supporting research in technological cutting edge areas, the NTC contributes to fulfilling PSU’s institutional educational initiatives (offering training to both students and personnel from private companies) and pursue the commercialization of its members’ inventions. An executive committee supervises the daily operation of the center, and an industrial board makes recommendations on the trends of industrial applications that the center could pursue. The facility operates under the multi-user equipment policy, provides equal access to all PSU researchers, and works hand-on-hand with the PSU administration.
additional educational services that PSU offers, will help to generate economical resources and while cultivating an atmosphere of mutual collaboration between PSU and the private sector (membership and basic technical service may be in the range from $5k to $10k per year). Intellectual properties generated by the NTC members, patent commercialization, analytical services, and consulting will generate NTC resources that will help sustain its operation. The center will serve as the nucleating entity for gathering teams of researchers from different disciplines with synergistic interests for the purpose of submitting large multi-investigator grants to Federal Government agencies.

The NTC will operate on the principle that not a single PSU Department, nor a single researcher member, can claim ownership of its implementation; this is expressed in the idea that we are all co-PI and there is no PI, as to reflect the spirit that the NTC is an initiative from a whole group of PSU researchers. Administratively, an annually elected Executive Committee (composed by NTC members) will supervise and be responsible for the daily operation of the center, and an invited Industrial Advisory Board, composed by members from industrial companies, will advise the NTC on the current trends of industrial applications. Currently, Drs. Meekisho, Yan, Weislogel and La Rosa (the participants in the initial 5-page length proposal), are coordinating the initial activities of the prospective NTC and are temporarily responsible for its liaison with the PSU administration. The NTC guarantees equal access to all PSU researchers, and works hand-on-hand with the PSU administration. A quarterly published NanoBulletin, summarizing the NTC’s activities and research accomplishments, will help to provide regional, national and international visibility. Due to its multidisciplinary scientific, technological and economical potential impact, and the existent ongoing research by PSU researchers in nanotechnology, the implementation of the NTC to support the development of nanotechnologies constitutes an essential requirement.

II. NANOTECHNOLOGIES PURSUED at the PSU NTC

The existent initial work on nanotechnology being pursued by PSU researchers (as described below) makes worthwhile the investment and effort in implementing a nanotechnology center. It will have an immediate catalytic effect to speed up the research activities in our campus and institutionalize PSU as a major player in the development of nanotechnologies.

In this section, we provide first a brief introduction on the two main trends (involving nanoscience and nanoengineering) that researchers follow worldwide in their quest to harness nanotechnology; it will help to highlight the much-needed new levels of collaboration between engineers and scientists (an aspect the NTC will help to germinate). Then, from sections II.2 to II.5, we include a brief description of the different areas of research to be pursued at the NTC, highlighting their potential, the work done already at PSU and how the NTC would benefit the corresponding research program.

II.1 The two basic approaches to Nanotechnology

From a simplified point of view, there exist two principal approaches to build nanostructures. Figuratively, they are referred to as the “top down” and “bottom up” approaches. Top down refers to the miniaturization of large micro-scale structures down to the nanoscale. Bottom up involves assembly of nano-scale structures from smaller components such as atoms and molecules. In top down, downsizing of devices is achieved by cleverly extending applications of existent micro-fabrication techniques, reducing scale from large to small. A specific example of top down is NEMS, a vision to extend the capabilities of MEMS (a technology, still in progress,
capable of fabricating machines of micrometer size) into the nano-scale domain. In contrast, bottom up (also called nanochemistry) typically employs natural phenomena of self-assembly and self-organization. In this simplified view point, the top down approach works on the basis of well established and novel engineering principles and may be considered to constitute the core of **nanoengineering**, while working out the mechanisms and underlying fundamental principles may be considered to constitute the core of **nanoscience**. While long-term gains of the nanotechnology are more likely to be realized by the bottom up approach, the short-term gains are more likely to be realized by the top down approach.

Capitalizing on the multidisciplinary background of the PSU researchers, the NTC will support both top-down and bottom-up approaches to nanotechnology. The former will be emphasized by the proposed development of NEMS technology, while the latter by the multiple research activities on nanoparticles, nanotubes and nanowires—including their structural characterization—all of which are ongoing areas of research activity on the PSU campus. On a pragmatic level, efforts in the NTC will also support research activities forging the interface between nano-structures that are built from the bottom-up self assembly processes with nano-structures produced by the top down approach. Indeed, engineered nanostructures functionalized with unique surface chemistry allowing fixation of targeted biomolecules, represents one of the research foci of the NTC. This inorganic-organic interface area has the prospect of building a new class of functional **hybrid devices** (utilizing active molecules integrated with electronics and near-field optics readouts) and will provide a distinctive feature of our capabilities. This area will be a unique niche pursued by the NTC to distinguish us from other nanotechnology programs. Achieving success in these areas targeted by PSU researchers will require a more extensive infrastructure than currently exists. We believe that a coordinated approach between the science and engineering schools is desirable to ensure that a sufficiently competitive research effort can be established.

**II.2 Nanoelectronics**

**II.2.1 Large-area Applications: novel solar cells, nanowire transistors (R. Koenenkamp)**

Nano-structures promise considerable advantages for electronic and optoelectronic large-area applications, as in photovoltaics, or for large-area displays, detectors, sensors etc. We plan to prepare nanostructured substrates for the fabrication of novel solar cells with extremely thin absorber layers, to fabricate nano-wire transistor arrays embedded in flexible films, and to fabricate flexible light emitting structures using low-temperature deposition and structuring deposition and structuring.

![Fig.3 Vertical nanowire transistor. a) Left. Schematic diagram of the transistor’s main components (source, drain and gate contacts) with the semiconductor CuSCN nanowire acting as channel material. Right: Cross section micrograph of stacked polymer film with center metal layer of 200 nm. b) Top view of longitudinal etched pores in the polymer prior to the filling with the p-type semiconductor. c) Free standing polycrystalline CuSCN after dissolving the polymer template (for illustration purpose). Adapted from Koenenkamp et al.](image-url)
techniques. Considerable experience in this field has been accumulated as evidenced by several peer reviewed published papers and five patent applications that have been awarded or are under prosecution (Koenenkamp et al., 1999-2003). The main advantage of using nano-structures in these applications is the possibility of tailoring the geometry on the scale of the electronic transport lengths and below the wavelength limits of visible light. Improved charge separation, altered emission and absorption characteristics, and improved mechanical behavior can be achieved in this way. While large-area applications are best addressed with relatively inexpensive non-lithographic methods, lithographic tools, such as electron or ion beam machines, are often extremely helpful in establishing an effective research approach. Therefore, acquisition and installation of instrumentation for preparation and characterization on the nanometer scale at PSU, as requested in this proposal, will greatly enhance our efforts.

II.2.2 Fabricating Micro-Gated Carbon Nanotube Field Emitter Arrays (J. Jiao)

Dr. Jiao’s group focuses on developing a novel procedure for fabricating Micro-Gated Carbon Nanotube Field Emitter Arrays (MG-CNT-FEAs). Carbon nanotubes are long, cylindrical carbon molecules, whose electronic properties depend on their structural details; theoretical calculations have suggested that the electrical properties of single-walled carbon nanotubes (SWCNTs) can rival, or even exceed, the best metals or semi-conductors currently known. The motivation for developing MG-CNT-FEAs stems from the assortment of potential applications with varying emitter requirements. For example, compared to flat panel display applications, which generally require electron emission currents of only 10-100 µA per pixel, elements for microwave amplifiers and cathodes for high frequency traveling wave tubes (TWTs) need to exhibit emission currents as high as 160 mA, with macroscopic beam current densities up to 50 A/cm² as well as with high transconductances. Achieving this level of performance requires the use of large arrays (>10,000 tips) with tip packing densities on the order of 10⁷ tips/cm² and average currents per tip consistently between 1-10 µA with the lowest possible extraction (gate) voltages to obtain highest possible transconductances. Dr. Jiao’s novel approach for fabricating MG-CNT-FEAs is based on a patent pending technique invented by her group. Jun uses this technique to fabricate the Pt posts within arrays of Si cells on a piece of Si wafer. Then an ion-induced deposition of ferrocene is used to deposit Fe catalyst on the top of each Pt post. The processed substrate is then placed into a CVD reactor. The preliminary result shows that this approach will lead to an improved technique for fabricating MG-CNT-FEAs once a limited number of processing parameters has been optimized. Unlike the conventional technique, which involves various steps of masking, chemical etching, and deposition for producing CNT-FEAs, the technique Dr. Jiao has developed will greatly simplify the process and significantly minimize the damage to the integrity of the materials. However, to make this technique more mature for the specific applications, a substantial amount of research is needed to investigate the effects of systematically varying the individual fabrication steps on the quality of the MG-CNT-FEAs. In order to successfully conduct these projects and to maintain Dr. Jiao’s research at a competitive level, an improved research infrastructure at PSU is crucial. Funding for this proposal will greatly benefit her ongoing research.

II.3 Development of MEMS and NEMS technologies (S. Yi, L. Meekisho, A. La Rosa, C. Li)

Nano-Electro Mechanical Systems (NEMS) technology is a vision to fabricate three dimensional devices on nanometer scales. NEMS is a top-down approach to nanotechnology
evolving from MEMS. MEMS integrates micro-sized mechanical elements, sensors, actuators, and electronics on a common silicon substrate; it uses compatible "micromachining" processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices. Examples of MEMS devices include drug delivery systems in medical and biomedical fields, optical switches, lab-on-chip systems, traction control and airbag deployment systems in automotive applications, guidance in military applications, implantable health monitoring devices like micro-accelerometers for heart rate control, etc. A flourishing area of research is Optical-MEMS, which combined with self-assembly methods, promises versatile multifunctional micro opto-electro mechanical (MOEMS) devices, an area we plan to develop at the NTC. The MEMS market for 2005 is projected to be nearly $7B.

**From bulk and surface micromachining MEMS technology to NEMS**

**MEMS by micromachining bulk silicon**

Micromachining bulk silicon is the simplest method to fabricate MEMS devices. It exploits the preferential etching that silicon undergoes across its different crystallographic planes. At PSU, Dr. A. La Rosa uses a focused ion beam (FIB) system for micromachining V-grooves in silicon (Figs. 4a and 4b), aiming to manufacture probe-arrays for near-field optics (NFO) applications (Fig. 4c). NFO is a novel technique that overcomes the limited lateral resolution of conventional optical microscopy, and brings the field of optical characterization to the nanometer domain (such a capability is not possible with conventional optical techniques). Although quite a helpful tool, the scanning serial process of the FIB machining method is relatively slow. A parallel process offered by photolithography would be preferred. This proposal is requesting a mask-aligner and characterization equipment for that purpose.

**MEMS by Surface Micromachining**

A dramatic enhancement to silicon micro-machining capabilities is the newer surface micromachining technology. In a process (Fig. 5a) that involves sequential deposition of polysilicon (or other “structural” material) and silicon oxide (“sacrificial”) layers, stand-alone three-dimensional movable structures are fabricated after chemically etching the oxide. The fabrication cost, however, increases dramatically (compared to bulk micromachining), and its implementation will requires major capital equipment and space laboratory. The micrometer size movable mirror shown in Fig 5b illustrates the capability of surface micromachining; it is intended for applications in controlling data traffic (re-directing information carried by optical fibers) in optical networks. A critical aspect in the design of these MEMS devices is the stress and stress-gradients of the structural material film layers, which is one focus of Dr. Lemmy Meekisho’s research. His expertise will be crucial in development of new designs of MEMS devices at PSU. Lemmy recognized early on the importance of MEMS and the new horizon of knowledge it could provide to PSU students, and has developed the course "Fundamentals of
MEMS and Microsystems", ME 410/510, that has been offered for two consecutive years at PSU. For the construction and packaging of MEMS devices, Dr. Sung Yi will exploit his experience in this field as Director of an institution that has developed MEMS. Sung’s research focuses in the areas of electronic packaging, delamination and failure mechanisms of electronic packages and composites, including computational simulation. Dr. Yi’s national and international connections with the industrial sector will be pivotal for the functioning of the NTC.

The advent of NEMS

Currently, micron-sized MEMS devices are being pushed towards nanometer dimensions thus being renamed NEMS (nano-electromechanical systems). An alternative to achieve this size reduction is to complement microfabrication processes with Electron Beam Lithography (described in the next paragraph). Of particular interest, for their potential application in wireless communication, are the nanomechanical resonant structures. As their size reach the nanometer scale, their resonance frequency can be tuned from 5 MHz up to the GHz regime, which make them ideal candidates to replace currently bulky frequency reference devices used by the wireless telecommunication industry. A. La Rosa and L. Meekisho will explore further the integration of these resonators with optics, an attractive area of research for optical-mechanics device developments. Indeed, it has been demonstrated very recently that nanoresonators (see Fig. 5c.) can be actuated by purely optical means. What is exploited here is the interference pattern established by the vibrating membrane and the substrate upon the incidence of a laser beam, which creates a temperature gradient that heats and cools the membrane during its oscillatory motion. By tuning the device’s size-dependent heating/cooling time-constant to the periodicity of the vibration frequency, large self oscillations (3 order of magnitude increase) with narrowing in frequency of the resonance response (quality factor varies from 7,000 to 30,000) are obtained. On the other hand, just to enrich their exquisite applications, nanoresonators are being used as test-beds to study the fundamental “zero point motion” fluctuations imposed by quantum mechanics to systems in its ground state, which is relevant to the development of precision detection systems. As mentioned above, Electron Beam Lithography (EBL) is a powerful tool that enables the fabrication of nanostructures. Dr. C. Li is an expert in electron microscopy and his participation in the NTC will be very important. The EBL technique works through scanning an electron beam following a designed pattern on specimen surface, usually silicon wafer, coated with resist. This process is followed by dissolving the exposed specimen in specified solution, where the exposed
part (or the unexposed part) will be dissolved away (similar to the procedure described in Fig. 5a). The advantage of this technique relies on its high resolution and flexibility to draw virtually any pattern. PSU has made investment in introducing top level TEM and SEM, which provides back up for research activities using this technique. The introduction of EBL will promote ongoing projects, e.g., more detailed study of quantum dot (Dr. Li collaboration with Dr. Moeck), more controlled formation of nano-materials (Dr. Li collaboration with Dr. J. Jiao), and preparation of nano-scale mechanical and electronic devices (Dr. Li collaboration with Drs. La Rosa, Meekisho and Koenenkamp).

II.4 Micro-Arrays, Micro-Fluidics, Surface Chemistry and Molecular Imprinting Technology

Micro-Arrays Technologies (S. Benight)

Micro- and nano-arrays—solid supports made out of glass, upon which a collection of gene-specific nucleic acids (or, alternatively, proteins) have been placed at defined locations—are well suited for implementing high-throughput analysis in biotechnology and biomedicine applications. In a DNA-array, for example, each spot, having a unique DNA sequence different from the DNA sequence of the other spots around it, will hybridize only to its complementary DNA strand; in this way each spot is acting as a probe to determine the levels of a specific mRNA produced by a collection of cells. Although DNA microarrays are currently the most developed, microarrays containing proteins, lipids, sugars, etc., are also being developed. DNA microarrays are being employed for genetic profiling, pathogen detection, and gene expression analysis. Microarrays containing proteins and other biological molecules have the promise of providing faster and more effective high throughput drug screening, revealing before unknown characteristics of molecule/molecule interactions. Because of their broad applications and high throughput capabilities, microarrays offer the opportunity of not only monitoring the expression of thousands of genes simultaneously, but also of characterizing multiple pathways and networks and molecular biological machines involving the collective interactions of large numbers of the genes and their gene products.

With these myriad applications and the promise of providing breakthroughs in genetics, diagnostics, drug screening and biological system analysis, the microarray market is expected to well exceed $10B by 2010. To fully realize this market potential there are a number of hurdles that must be overcome. Many of these will be directly dependent on developments in nanotechnology and nanofabrication (the foci of this proposal). In particular, will be the requirement of improved micro fabrication and fluidics technologies, development of nanoscale materials and nanofabrication methodologies for constructing nanofluidic devices. The marriage of nanomaterials and nanofluidics will enable the construction of a new generation of “nanoarrays”. A primary focus of Dr. S. Benight’s efforts is the development of development biological nanoarrays.

Engineered micro-porous structures (M. Weislogel)

Dr. Mark Weislogel is involved with NASA’s projects on microgravity fluid phenomena. Mark is exploiting recent advances in the analysis of capillary driven flows in containers possessing interior corners, which uncover optimal geometries for transport at micro-scales over surfaces and through media that may be modeled as constructs of micro-scale interior corner networks. For example, new engineered micro-porous structures are predicted to yield order of magnitude improvements in capillary driven mass flow rate—a key measure of system
performance in numerous fundamental and industrial processes. These findings have direct application to the design of high performance wick structures for capillary controlled heat pipes, capillary pumped loops, and loop heat pipes commonly used in NASA’s spacecraft thermal control systems, but gaining acceptance in the terrestrial micro chip cooling industry (i.e. laptop thermal control). Important applications also include high performance membrane designs used in fuel cells, bioreactors, and systems requiring high transport across liquid vapor interfaces. The theoretical improvements predicted have been verified at macroscopic scales for the large geometrically-complex capillary systems aboard spacecraft, but have not been demonstrated, developed, or exploited at the microscale.

**Surface Chemistry and Molecular imprinting technology (M. Yan)**

Progress in nanotechnology continues with the exploration of alternative strategies that use "soft lithography" for the fabrication of nanostructures. Instead of Silicon, these techniques use transparent elastomeric polydimethylsiloxane (PDMS) "stamps" with patterned relief on the surface to generate features. The stamps can be prepared by casting polymers against masters patterned by conventional lithographic techniques. Patterns with critical dimensions as small as 30 nm are possible. Soft materials have the advantage of being more compatibility with bio-samples, and require relatively less economic investment compared to hard materials processes. The whole field of nano-chemistry will be opened by harnessing nano-fabrication methods using soft materials.

Along these directions, the research in Dr. Yan’s laboratory focuses on microfabrication and molecular recognition. Her group is developing surface chemistry and molecular imprinting techniques that can be readily integrated with various microfabrication processes. The long-term goal is to fabricate miniaturized functional devices for sensing and analysis. Dr. Yan uses conventional photolithography as well as soft lithography processes in her research. Due to the lack of facilities at PSU, Dr. Yan’s research group has established collaborative relationship with researchers at Pacific Northwest National Laboratory and OGI. The ability to access these facilities has been absolutely critical in establishing her research program and producing results for journal publications and grant proposals. A similar facility on campus will no doubt accelerate her research progress and allow exploring additional research areas that have not been practical.

**II.5 Nanoparticles (S. Reed, P. Moeck, J. Morris, and C. Li)**

Metal or semiconductor materials exhibit unique properties when prepared on the nanometer scale. Semiconductor quantum dots (QD) display size dependent chemical, optical, and catalytic properties and gold nanoparticles show higher reactivity than bulk-gold. While only recently discovered, many of these materials are considered the foundation of next generation electronics that will occur at the nanometer scale. These materials are having a similar impact on the biological sciences as their unique optical properties are being used to create sensors with single molecule sensitivity. Correlating the structural and optical properties of these materials on a single-nanoparticle level will enable the preparation of materials optimized for electronic and optical applications. This bottom-up approach to nanotechnology—using an understanding of the nano-scale structure to aid the design of the micro and macro properties of devices—is essential to the rational design of the next generation of many technologies. Drs. Moeck (Physics), J. Morris (ECE) and S. Reed (Chemistry) are combining talents in nano-particle synthesis (Reed and Morris) and structural characterization of nanoparticles (Moeck) to create nanomaterials with
novel optical and electronic properties. Access to a nanolithography facility, whose implementation constitutes one objective of this NTC initiative, would facilitate the isolation of individual nanoparticles for the collection of structural and optical information. The NTC will also support the development of new devices (Moeck) for implementing novel characterization methods in transmission electron microscopy (TEM), aiming to contribute to the “aberration-correction revolution” that TEM is currently undergoing, as exemplified by a plot of progress in resolution versus time in Fig. 6. Specific work in all these areas is detailed below.

Dr. Reed uses nanoparticles to alter the optical properties of adjacent chromophores, acting as antennae for absorbed and emitted light. Biopolymers, such as DNA, are used as nano-scale rulers by attaching metal particles and fluorophores at defined locations. This allows for the systematic study of metal-fluorophore interactions. These studies will lead to the design of molecular sensors for the fluorescent detection of specific proteins, DNA, or environmental pollutants. Another project involves the preparation of mimics of cellular structures. Cells have evolved to efficiently utilize energy for motility, reproduction, and synthesis of proteins and chemicals, all while efficiently managing energy utilization and waste production. They are the ultimate nanoscale factory. Simple mimics of cells can be useful for designing more efficient methods of chemical synthesis with intrinsic waste management capability. Such environmentally benign or green chemistry can play a role in minimizing chemical hazards to individuals and the environment.58

Dr. J. Morris research aims to the fabrication of regular, reproducible, stable arrays of metal islands of nm dimensions (1 to 10 nm), separated by nm gaps (2 to 5 nm), embedded in insulator materials. Such films in addition to displaying switching effects, can lead to the fabrication of single-electron transistors59 (in single electron devices the nanometer size of the particles is crucial here to allow operation of the device at room temperature60), and can provide a viable solution to the challenges posed by the interconnection of nanoelectronic devices (by exploiting electrically induced coalescence of metal islands by polarized laser illumination). A basic novel fabrication concept consists of establishing an array of Cr dots on a (SiO2) substrate surface by field ionization and deposition from an Atomic Force Microscope tip. Subsequent deposition of Au by thermal or electron-beam evaporation will grow islands on the Cr nuclei, provided the substrate temperature is held above the point where the Au diffusion distance on the substrate surface exceeds the Cr dot separations. This technique will not only yield regular reproducible arrays, but also provides stability with the Cr in its conventional role as interfacial “glue.” The second step will be to use the product of this technique to create a hard imprint master for soft polymer substrate printing; metal islands then nucleate preferentially in the depressions. The acquisition of an electron beam evaporator, requested in this proposal, is a top priority for implementing these applications.

Dr. P. Moeck current research interests encompass the self assembly, structural, and morphological characterization of mesoscopic semiconductor structures that consist of about 10^4 to 10^5 atoms and are called quantum dots (QD). His group uses TEM for both i) studies of fundamental materials science issues such as e.g. the size dependency of phase diagrams in the nanometer realm, and ii) the development of dedicated structural characterization methods for nanocrystalline and nanostructured materials. The first area of research builds on his recent discovery of a structural instability of self-assembled QDs grown by the Stranski-Krastanow method. This structural instability is, for example, demonstrated in a novel nanocrystal QD phase as shown in atomic resolution in the insert of Fig. 5. Key propriety ideas on how to achieve desirable structural transition in self-assembled semiconductor QDs are outlined in his recent
Those QDs that have undergone lattice mismatch strain-reducing atomic rearrangement processes will be structurally more stable, i.e. will possess an additional distinct advantage over the QDs that are obtainable by the Stranski-Krastanow growth method. From the viewpoint of increasing the operation time of optoelectronic devices such as quantum dot lasers, the structurally more stable QD will be preferred. Dr Moeck’s second area of research responds to the experimental challenges to characterize the atomically ordered QDs described above: they are typically of low symmetry and unknown atomic arrangements. Dr. Li and Dr. Moeck’s group are currently developing Dr. Moeck’s proprietary “goniometry of direct lattice vectors” method into a coherent approach to nanocrystallography in current state-of-the-art TEM and future aberration-corrected TEMs. This novel methodology complements the currently undergoing “aberration-correction revolution” (Fig. 6). Aberration-corrected transmission electron microscopes will deliver in a few years “genuine atomic resolution” even for the densest packed crystals at large tilt angles and in various technologically important environments. (This is something that cannot be achieved as a matter of principle with state-of-the-art TEMs of the currently employed design.) The ongoing “aberration-correction revolution” (and its complementing nanocrystallography) are, thus, as important and technologically significant as the invention of the TEM itself was about 70 years ago.

The above description indicates that multidisciplinary expertise related to nanotechnology exists at PSU. The acquisition of critical infrastructure will provide a critical component in this pursuit. In nearly every aspect the requested equipment and support personnel will add considerable value to the research efforts of at least 12 PSU researchers and push toward our goal of being competitive for high levels of federal funding.

III. EQUIPMENT REQUESTED and BUDGET

III.1 Long-term and short-term objectives toward the implementation of the NTC.

The NTC aims to become a centralized multidisciplinary nanodevice fabrication facility that provides service and access to researchers from different departments units at PSU. Strategically,
we propose to first pursue the implementation of a clean room lithography facility (a $2M/two-year project), which will provide the basis of a major nanotechnology center (a $5M/five-year project). The $410k investment requested in this proposal (as detailed in the next section) represents just an initial step in the direction of a more expensive endeavor. We plan to keep working as a group and submit joint proposals to the appropriate federal agencies in order to secure further funding. Over a five year period we plan to submit five large multi-investigator grant proposals. (One in the area of Materials and another in Biotechnology are foreseen for 2004). The $410k initial support from PSU toward the creation of the PSU-NTC will be used as a leverage to successfully compete in our large proposals as funding agencies typically evaluate the degree of institutional support.

Laboratory space infrastructure constitutes one of the major issues to ensure the success of the NTC. Our joint multimember proposals, that we plan to submit to major funding agencies, will be judged, in great part, based on the infrastructure available at PSU to undertake major nanotechnology programs. In fact, this is currently the case for most of the participants in this proposal who have found their proposals rejected, despite the good merit marks from panel reviewers, based, in part, on the lack of demonstrated research infrastructure. A strong commitment from the PSU administration to provide access to adequate laboratory space is then quite relevant. Our long-term goal is to operate in a 12,000 sq. ft. facility. Recognizing the hurdles behind this ideal scenario, our group has considered a few possible alternatives. One of them considers the option of laboratory space in the future Hi-Tech Incubator, although its construction is in the 10-year scope, which does not fit in the immediate need to construct a NTC. Another possibility is to use the vacated space in Science Buildings 1 and 2 as our engineer colleagues move to their new Engineering Building.

While the large laboratory space issue is being resolved, counting with a strong commitment from the PSU administration, the equipment requested in this proposal will operate momentarily at the laboratories of individual PSU researcher’s who will be responsible for their proper functioning and make them accessible to its potential users. (We will keep exploring the possibility to use, in the short term, several small locations, like Room #29 in SB-I, that could be used after being properly conditioned).

III.2 BUDGET for this PROPOSAL

During the first years, an emphasis will be placed in the acquisition of analytical equipment since they are more likely to have a multiple impact in different areas of existent research programs at PSU.

- **Electron Beam Evaporator, EDWARDS, E610A, Turbo pump with roughing pump ($85k).** Vendor: BidService (732) 863-9500. This system is to evaporate rod material out of small crucibles.
  
  **Impact:** J. Morris, M. Yan, J. Jiao. **Multi-users:** All members from the 4 departments.

- **Karl Suss MA6/BA6 Large Gap Mask Aligner, $135k.** Vendor: BidService (732) 863-9500. Photomask aligner is used to transfer patterns from photomasks onto a layer of photoresist that has been coated onto samples (similar to that of printing a picture from a negative film).
  
  **Impact:** M. Yan, M. Weislogel, A. La Rosa. **Multi-users:** This equipment is a core component in any lithography service facility; the number of users, by inside researcher and outside customers, is likely to increase upon becoming available.

- **Nanoindenter ($105k).** Vendor: Hysitron Inc. Phone: (952) 835-6366.
The nanoindenter allows users to characterize the mechanical properties of materials on nanometer length scales. Elastic modulus and deformation behavior are determined from an analysis of the force vs. displacement response measured during indentation of the material. "Scratch" testing can also be performed to evaluate the friction and wear behavior of materials using this instrument.

**Impact:** Dr. S. Yi, L. Meekisho. **Multi-users:** all members from the ME department.

- **Epi-Fluorescence Inverted Optical Microscope.** Axiovert 200 MOT Microscope. **$55k**
  
  Vendor: Carl Zeiss Microimaging. Quote: 121-05230489-01,
  
  Contact Person: James Stevenson. Voice mail 1-800-543-1033 X7123
  
  **Impact:** A. La Rosa, S. Reed, S. Benight. **Multi-users:** Practically helpful to all the members

  - Optical characterization is the most common approach to analyze materials.

- **External control interface for an existent Atomic Force Microscope currently housed at the ECE department.** Vendor: Quesant Inc. **$20k.** The new component will allow flexible external control of the AFM as necessary in the implementation of new applications.

  **Impact:** J. Morris, P. Moeck. **Multi-users:** AFM has become a standard characterization technique in nanotechnology.

**Total $410k**

The total budget reflects the order of magnitude of budget figures the ORSP provided for the current competition. We are also striving to support personnel salary for two postdoctoral associates ($90K) and an Electron Beam Lithography (FEL) system ($160k). It is possible that the price variability may allow stretch our budget and manage to include at least one of these two items in the list above. The personnel will provide instruction and services for faculty desiring to use the equipment; in addition they will provide assistance in data acquisition and analysis and greatly aid research efforts utilizing the facility. The FEL system, on the other hand, would become a valuable nanofabrication tool. To optimize the budget we will continue searching for the best prices in the market, requesting additional quotations from different vendors and justify the purchases with the best option.

**III.3 Basis for expectations of success in securing and maintaining significant external sponsorship**

With the new instrumentation and accompanying necessary technical support the basic infrastructure for a functional nanofabrication facility will be established. We will use the NTC as a platform from which to lever research grants and contracts from both the Federal Government and Private Industry.\(^{64,65}\) The PSU NTC and the capabilities it will enable will provide a more productive research environment and greatly enhance our competitiveness on the national scale for obtaining significant resources from research grants and contracts from both the public and private sectors. An established nanofabrication facility will provide the ammunition to aggressively pursue research grants from the number of participating agencies associated with the new nanotechnology initiative. These agencies include (among others): NIH, NSF, DOE, NASA and DOD. Establishment of a nanotechnology center will also demonstrate the commitment of the University in striving to become a major player in the nanotechnology arena. The NTC will provide our researchers with the necessary first phases of infrastructure required to demonstrate our capabilities in creating novel nanomaterials, discovering new nanomaterials via superior characterization methodologies and designing and manufacturing devices on the nanoscale. These demonstrations will provide us a firm foothold in the area, greatly enhance our visibility on the
national and international scales, provide an attractive mechanism for initiating and establishing strong ties with surrounding industry and national laboratories, and place us on a much firmer footing for seriously competing for research grants and contracts.

III.4 Financial and programmatic plan

By properly leveraging the instrumental capability foundation provided by the funds requested in this proposal, our goal is to increase research expenditures (with associated indirect costs) by 100% above the current levels over the next five years. In all likelihood the number of researchers from PSU involved in nanotechnology research that will benefit from a nanofabrication facility will grow considerably in the next five years. But to make a conservative estimate of the new funds expected to be generated that can be directly attributed to the nanofabrication facility we consider only the approximately 10 researchers that participated in this proposal. We estimate the current expenditures associated to these researchers to be approximately $500K annually, with associated indirect costs. It is also understood that the majority of this is from a few individuals and that present levels of outside support for a few of the researchers (in particular those that have recently arrived on campus) is nil (although there exist great expectations). The projected increase in research expenditures (to $1M/year) by the end of 2008 is expected to result from increased grant and contract funding mainly derived from three mechanisms. These are: (1) individual P.I. grants and contracts; (2) multi-investigator grants and contracts; (3) contract services performed by the facility for industry. In the calculation that follows we assume that there will be an average 100% increase of expenditures per researcher over the five year period at 20% per year incremental increases. With the current level at $500K, the starting level assumed for each researcher is $50K/year. If our goal is attained, this will amount to $100K in new expenditures in the first year, $200K in year 2, $300K in year 3, $400K in year 4 and $500K in year 5. The associated indirect costs (@42%) will be $42K in year 1, $84K in year 2, $126K in year 3, $168K in year 4 and $210K year 5. The total indirect costs returned by mechanism (1) will be $630K.

In mechanism 2, over the five year period we plan to submit five large (direct costs greater than $1M) multi-investigator grant proposals to the appropriate federal agencies. Assuming a hit rate of 20% and a direct cost amount of $1.2M, if successful this will amount to an indirect cost return of $520K via mechanism 2.

Returns from mechanism 3 are more difficult to estimate. So to err on the conservative side we assume a total of $200K will be gathered from services performed for industrial firms with indirect costs of $80K. Thus, via mechanisms 1, 2 and 3 we aim to generate $630K + $520K + $80 K = $1.23 M in indirect costs. Assuming we are only 50% successful in our conservative estimates, i.e. only $615K in new indirect costs generated over the five year period, our efforts will have resulted in a pay back exceeding by $205K the $410K initial investment requested in this proposal. Provided these estimates are reasonable, investment in a nanofabrication facility will provide significant returns.

This initiative for the creation of the NTC provides in addition an opportunity for all PSU researchers to work hand in hand with the PSU administration. We believe that a coordinated approach between the science and engineering schools is desirable to ensure that a sufficiently competitive research effort can be established. Upon its implementation, the NTC will be a brand that PSU can use to “sell” itself as a major player in contributing to the worldwide development of nanotechnology, which will help to fulfill institutional initiatives on education and service.
Initiation of Basic Infrastructure for the Development of Nanotechnology at PSU.
Instrumentation and Technical Support for Fabrication, Characterization and Packaging of Nano-Polymer/Fluidic/Optical Devices and Nanostructures.

REFERENCES

7. Proteomics encompasses systematic studies of the identity, changing, abundance, distribution, modification, interactions, structure and function of large set of proteins, as well as their involvement in disease.

Prof. Venkat K. Rao, from The Royal Institute of Technology and collaborator of Dr. Moeck, recently achieved a breakthrough in developing spintronics material: P. Sharma et al., *Ferromagnetism above room temperature in bulk and transparent thin films of Mn-doped ZnO*, Nature Materials 2, 673-677 (2003).

M.C. Roco, “Research Programs on nanotechnology in the world,”
http://www.wtec.org/loyola/nano/08_01.htm


http://nano.gov


http://www.mems-exchange.org/MEMS/what-is.html


Dr. S. Yi served as Head of Engineering Mechanics Division, School of Mechanical and Production Engineering, Nanyang Technological University, Singapore (2001-2002).


http://www.cse.ucsc.edu/~sugnet/microarray/microarray_FAQ.html


Intel, a major semiconductor industry in the surrounding Portland area, disclosed on 4/25/01 that it is engaged in R&D and investment activities in MEMS ( http://www.intel.com/research/silicon/mems.htm ) highlighting the added value that MEMS can produce to their products (more flexible wireless building blocks, cooler microprocessors and bio-chips for diagnostics( “MEMS Research at Intel”, ftp://download.intel.com/research/silicon/BobRao.pdf). Funding from Intel has typically gone to major players like UCLA, or in the form of equipment donations to institutions, like the University of New Mexico, that show interest in developing MEMS (“Intel donates 1 wafer line to New Mexico MEMS project” http://www.eetimes.com/semi/news/OEG20030218S0042 ). A strong show on nanofabrication capability at PSU can lure Intel to fund applications at our campus.

December 29, 2003

William Feyerherm
Vice Provost for Research
Portland State University

Dr. Feyerherm:

I am writing in support of a proposal prepared and submitted by an interdisciplinary group of faculty members entitled, "Initiation of Basic Infrastructure for the Development of Nanotechnology at PSU." This group of faculty members, spanning four departments in the College of Liberal Arts and Science and the College of Engineering and Computer Science, has identified a critical and important technology worthy of their focused efforts. Nanotechnology is clearly a discipline ripe for research, and PSU has several disjointed efforts which are currently working independently. By drawing those researchers together and providing them with a shared support, they can begin to form the critical mass required to attract major external funding from both governmental and industrial sponsors. Hence, I urge you to seriously consider this proposal for seed funding.

The proposal, as submitted, should be viewed as a work in progress. While several possible research projects have been identified, none have been developed in the depth that allows full understanding of the project scope, objectives, tasks, nor budget. Because of this, the initial budget must be viewed as tentative and should be allowed flexibility. As an example, some of the lab equipment being requested may be available through other off-campus facilities such as the Washington Technology Center based in Seattle or the Center for Multiscale Materials and Devices (MMD) based jointly at University of Oregon, Oregon State University, and Pacific Northwest National Laboratory. In fact, the MMD is currently proposing a restructuration that would establish the Inherently Safe Nano Materials Institute at UO, the Microproducts Breakthrough Institute at OSU, and the Center for Emerging Technologies at PSU. This effort, if it is to be successful in attracting the $20M funding requested of the Department of Defense, must demonstrate institutional support at each university. The proposed "Initiation of Basic Infrastructure for the Development of Nanotechnology at PSU" presents a unique opportunity to demonstrate that support.

Perhaps, then, a more realistic commitment at this time would be a relatively modest first-time commitment of about $400K to the "Initiation of Basic Infrastructure for the Development of Nanotechnology at PSU" with the understanding that this group would work closely with researchers from OSU, UO, and PNNL to identify collaborative projects and complementary laboratory equipment to strengthen the statewide thrust in nanotechnology research. Please consider making such a commitment to this PSU research group.

Respectfully submitted,

Grzegorz Spód
Professor and Chair
Mechanical Engineering
Investing in Research Committee
Office of Research and Sponsored Projects
Cramer Hall, Room 111
1721 SW Broadway
Portland, Oregon 97201-0751

December 30, 2005

Dear Investing in Research Committee,

The Department of Physics at PSU reconfirms its belief in the viability of the NanoTechnology Center. The Department is committed to the goals as outlined in this proposal especially since it fits extremely well within our departmental priorities. This multidisciplinary proposal for Basic Infrastructure for the Development of Nanotechnology at PSU constitutes an important step and we commend the participants for their efforts. We strongly urge support for this endeavor for the benefit of all the PSU departments.

Yours,

Erik Bodegom
Professor and Chair
Department of Physics
(503) 725-3891

William Feyerherm,
Vice-Provost for Research & Graduate Studies,
117 Cramer Hall.

Re: Establishment of Basic Infrastructure to Develop a Nanofabrication Facility at PSU

Dear Bill,

I am writing as Chair of Electrical & Computer Engineering to request your support for the proposal above, submitted by Professor Andres LaRosa and others (including myself.)

The primary point is that the proposal fits within this Department's broad strategic goals for the development of its research directions, and hence also its curricular development. We are fortunate to be situated within "Silicon Forest" and to have the potential for such great research interaction with local industry as partners. However, we are not yet achieving the level of service in this area that one would expect, and faculty find themselves in a Catch-22 in trying to make headway. The equipment infrastructure does not yet exist to provide a comprehensive fabrication capability in support of basic research, and without that resource faculty cannot do the initial research necessary to develop sponsor confidence and the funding necessary to develop such a facility. The campus can break this cycle by investing in equipment, carefully selected to provide the maximum benefit to the greatest number. Clearly, nanotechnology (including nanoelectronics) will be of vital importance to local industry in the years ahead, and PSU must establish itself as a participant in this field, and as a contributor thereby to the local economy. The ECE Department has identified the local semiconductor industry as inadequately served in either research support or education, and is trying to fill the void left by OGI's abdication of these roles. Access to equipment such as that proposed here will be a step in the right direction.

Industrial support will be vital to the next step of obtaining significant federal funding for the establishment of a research center. A credible center proposal must include participants from multiple departments, and Professor LaRosa deserves full commendation for pulling together a genuine multi-disciplinary group, and for the successful development of this initial proposal. It is the first such multi-departmental grass-roots proposal I am aware of at PSU, and as a genuine faculty initiative has solid potential for continued successful development by continued cooperation. For this reason alone the proposal deserves serious consideration.

Sincerely,

James E. Morris
Professor & Chair