Background

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Nanotechnology in the Pittsburgh Region

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The emerging fields of nano engineering affords the ability to work at the molecular level, atom by atom, to create structures with fundamentally new properties and functions, essentially providing unforeseen powers to understand and control the basic building blocks of all natural and man-made things. Nanotechnology is often cast as an enabling technology that is helping to create a vast array of opportunities in a broad range of industries and disciplines.

Recent progress in the measurement, modeling and manipulation of matter and phenomena at the scale of 1 to 100 nanometers has us on the verge of revolutionizing information processing, data storage, sensors, power generation, materials, environment, robotics and medicine. To illustrate this scale, one nanometer is one-billionth of a meter, approximately one-thousandth the width of a human hair.

Nanotechnology is one area of research and development that is truly multidisciplinary. It encompasses a wide range of scientific disciplines, including physics, chemistry, biology and materials science. Research at the nanoscale is unified by the need to share knowledge on tools and techniques, as well as information on the physics affecting atomic and molecular interactions in this new realm. Materials scientists, mechanical and electronic engineers and medical researchers are now forming teams with biologists, physicists and chemists.

The number of components that can be fabricated on a semiconductor wafer or chip has approached or exceeded the limits of conventional technology. Nanotechnology provides the foundation to build chips, one atom at a time, to create devices much smaller than those that can be manufactured using traditional semi-conductor processing methods.

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The results of nanotechnology offer maximized use of space; every particle would have a purpose. Essentially every atom can be designed to fit in a designated place in nanotechnology, which means engineers can design almost any structure consistent with the laws of physics specifiable in molecular detail.

In 1986, Eric Drexler used the term nanotechnology to refer to his work toward molecular machines building more machine systems via molecular reactions. Productive nanosystems and molecular manufacturing are modern terms that refer specifically to Drexler's approach. However, this is a very small area of what's currently called nanotechnology, a term that has been broadened over time by researchers working on a wide range of small stuff. It should be noted that a lot of nanotechnology is not molecular. Many types of nanoparticles, for example, are only approximately similar within a sample, yet not identical to each other as molecules are.

In response to nanotechnology’s expansion, Drexler developed the terms molecular nanotechnology, molecular manufacturing, and productive nanosystems to refer more succinctly to his work.

Many of the significant applications of nanotechnology are expected to drive ever-more-powerful computers and communication devices. This will be essential if we are to continue the revolution in computer hardware beyond the next decade. Nanotech devices enable an entire new generation of products that are cleaner, stronger, lighter and more precise.

Applications

In future decades, additional applications may offer a sea change in the life sciences. So-called nanorobots might serve as programmable antibodies. As disease-causing bacteria and viruses mutate in their endless attempts to thwart medical treatment, some scientists envision nanorobots that could be reprogrammed to selectively seek out and destroy them. Other nanorobots might be programmed to single out and kill cancer cells without damaging surrounding healthy tissue.

Nanoscale zinc oxide particles absorb UV radiation in sunscreen lotions, and nanoscale “whisker-like” particles are used to coat the surface fibers of fabric to create a stain-repelling surface. Healthcare companies are now marketing antimicrobial bandages coated with silver nanocrystals, and silver nanoparticles on the surfaces of many new refrigerators, air conditioners and washing machines act as antibacterial and antifungal agents. Artificial bone composites made from nanocrystalline calcium phosphates, the same mineral as natural bone, have strength in compression equal to that of stainless steel.

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Regional Companies

One local company markets a nanotechnology product that makes our drinking water safer. Lanxess (which was formerly part of Bayer) has developed a nanoparticulate iron oxide hydroxide with a high surface area and a high adsorption capacity for arsenic. Bayoxide® E 33 is so effective at removing arsenic from groundwater that a contact time of three to five minutes can reduce an arsenic concentration of 10 to 50 µg/liter to below five µg/liter. (The Environmental Protection Agency has mandated that a liter of drinking water may not contain more than 10 µg of arsenic.) Use of the technology began in England in 2002 and moved into the U.S. in 2004 in Collegeville, Pennsylvania. Today 22 municipalities in 17 states use Bayoxide® E 33.

Two very successful nano-based products that have been in the marketplace for several years are PPG's CeramiClear™, and SunClean™. CeramiClear uses nanoparticles embedded in the clear coat layer of an automotive paint system to provide increased resistance to scratches, car washes and hard to remove tree sap. The product is the standard automotive finish on Mercedes Benz cars.

SunClean self-cleaning glass is made using an ultra-thin layer, several nanometers thick, of a light-sensitive coating of titanium dioxide which is fused directly into the glass while it is still molten, thereby making it an integral part of the outer glass surface. The result is a glass product with an ultra-thin layer of metal that does not cut down on the light passing through the window, but does chemically react with the ultraviolet rays in sunlight to oxidize organic material on the glass surface. This process, called photocatalysis, breaks down dirt and other organic materials and prevents them from sticking to the glass. The titanium dioxide coating also has hydrophilic properties which cause water to sheet evenly over the glass surface instead of beading. This sheeting action helps to flush the surface clean and to accelerate drying, leaving the glass with minimal spotting and streaking. The windows virtually clean themselves every time it rains.

NanoDynamics, Inc., a maker of smarter golf balls and metals, ceramics and composite nanomaterials, launched a life sciences subsidiary in Pittsburgh last year, called ND Life. NanoDynamics received $1.15 million in funding from the Pennsylvania Department of Community and Economic Development in June 2005 to establish a laboratory in the Pittsburgh Life Sciences Greenhouse (PLSG) Incubator. The PLSG is a private/public partnership dedicated to supporting the growth of regional life sciences companies in the areas of bioinformatics, bionanotechnology, diagnostics, medical devices, medical robotics, therapeutics, tools and services.

ND Life opened its PLSG offices in October 2005 and is commercializing a recently licensed polymer nanotube technology (developed at the University of Pittsburgh's McGowan Institute for Regenerative Medicine) to help detect exposure to chemical agents or bacteria. Expected to grow to 50 employees over five years, ND Life will drive rapid innovation and commercialization of nanomaterials for antimicrobial, biosensor, and pharmaceutical applications.

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Plextronics is a Carnegie Mellon spin-off company that specializes in printed solar, lighting and other electronics. Headquartered in Pittsburgh, PA, the company's international focus is on organic solar cell and OLED (Organic Light Emitting Diode) lighting, specifically the conductive inks and process technologies that enable those and other similar applications. Particularly relevant as the worldwide search for renewable energy becomes more urgent, the company's technology will enable the mass production of printed devices, such as low-cost organic solar cells and high-efficiency lighting.

To recognize the potential impact of Plextronics' technology, it's important to first understand the fundamentals of both printed electronics and the marketplace. Printed electronics comprises next-generation light, power and circuitry products, including flexible displays, plastic solar cells and organic RFID tags. The market for printed electronics was approximately $1 billion in 2006 and is expected to exceed $300 billion within 20 years.

The flexibility of the company’s signature product, Plexcore, enables polymer design to be modified at the nano-molecular level and an ink to be formulated that optimizes the solid state lighting application. When printed, this ink becomes an "active layer" which drives performance of the lighting device. The Department of Energy predicts that if solid state lighting can eventually replace fluorescent and incandescent lighting, it will decrease energy consumption by 29 percent and ultimately saving consumers more than $125 billion by 2025.

Since its founding, Plextronics has garnered significant industry accolades. The company received the Clean Energy Entrepreneur of the Year award from the U.S. Department of Energy's National Renewable Energy Laboratory, a designation that was developed to promote and support the creation of world-class businesses delivering clean energy technology options into the energy market. Plextronics also has been ranked in the top 50 of Lux Research’s most well-rounded, venture-backed nanotechnology start-ups. It also was ranked 27th out of 136 companies in a report ranking nanotech start-ups for partnership value.

Plextronics also received the Organic Semiconductor Industry Award for start-up of the year, which was given unanimously by the judges for demonstrating technology and commercial leadership, and it also was honored in 2006 by the *Wall Street Journal* as a runner-up for its Innovation Award in Materials and Other Base Technologies. Plextronics is the sole Pennsylvania-headquartered company to receive this recognition.

NanoMaterials

Products developed and commercialized in the marketplace are seldom used in their monolithic state. For instance, metallic alloys usually are combined with other materials to assemble structures able to perform in commercial products such as automobiles, airplanes, appliances, buildings,

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electronic products, etc. These assemblies are laminates or other components utilizing coatings, paints or adhesives.

Similarly, glass used in automotive or architectural applications is composed of multilayered assemblies, such as polymeric films, that are able to impart specific properties and attributes, such as optical clarity and elastic properties to enhance performance under impact conditions. These commercial products are composed of individual materials and processes that employ various organic and inorganic technologies, which, in turn, impart additional properties and attributes.

Although southwestern Pennsylvania is home to a wide range of nanotechnology research capabilities, one particular focus, nanomaterials, affords the potential to capitalize on the intersection of strong university research capabilities, major industrial leadership and near-term commercial market opportunities. Pittsburgh is home to the headquarters and central research and development operations of leading global materials companies, such as Alcoa, Bayer MaterialScience, Lanxess, PPG Industries, Kennametal, Allegheny Technologies and U.S. Steel, as well as a number of smaller companies and start-ups, including Crystalplex, Plextronics, Thar Technologies and NanDynamics' Pittsburgh operations, ND Life. As a result, the region is well positioned to be a major player in materials that use nanotechnology.

New Developments

Much of nanoscience remains at both the theoretical and experimental level, making research a priority in the evolution of nanotechnology that is ready for application and use in industry.

New areas of focus in nanotechnology research are planned in all federal departments and agencies, and it is within this setting that Carnegie Mellon University's Center for Interdisciplinary Nanotechnology Research (CINR) has become a hub for collaboration and research.

Established in 2001 to bring together the significant research being conducted in the realm of nanotechnology in various corners of the university, CINR represents a single axis around which nanotechnology research revolves. The center operates as both a focal point and catalyst for new research as well as a clearinghouse for nanotechnology information.

In addition, a multidisciplinary team of Carnegie Mellon researchers has been working to create and design new technologies at the Center for Nano-Enabled Device and Energy Technologies.

Under the direction of Dr. Elias Towe, a professor of electrical and computer engineering and materials science and engineering, the Center harnesses nanoscale research underway at both the College of Engineering and the Mellon College of Science. Housed in the Institute for Complex

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Engineered Systems, the center primarily focuses on nano-scale materials that are deliberately synthesized, self-assembled, assisted to self-assemble or engineered to create novel properties, processes or principles. It is the new properties or principles that are taken advantage of in the design and engineering of innovative devices, arrays of devices and ultimately systems. The Center's approach is two-fold. The first approach relies on solid-state synthesis and structuring to produce nanostructures with new physics or chemistry that lead to novel devices. The second approach is based on chemistry, where chemical synthesis creates unique molecules that are used to make novel materials.

Carnegie Mellon University also has received NSF grant awards to build a heavy-ion mass spectrometer. This one-of-a-kind mass spectrometer will characterize with unprecedented sensitivity large biomolecules, such as intact proteins, protein complexes, virus particles and DNA. It may also provide a new tool for analyzing large man-made polymers used in nanotechnology. Mass spectrometry research may well advance research in proteomics, virology, molecular biology and nanotechnology.

The NanoRobotics Lab at Carnegie Mellon is a new generation of robots so small that they will function in ways unimaginable for their counterparts, by clinging to polished glass for spacecraft component inspection; interacting with single soil grains to search otherwise impossible terrains for life and forming colonies of thousands of individual robots for scouting and the collection of resources. Nanorobotic technology ultimately would transform the future of space by infusing ubiquitous devices that are self-contained, self-powered, autonomous, adaptable and significantly lighter, smaller and more reliable than their predecessors.

Metin Sitti, director of the NanoRobotics Lab, is currently developing biomimetics, which mimick nature through biologically inspired creations. The gecko's sticky feet have been an inspiration in Sitti's world of miniature robotics. Not only can tiny gecko-like robots be used to inspect, maintain, and repair space shuttle equipment, explore Mars, and conduct search and rescue missions, but the "sticky feet" also have inspired a new age of adhesives. In fact, gecko-inspired adhesive may even replace Velcro.

Another development in the NanoRobotics Lab is endoscopic micro-capsules, which are being used in the medical field to provide non-evasive inspection of the digestive tract. By swallowing a capsule which contains a tiny camera, the patient's digestive tract can be photographed for doctors to review.

Efforts also had begun to establish a nanobiologic initiative that would work to fuse nanodevices, biomimetics and informatics into wholly integrated disciplines, with Carnegie Mellon spearheading partnerships with NASA and The Pennsylvania State University. The Penn State University Center for Nanotechnology Education and Utilization (CNEU) is dedicated to research, development and

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education across all aspects of micro- and nanotechnology. The Center's resources are focused on addressing the incorporation of nanotechnology into K-12 education, into post-secondary education and into industry applications, and the Pennsylvania NanoMaterials Commercialization Center assists with this outreach in Pittsburgh.

The Penn State CNEU is the home of the Pennsylvania Nanofabrication Manufacturing Technology Partnership and the NSF Regional Center for Nanofabrication Manufacturing Education, an NSF-sponsored regional Advanced Technology Education Center. It also is the Penn State home of the NSF National Nanotechnology Infrastructure Network, the national nanotechnology resource for enabling academic and industry R&D.

The University of Pittsburgh's Center of Molecular and Materials Simulations uses computers to understand the properties of carbon nanotubes. Potential applications of the carbon nanotubes range from the construction of nanoscale transistors to the storage of hydrogen for use in transportation. And in another University of Pittsburgh project, funded by the U.S. Department of Defense's Army Research Office, researchers were able to create self-assembling nanotubes that change colors and form what is called a "nanocarpet." The significance of these developments is centered on the potential for using nanotechnology that can be trained to kill bacteria, such as E. coli, with just a jab to the cell membrane. In addition, there is vast potential for developing products that can simultaneously detect and decontaminate biological and chemical weapons. The end product could be a paint that, when exposed to biological or chemical agents, would change color and simultaneously destroy deadly substances.

In yet another separate University of Pittsburgh project, physicists funded by the NSF and the U.S. Department of Energy found a new way to create and move small bits of optical energy called "excitons" over relatively long distances. By applying laser light to separate an electron from an atom, an exciton is created composed of an "excited" electron plus the hole remaining on the atom, which moves like an energy particle and potentially could carry information. The development could be an important step in creating semiconductors in which excitons are shuttled and controlled to form excitonic circuits.

The Pennsylvania NanoMaterials Commercialization Center

This cluster of materials and polymer-based companies in southwestern Pennsylvania has provided the impetus to develop and commercialize the new field of nanomaterials for exciting new products and manufacturing processes. To capitalize on this exciting new area, the Pennsylvania NanoMaterials Commercialization Center was founded in 2006 through the vision of four leading materials companies in the region: PPG, U.S. Steel, Alcoa and Bayer MaterialScience, with the assistance and guidance of the Pittsburgh Technology Council.

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The Pennsylvania NanoMaterials Commercialization Center is an initiative that combines the strengths of the four *Fortune* 500 companies listed above, along with other entrepreneurial companies and researchers, and its mission is to initiate, establish and promote research and development of nanomaterials science and technology and to expedite the transition of new nanomaterials research to commercialization. It achieves this by providing assistance and funding to promising nanomaterials research which has a well defined defense or commercial application for products and structures in markets critical to the U.S. manufacturing base and for the southwestern Pennsylvania regional economy.

The projects that the Center supports will:

- establish southwestern Pennsylvania as a premier location for nanomaterials research and production.
- link the region's nano capabilities with the efforts of the National Nanotechnology Initiative.
- provide leverage nanomaterials-related research at Pennsylvania's universities to develop commercially viable products.
- strengthen Pennsylvania's nanomaterials-related companies to expand employment opportunities within the commonwealth.

The integral aspect of this program is the selection and funding of worthwhile and promising projects, based both upon the likelihood for technical and commercial success. The teams performing these projects are made up of researchers and commercial entities. The researchers can belong to universities, government labs or commercial R&D labs. Commercial entities can be start-up companies, small or large established companies, all of which must have the ability to commercialize the technology.

Current areas of nanotechnology focus for the center include:

- enhanced dielectrics that have significantly improved breakdown voltages.
- novel polymer or metallic based nanomaterials that can be tailored for enhanced properties, such as reduced electrical resistivity, increased strength, lighter weight and better thermal performance.
- new nanomaterial-based coatings and films that provide enhanced scratch, wear, corrosion and barrier resistance.
- optical response materials that respond to light over a wide range of wavelengths to produce unique new properties, such as variable reflectivity, emissivity and electrical conductivity.

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- smart materials that incorporate nanoparticles to produce unique new features, such as tiny embedded sensors to predict material failure and/or self healing effects.
- enhanced effect materials that employ nano-sized particles of existing metals and alloys to increase chemical and thermal reactions, due the particle's higher surface areas. These materials can produce better catalysts and higher energy producing fuels at lower cost with reduced weight.

The Center's portfolio of funded companies includes:

Arkema, Inc.
Bayer MaterialScience LLC
Crystalplex
ICx Technologies
Illuminex Corporation
Integran Technologies USA
nanoGriptech LLC
NanoLambda, Inc.
Plextronics
Strategic Polymer Solutions, Inc.
Y-Carbon

Currently, the Center's two public funding partners are the Pennsylvania Department of Community and Economic Development and the Air Force Research Laboratories at Wright Patterson Air Force Base in Dayton Ohio.

Corporate partners include Alcoa, Bayer MaterialScience, PPG Industries, Plextronics and U.S. Steel. Perhaps no other city in the U.S. can boast of a nanotech initiative that is supported by four *Fortune* 500 companies headquartered in that city.

University partners are just as prestigious: Carnegie Mellon, Lehigh University, Penn State and the University of Pittsburgh. Supporting partners include the Pittsburgh Technology Council and Catalyst Connection.

Positioned for Growth

Worldwide more than $12.4 billion in both public and private funds were spent on nanotechnology research and development in 2006, which was a 25 percent increase as compared to a year earlier. By 2015, the total global demand for nanoscale materials, devices and tools will exceed $1 trillion, with an accompanying demand for two million workers in this field.

The U.S. nanotechnology market largely will lead the rest of the world. The U.S. market for nanotextiles, alone, will reach $115 billion 2012.

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The United States has the largest share of global investment in nanotechnology. The U.S. market share in was 25 percent in a 2005 study, followed closely by the Japanese market and western Europe, with major investment in countries like Germany, UK and France. Other countries like China, Russia, South Korea, Canada and Australia hold the rest of the world market share.

In December of 2003, President Bush signed the 21st Century Nanotechnology Research and Development Act, which put into law programs and activities supported by the National Nanotechnology Initiative (NNI). The authorization bill called for expenditures of $1 billion annually for nanotechnology research and development for fiscal years 2005 through 2008 within 18 federal agencies, including the National Science Foundation, Department of Energy, National Aeronautics and Space Administration, National Institute of Standards and Technology and the Environmental Protection Agency. The NNI aim was to further long-term, fundamental research and discovery of novel phenomena, processes and tools for nanotechnology. The NNI effectively help spur the U.S. dominance in number of patents filed and companies started.

The nanotechnology R&D legislation also required the creation of research centers, education and training efforts, studies into the societal and ethical consequences of nanotechnology and activities directed toward transferring technology into the marketplace. The bill set up advisory committees and regular program reviews, and it delineated additional tasks for the National Nanotechnology Coordination Office.

Nanotechnology already is used in consumer products like transparent sunscreens, tennis balls and stain-resistant clothing. But its capacity for mixing and matching molecules seems especially suited for transforming medicine.

Regional University Programs and Facilities

Pittsburgh universities' nano focus is where the greatest breakthroughs in nanoscience are expected to occur, and it offers the potential for a broad range of applications, including environment and energy, materials and computation, biomedical and health care, devices and systems.

The University of Pittsburgh has several centers of research and academic excellence within its Gertrude E. and John M. Petersen Institute of Nanoscience Engineering. In early 2006, Pitt finished construction of new $6.1 million 4,000 square-foot nano-scale fabrication and characterization -- facility and began increasing its nanoscience and engineering faculty. The faculty now stands at 49 and is represented by individuals in multiple disciplines, including chemists, biologists, physicists and engineers.

The university has a history of acquiring and constructing state-of-the-art nanoscience equipment. With the opening of this facility, the best available technology will be housed in a single location, and the new equipment will allow researchers to see and change materials and structure on the atomic level. Key technologies available and their capabilities include:

- transmission electron microscope which directs a beam of electrons at a material and "reads" the reflected and scattered electrons to create an atomic-level image of the surface.
- scanning probe microscope wherein a tiny tip hovers above the material and reacts to changes in voltage of electrons jumping between itself and the surface; this allows for mapping at the atomic level.
- modular X-ray diffraction system which X-rays nanostructures to reveal their density, crystallinity and the presence of impurities or structural defects.
- inductively coupled plasma reactive ion etching system which is a beam of charged particles that cuts nanometer-wide grooves, pits or holes in materials.
- electron-beam lithography system wherein a beam of electrons "writes" nanometer-sized patterns on materials.
- dual-beam nanopatterning system where beams of electrons and/or other charged particles cut nanometer-wide patterns in material.
- multisource e-beam deposition system and plasma-enhanced chemical vapor deposition which is a deposition system for metals, semiconductors, insulators and organic materials.

The University of Pittsburgh School of Engineering was recently awarded a National Science Foundation Nanotechnology Undergraduate Education grant for $200,000. The two-year grant has allowed the university to develop a course on integrated nanoscale science and engineering. The NSF only gave out10 such awards in the United States.

Through 2009 the course will introduce nanoscale devices and their applications created from a range of nanomaterials, including carbon nanotubes, nanoparticles and nanowires

Augmenting the University of Pittsburgh's nanoscience and engineering department is its recently created department of mechanical engineering and materials science. Formed when the university combined its departments of mechanical engineering and materials science and engineering, the new department is the largest in the school, in terms of both students and faculty.

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The mechanical engineering and materials science department is charged with developing nano-manufacturing as an area of research excellence, complementing existing university-wide research conducted at Petersen Institute for NanoScience and Engineering. A new shared nano-manufacturing laboratory has been established in support of this innovative research thrust.

The department is expected to enhance the impact of the Basic Metals Processing Research Institute (BAMPRI) through key investments in research and new opportunities for collaboration. The BAMPRI, for 30 years a mainstay of the materials science and engineering department, conducts focused research programs for the steel production, fabrication and end-user industries with the goal of increasing competitiveness and introducing new or improved steel products or processing.

The department has integrated and promoted energy research in the School of Engineering. Faculty experts in thermal barrier coatings, fuel cells, combustion, cooling, energy harvesting, turbines and renewable energy sources also will play leadership roles in the university and regional energy community. Many ongoing research projects are collaborating with the U.S. Department of Energy National Energy Technology Laboratory.

Carnegie Mellon University’s Materials Research Science and Engineering Center is an interdisciplinary research and educational enterprise dedicated to the understanding, control and optimization of grain boundary dominated materials properties. The collaboration of researchers with complementary backgrounds, skills and knowledge is critical to meeting the Center's technical objectives. The National Science Foundation established the Center in 1996 and remains its primary sponsor, in addition to other industry sponsors.

The Center is interdisciplinary, with students and faculty participating from the departments of materials science and engineering, civil and environmental engineering, mechanical engineering, mathematics and physics. At any time, 12 to 17 faculty and about 25 graduate students participate.

The mission of the Center is to work on real-world problems that potentially can be solved with appropriate nano-enabled technologies. The unifying theme of the Center is nanometer-scale materials that are deliberately synthesized, self-assembled, assisted to self-assemble or structured by engineering know-how to create novel properties, processes or principles. It is the new properties or principles that are taken advantage of in the design and engineering of innovative devices, arrays of devices and ultimately systems.

The Center's current approach to creating unique materials is two-fold. The first approach relies on solid-state synthesis and structuring to produce nanostructures with new physics or chemistry that leads to novel devices. The second approach is based on chemistry, where chemical synthesis creates unique molecules that are used to make novel materials. These, in turn, are used to produce structures with novel function or utility.

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The current focus of the Center is on nano-enabled sensor and energy technologies. This focus is intended to address some of society's most important problems. Energy, as an example, is probably one of the most pressing issues of our time. The other problems are the quality of the environment, water, food, and more recently terrorism and war. Nano-enabled sensor technologies can be brought to bear on some of the latter problems. The sensor work at the Center is on chemical and biological sensors, physical sensors and imaging sensors.

In energy, the interest is on technologies for clean energy generation and storage. Specifically, there are on-going projects in the generation of hydrogen as a fuel for fuel cells. There also are projects on novel fuel cell technologies. In addition, there are others on spectrally broadband photovoltaic cells for solar energy conversion.

The secondary focus of the Center is on nano-enabled information technologies that include devices and sub-systems for electronic and photonic information manipulation, as well as magnetic data storage systems.

The Pennsylvania State University has received $110 million from federal agencies for nanotechnology research since 2000, and it currently is ranked number one in materials research expenditures by the NSF. Its materials science faculty is ranked number one internationally.

There are more than 57 patents protecting nanotechnologies and 29 equity-based licenses issued from Penn State research.

Penn State has more than 200 faculty researchers and 100 nanotechnologists, including eight Ph.D.s engaged in nanoscience and technology. The university also has built a state-of-the-art, 275,000 square-foot, $125 million nano-bio-materials complex, that houses a new pallet of tools and techniques at the nanoscale, where living and inorganic molecules intermingle and materials display novel properties.

Penn State was an early leader in the fields of nano materials and nanotechnology education dating back to 1931 when Penn State physicist Ferdinand Brickwedde produced the world's first measurable amount of deuterium, a hydrogen isotope needed to make "heavy water," which is an essential ingredient in basic atomic research.

In 1993, Penn State opened its nanofabrication facility, a part of the National Nanofabrication Infrastructure Network, and continued with the Center for Nanotechnology Education and Utilization, one of the nation's leading nanotechnology workforce development programs.

Penn State's Center for Nanoscale Science was established as a National Science Foundation materials research science and engineering center to carry out interdisciplinary research and educational outreach in the areas of molecular nanofabrication, biomolecular motors and collective phenomena in restricted geometries.

Increasingly, the advances in nanoscience and technology are crossing the boundaries of departments and colleges, drawing researchers into collaborations that are enriching their individual disciplines. At Penn State, chemists and physicists, engineers and materials scientists, biologists and clinicians, all now speak to each other in the common language of nanoscience.

In response to this expansion of the sciences, Penn State has incorporated nanotechnology into all of its science programs. The university’s undergraduate focus on nanotechnology is designed to enrich students' knowledge and understanding of their core disciplines and enable them to bridge the gaps between the sciences in the commercial sector.

For undergraduates interested in pursuing a career in nanotechnology, Penn State's College of Engineering Science and Mechanics offers a nanotechnology minor, which is designed to prepare students from diverse disciplines for careers in a broad range of industries innovating with nanotechnology. The minor provides students with fundamental knowledge and skills in simulation, design, modeling, synthesis, characterization, properties, processing, manufacturing and applications at the nano scale.

In addition to the nanotechnology minor, and available to students at all of the two-year and four-year colleges and universities in the commonwealth system, an intercollegiate capstone semester of six courses is offered at Penn State's University Park campus. This hands-on, clean room-based laboratory program is designed to prepare students to enter the commercial world of nanotechnology and to meet the demands of a constantly advancing workplace. This landmark program is administered by the Pennsylvania Nanofabrication Manufacturing Technology Partnership and led by Penn State's Center for Nanotechnology Education and Utilization in collaboration with the National Science Foundation.

Other resources that support nanotechnology research and development are provided by The Technology Collaborative, the Pittsburgh Life Science Greenhouse and the Electro-Optics Center.

In addition, The Minerals, Metals & Materials Society, which is headquartered in Warrendale, PA, a northern suburb of Pittsburgh has assisted in organizing the annual Commercialization of NanoMaterials Conference which has been held in Pittsburgh since 2007.

As a result of these initiatives, nanotechnology talent is growing steadily to the Pittsburgh region. These resources and talent provide good reason to predict that the regional nanotechnology cluster is gaining an international reputation.

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