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ABSTRACT

* Regional center planned for nanofabrication and nanocharacterization

* Capabilities of the unique x-ray nanoprobe facility at the Advanced Photon Source

* Overview of research programs in nanomagnetism, ferroelectrics, nanocrystallline diamond, photochemistry and others

* Opportunities for collaborative research

INTRODUCTION

Nanotechnology, like the computing industry, has the potential to revolutionize nearly all the sciences. While predicting which emerging technologies will have significant long-term economic effects is never easy, few deny that nanotechnology will shape the future of the high-tech economy. The ability to manipulate material at the 1 to 100 nanometer level, approximately the length of twenty atoms, gives us unprecedented control over the properties of materials we create. It is control at this level that makes nanotechnology relevant across the sciences, not just to one particular field.

Never before have we had the potential to assemble material from its fundamental building blocks. As we continue to master control at this level, our influence over the properties of the materials being created, and hence the potential applications of nanotechnology, will increase dramatically.

To understand nanotechnology's influence, it is helpful to differentiate between the future applications of nanotechnology and those that exist today. Some of the most powerful future applications of nanotechnology lie in the computing industry. A greater control at the nanoscale allows for data storage at a much smaller level. Nanotechnology will make possible computers the size of a sugar cube thousands of times more powerful than those existing today. Increasing control at the nanoscale will also be relevant to biology, where microscopic "nanobots" could be inserted into the body and be programmed to find and destroy cancerous cells. On a more basic level, control of the fundamental building blocks of metals will allow for the creation of materials with electrical and physical properties impossible today. While the time frame for these advances has been debated (varying between 5-10 years and 10-20 years), few deny that as nanotechnology research advances, major new technological developments will become a reality. While some of these developments may be several years down the road, the foundation necessary to capitalize on nanotechnology must be laid now.

Some applications of nanotechnology already exist today. Nanoparticles have increased the performance of many existing technologies, including protective coatings, machine lubricants, and even sunscreen. Nanophase, a company based in Romeoville, IL, discovered that nanoparticles which are smaller than the wavelength of visible light yet larger than the wavelength of ultraviolet light can be used as a clear sunblock. Similar companies with products based on advances in nanotechnology are beginning to appear and make a significant economic impact all across the country.

ILLINOIS'S STRENGTHS IN NANOTECHNOLOGY

For research institutions engaged in nanotechnology research, Illinois is a leader among states. Illinois is the home of Argonne National Laboratory, which has scientists from many disciplines conducting research in nanotechnology. Argonne is home to the Advanced Photon Source (APS), the most powerful x-ray source in the world and an extraordinary and unique tool in the study of nanoscience. Moreover, Argonne can provide a unique opportunity for collaboration between the many research universities working with nanotechnology.

Argonne's proposed Center for Nanoscale Materials illustrates such a collaborative opportunity. Argonne's proposal was developed in tandem with the regional research universities to ensure that the facilities constructed would be maximally beneficial. One aspect of the proposed Center will be unique, and will attract users from around the world: A"hard-x-ray" nanoprobe at APS has been promised federal funding for the creation of APS beamlines dedicated to the study of nanotechnology. Argonne is hopeful that the entire Center will be funded by the Department of Energy in fiscal year 2004. Argonne has also received $2 million in State funding for the planning of the building that will house the Center, and a commitment for the entire building in future years.

Argonne is already linked directly in nanoscience with another of Illinois' great research institutions, the University of Chicago (which operates Argonne for the Department of Energy), through the newly-established University of Chicago-Argonne Consortium for Nanoscience Research. This Consortium, linking the University of Chicago's strength in science and medicine with Argonne's strength in science and engineering, is the sort of collaborative effort that must be cultivated if Illinois is to succeed in nanotechnology. The program will foster collaboration between world-renowned scientists at each institution, enhance Illinois' research capabilities, attract federal funding, and train new scientists in nanotechnology.

Northwestern University is developing several highly advanced nanotechnology programs, most notably their new Institute for Nanotechnology. This institute, funded in large part by a $14 million grant from the Department of Health and Human Services, will conduct interdisciplinary research by bringing together Northwestern faculty from a variety of departments already engaged in independent research in nanotechnology. Research at the Institute will be coordinated through Northwestern's other planned nanotechnology programs, the Center for Nanofabrication and Molecular Self-Assembly, and the Center for Transportation Nanotechnology. When these programs are fully operational, Northwestern will be a major national presence in nanotechnology and a great asset to Illinois' nanotechnology research. Furthermore the University of Illinois, one of the nation's premier institutions in engineering, has many faculty members conducting groundbreaking research in nanotechnology and the Illinois Institute of Technology (IIT) has the potential to develop nanotechnology initiatives through its engineering program. Other strong players in nanotechnology will include Northern and Southern Illinois Universities, and many outstanding universities in other states, e.g. Notre Dame in Indiana and U. Wisconsin in Madison.

These institutions are beginning to communicate regarding their research activities through Argonne's Nanotechnology Research Institute, which will provide guidance to Argonne as it develops its nanotechnology facilities.

Aside from the research institutions, the Illinois Department of Commerce and Community Affairs (DCCA) has shown significant insight through its support of Illinois' high-tech programs. Its support was crucial in the construction of the APS at Argonne in the early 1990s and its $2 million contribution to the construction of the building for Argonne's Center for Nanoscale Materials has helped demonstrate State support for the project. The Illinois Coalition's efforts to raise awareness of nanotechnology and to advise DCCA on the importance of nanotechnology have been greatly beneficial. Also, the City of Chicago recently announced its efforts to bring together various high-tech and entrepreneurial communities as part of its plan to attract high-tech businesses to the City and, importantly, has involved the University of Chicago and Argonne in these efforts.

ARGONNE'S RESEARCH PORTFOLIO

Argonne scientists have made several breakthroughs in the study of nanofluids. These fluids, made by suspending solid particles smaller than 40 nm in diameter in traditional heat transfer fluids, can double the heat transfer rate of normal fluids. In order to achieve this effect through pumping, the power would have to increase tenfold. Scientists at Argonne have developed a one-step manufacturing method that produces the only nanofluids to achieve long-term stability without the use of dispersants. Furthermore, Argonne's copper nanofluids offer the highest thermal conductivity enhancement for a given particle loading, making dispersion easier to maintain and reducing viscosity changes. For further information visit http://www.techtransfer.anl.gov:80/techtour/nanofluids.html

The Magnetic Films group at Argonne does a significant amount of work relating to nanomagnetism. The group is especially known for its work on magneto-optics, magneto-transport, and magnet coupling across a variety of spacer materials, including superconductors. In the future, the group plans to expand its efforts in order to laterally pattern their film structures via lithography and to create new patterned structures via self-assembly. Magnetic films are currently used in the magnetic recording industry, and there are efforts being made to develop a new generation of magnetic nonvolatile random access memory (RAM) which would revolutionize the computer industry. An Argonne scientist, Samuel Bader, was recently honored with the John A. Thorton Memorial Award of the American Vacuum Society, one of the premier honors given by the society, for his work with surface and thin-film magnetism. For further information visit http://www.msd.anl.gov/groups/mf/index.html

The Argonne Cluster Studies group has a program combining experimental and theoretical studies of a broad spectrum of fundamental physiochemical properties of atomic clusters and nanoparticles, with an emphasis on one and multicomponent metallic systems. The group studies various properties of these systems, including structural characteristics, phases and phase changes, thermal stability, electrical, optical, and magnetic characteristics, and chemical reactivity. These studies are part of an effort to further understand issues such as the dependence of the reactivity of clusters and nanoparticles on their size and composition, and the chemical manipulation of magnetic and electric properties of nanoparticles. The group has recently begun an effort towards the controlled assembly of nanoparticles from size-selected deposited clusters with the ultimate goal of rational design and synthesis of nanoparticles and nanosystems with predefined properties and functionality. For further information visit http://chemistry.anl.gov:80/research/metalclu.html

The Superconductivity and Magnetism group has done significant work with hybrid structures consisting of two dissimilar materials interacting across an interface. The interaction of these materials is mediated by the exchange of spins, charges, or electromagnetic fields across the interface. While in macroscopic materials these proximity effects are negligible, in nanoscale hybrid materials they can be very important. One hybrid structure which is being worked with at Argonne is the superconductor/magnet composite. Scientists predict that diffusing superconducting electrons into the magnet and spin polararized electrons into the superconductor will produce new and useful behavior. Work has also been done with other hybrids, including semiconductor/superconductor hybrids which promise the localization of single electrons in quantum well traps induced by individual vortices, and soft magnet/hard magnet hybrids which enable manipulation of nanoscale exchange interactions to produce novel magnetic switching. This new class of hybrid materials will be crucial in the attempt to find viable semiconducting materials which can serve as both charge transport and a magnetic storage medium. For further information visit http://www.msd.anl.gov.