Who says that bigger is better?

Area Development Site and Facility Planning
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With a myriad of applications, the developing nanotechnology industry is moving full speed ahead toward a new world of tiny technology.

WHILE THE INDUSTRIAL and computer revolutions jump-started many of civilization's grandest advancements, another one quietly under way today could prove to be the greatest of them all.

The "next best thing" is the small-tech revolution. Still mainly in the research stage, it is poised to make a thunderous debut on the global stage with almost unbelievable products for civilian and military use.

Leading the revolution is nanotechnology, which is technology, engineering, and science R&D based on the nanoscale. How small is that? A nanometer is three to four atoms wide (or one-billionth of a meter), and it takes one million nanometers to traverse a pin's diameter. Nanotechnology deals with objects less than 100 nanometers in scale, while microtechnology works with objects larger than that measurement. In short, this science-fiction-like technology creates useful material, devices, and systems through the control of matter on the nanometer scale, building them atom by atom, molecule by molecule, as if they were Tinker Toys.

Although nanoscience is not wellknown by the media or the public, that's bound to change once commercialization efforts gain momentum. By 2015 it is estimated that the field will support a $1 trillion annual market worldwide.

Albany NanoTech: From Concept to Market

At the University at Albany in New York, the acclaimed Albany NanoTech center houses $125 million worth of tools in 70,000 square feet of first-class R&D and premanufacturing space, which includes a 200-millimeter-wafer nanofabrication facility. Its prototype-manufacturing infrastructure is focused on

nano/microelectronics, nanophotonics and optoelectronics, nano/microsystems/MEMS (micro-electromechanical systems), and nanopower science and technology.

The center's worldwide reputation as a nanotech powerhouse continues to grow. In 2001, IBM and New York State announced the creation of a $150 million Center of Excellence in Nano-electronics. And this spring Sematech, an Austin, Texas-based consortium of 10 computer-chip manufacturers (such as Intel, Motorola, and IBM), located a $353 million research center there. In the near future, a Japanese firm will open a new $300 million, "next-generation" tool-development facility onsite for 300-millimeter-wafer R&D and prototype manufacturing.

Nanotechnology research can be approached via a "top-down" or "bottom-up" method, explains Mike Fancher, Albany NanoTech's director of economic outreach. "Imagine [that] you want to carve a statue out of block of marble," says Fancher. "Using the top-down method you'd carve out pieces to get the form desired, while with bottom-up you would be building the form from the inside out, placing each atom of marble exactly where you want it." Today, many universities are embracing the bottom-up modality, he notes, but a few engage in top-down mode.

"Stanford, MIT, Albany, the University of Michigan... Every university is playing with nanotech," he continues. However, at this stage in the industry's growth, major nanotech facilities are uncommon. Fancher points out that it typically costs at least $150 million to just build the brickand-mortar part, and "an additional $400 million to $500 million to pay for what's inside." Most nanotech facilities today are primarily engaged in research. In contrast, Fancher says that his facility's focus has been both in development and early manufacturing - a position making Albany "very unusual" in the industry.

Yet, costs aside, new facilities continue to be built. For example, this past July the University of Southern Mississippi (USM) announced a deal to bring Hybrid Plastics to its Hattiesburg campus. A major reason for choosing the site, according to the firm's CEO Dr. Joseph Lichtenhan, was to "affiliate with one of the top-10 polymer-science programs in the country," a reference to USM's internationally renowned School of Polymers and High Performance Materials. Hybrid will set up a 1,500-square-foot lab within USM's Shelby Freland Thames Polymer Science building, giving both parties the ability to collaborate in R&D and the commercialization of polymers and derivative nanocomposites. The facility will allow the firm to manufacture nanostructured materials that improve the thermal and mechanical properties of traditional polymers. Eventually, it is hoped that a new Nanotechnology Center of Excellence will be established at USM, focused on improving agricultural

products, coatings, paints, cosmetics, electronic polymers, and composites.

Astounding Products

This year has been a particularly important one for the nanotech industry. As Wired magazine reported, "If the excitement at New York's NanoBusiness Conference is any guide, future historians will declare early 2003 to be nanotechnology's tipping point, the pivot on which the industry slid from 'not quite ready' to 'raring to go.'"

What discoveries may spring forth from work conducted at over 1,000 nanotech startups and nano R&D centers?

* Imagine products that improve drug delivery and foster the creation of better drugs, earlier detection of diseases, and an overall lowering of the death rate.

* Using nanotechnology, the semiconductor industry could see $300 billion in annual production in the near future, the National Nanotech Initiative (NNI) says.

* Nanocrystals could boost DNA and genome research.

* Nanotech fibers called "carbon nanotubes" are stronger than spider silk and store electricity. They may allow for the creation of "wearable" DVDs or MP3s for consumers, and communication devices for soldiers.

* A few nanotech products have already been commercialized for use in textiles, cars, medical devices, cell phones, appliances, as well as military situations.

* Nanomaterials were the first objects to move to product status, most notably in the area of paints and coatings. A "fun" application is a car body paint that changes colors when light hits it from different angles.

* The films and coatings industries also widely employ nanotechnology to make stronger, more durable, less expensive, "invisible," and scratch-resistant products.

* Nanoparticles and powders fight corrosion and boost surface strength. They're easily found in popular nanoparticle-infused clothing that is very resistant to wrinkling, stains, or water.

* Microelectronics are becoming more involved with communications and sensors and have enormous homeland security potential. At the consumer level, in many cities they signal approval from a chip in a "gas pass" to the gas pump.

* Nano's impact in a post-September 11 world will be huge, according to Fancher.

"You can't pay guards at every bridge and building, but [you] can install homeland security nano-solutions to sense, monitor, command, and control an area, giving the person in the field as much info as a battlefield commander. The government is moving toward that very rapidly right now."

At a recent European conference, Robert Mehalso, president of Microtec, predicted that as nanotech's impact broadens, "All industries will be affected; many companies will disappear; industries will be restructured; and many new companies will be formed."

Big Plans for "Small" Research Centers

The mission of the National Science Foundation (NSF) - an independent agency of the U.S. government - is to promote the progress of science; secure our nation's defense; and "advance the national health, prosperity, and welfare." Since anticipated "whiz-bang" innovations in nanotech will easily help NSF fulfill its mission in all three areas, it's no surprise that in 2001, the agency announced awards totaling $65 million over five years to fund six major U.S. centers in nanoscale science and engineering.

The centers involved are Center for Electronic Transport in Molecular Nanostructures, Columbia University, New York; Center for Nanoscale Systems in Information Technologies, Cornell University, New York; Center for the Science of Nanoscale Systems and their Device Applications, Harvard University, Massachusetts; Center for Integrated Nanopatterning and Detection Technologies, Northwestern University, Illinois; Center for Directed Assembly of Nanostructures, Rensselaer Polytechnic Institute, New York; Center for Biological and Environmental Nanotechnology, Rice University, Texas.

Specifically, the NSF expects the centers to make small-scale headway in information, medical, manufacturing, and environmental technologies, and to form strong partnerships with industry, national labs, and other sectors. Additionally, these centers are asked to support educational programs that are developing a skilled technological work force and to increase the public's understanding of science and engineering.

The preliminary funding established the National Nanotechnology Initiative (NNI), a program that the NSF guides in addition to the National Science and Technology Council's Subcommittee on Nanoscale Science, Engineering, and Technology. Along with other federal agencies, these groups help establish a national program for the industry.

The NSF's investments are diverse. Besides the six centers, it also funds other nanotech projects (nearly 1,300 worked on by 6,000 faculty/students this year); nine other large science centers, bringing the total to 15; related nano facilities, such as Purdue University's Network for Computational Nanotechnology; and small-business initiatives.

Federal support for NNI continues with $774 million allocated for 2003 (with $221 million specifically for NSF), and $849 million requested for 2004 (with $249 million for NSF). In tandem with these funding efforts, a congressional "show of confidence" in NNI materialized this May with the passage of H.R. 766, the "21st Century Nanotechnology Research and Development Act." It authorizes $2.36 billion over three years for nanotechnology, nanoscience, and nanoengineering research, of which almost half goes to the NSF and the remainder to the Department of Energy, the Department of Commerce, NASA, and the Environmental Protection Agency. Essentially, the act provides a statutory foundation for much of what is currently in place via NNI.

Through nanotech funding, the federal government intends to accomplish amazing things. Goals include everything from unlocking the secrets of biosystems at the nanoscale and overcoming existing limits to miniaturization, to manufacturing devices and systems at the nanoscale, and merging nanotechnology with information technology, biology, and social sciences.

Small-Tech Hot Spots

This past March, Small Times magazine, a leading small-tech industry publication, published a statistical analysis ranking all 50 states in terms of nanotechnology, MEMS, and microsystems growth. Each region's rating was derived by combining scores earned in six categories: research, industry, venture capital, innovation, work force, and costs.

Steve Crosby, president and publisher of Small Times Media, says that small tech is leading existing industries into the next generation of products and helping to create entirely new industries. His magazine's rankings show how the leading states are achieving this new growth. A common thread in every success story, he explains, "is a balanced cluster of new and existing businesses, world-class research, investment capital, and a supportive government." In addition, states that win the nanotechnology race "could all see a significant economic boom," predicts Crosby.

Here's a snapshot of quotes from Small Times about the top-10 states that are ready to jump to the next level of economic growth thanks to small tech:

* California: The state "has the critical mass to attract researchers, companies, and VC cash, even in rough economic times."

* Massachusetts: "This state's deep talent pool propelled Massachusetts into second place."

* New Mexico: "The Land of Enchantment's efforts to wean the state from the federal bankroll are paying off here."

* Arizona: "Intel, Motorola, and Honeywell put their headquarters in California, Illinois, and New Jersey... but they're keeping their brains in Arizona... Although coming in fourth on the list, years of financial losses are taking a toll on Arizona's corporate R&D programs."

* Texas: "The Lone Star State's big guns are leading the charge to make the state number-one, and they could succeed... Texas has some of the right ingredients, but it could use some more 'buying in.'"

* Maryland: "Maryland's location gives it easy access to the nation's key funding sources... [Its] small-tech community posted high scores for winning federal and academic research grants..."

* New York: "New York has the Big Apple's brains and bucks, and upstate's innovation and enterprise... Many of [its nanotechnology] efforts are concentrated at Albany NanoTech, a fabrication and prototyping resource that has attracted hundreds of millions of dollars from industry and the state and federal governments."

* Illinois: "Things are looking up in the Windy City, where researchers, business leaders, and policymakers appear ready to cash in on the state's impressive intellectual capital... [It's] a standout for small-tech research."

* Michigan: "Michigan shoulders its way into the Big-10 with some smart initiatives and cooperative partners."

* Pennsylvania: "Pennsylvania plays nice with its neighbors to the west and southeast, with impressive results... offers a combination of strong basic and applied research...[and] posted the third-highest score for small-tech-related grants from NSF in 2002."

What accounts for such success? It's a potpourri answer, but typically encompasses a mix of well-trained, innovative people; a history of university lab work underpinning biotech, infotech, and defense industries; lots of venture capital and/or government

funding; and cooperative business, research, and government leaders. Small Times notes that each of the above-named states, except for Arizona, has a national laboratory or is tied to "some of the most acclaimed state and private science and engineering universities in the nation." Arizona has Motorola Research Labs, a high-powered industrial center in Tempe that is focused on nanoscale and micron R&D.

Michigan is a particularly interesting state to watch, says Crosby, since "as far as I know, it's the only state which has actually targeted nano- and microtechnology, and put together a pretty ambitious program to go after it."

Nanotech Goes Global

"Every industrialized country has created its own version of NNI," points out Albany's Fancher. "The race is on." Typically, nanotech research is found in regions with established semiconductor and software industries. No surprise, then, that Japan, China, Korea, and Taiwan share a high interest in nanoscience with the United States and the European Union.

Across the pond, the European Nanobusiness Association (ENA) brings together researchers, industry, and investors to strengthen nanotechnology commercially. Founded in 2002, it hopes to have 1,500 individual members and 400 company memberships by 2004. In January, the association announced plans to create 12 nano hubs within existing nano-focused organizations in London, Newcastle, and Cambridge; Oslo; Helsinki; Copenhagen; Dublin; Munich; Eindhoven; Madrid; Budapest; and Sofia.

A recent ENA report says that Japan's 2003 nanotech funding is about $1 billion, while European spending could be $3.3 billion between 2003 to 2006. However, since funding is computed differently on the continents, it's hard to tell exactly who's pumping more into nanotech than someone else. A more important consideration, say insiders, is that cooperation increases between researchers, investors, governments and nanotech facilities to spur research and commercialization globally.

[Sidebar]

Nanotech fibers called "carbon nanotubes" are stronger than spider silk and store more electricity.

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