



LEFT: Nanoscience is unraveling what makes colloids self-assemble into building blocks for hundreds of common items such as aerosols, gels, inks, detergents, even polymers and proteins. View is 50-micron scan. (Atomic Force Microscopy image taken on an Asylum Research microscope at NIST. Courtesy: Asylum Research)

about 100 nanometers. Experts say if we can understand and manipulate our world at this tiny scale, we'll unlock a vault brimming with discoveries and promise.

Nanotech Holds Medical Promise. A DNA molecule is 2.5 nanometers wide. The National Cancer Institute and National Institutes of Health are investing in nano-research to find better ways to diagnose and treat cancer. NCI/NIH are working on cell-sized nano-containers to deliver gene therapy, quantum dots to find tumors only a few cells wide, and even custom-designed drug therapies based on a patient's DNA.

"There is a lot of exciting nanotechnology research in the lab now and the goal is to get it into clinical trials," says Dr. Mansoor Amiji, a Northeastern University nano-researcher investigating therapies for childhood cancers. Small biotech, such as Abraxis Bioscience, have already received FDA approvals for drug nano-formulations. And Genentech is joining other larger biotech in nano R&D.

Nanotech Fueling "CleanTech" Revolution. The Nano Science and Technology Institute (NSTI) is at the center of the nanotech-clean-tech convergence. "There is a burst in nanotechnologies aiming to cut pollution, waste and energy use for industrial firms," said Dr. Matthew Laudon, NSTI's Executive Director.

Laudon notes many examples. NanoH₂O (Santa Monica, CA) has nano-membranes to improve water reclamation and desalination. The University of Wisconsin is working on nano fuel cells for cellphones, PDAs and TV. "Smart batteries" from nanotech designs will store power for years and release current on-demand. Nano-thin roll-printing will make solar cells cheaper. NSTI's Nanotech 2007 conference is co-located with CleanTech 2007 (Santa Clara, CA; May 20-24, 2007) and will showcase many leading-edge nanotech solutions for clean-tech. Visit www.nanotech2007.org and www.cleantech2007.org.

Nanotech and the Consumer Economy. While nanotech may help cure cancer or curb global warming, maybe you just want your laptop battery to last longer. Nanotech is there too.

The biggest names in electronics and semiconductors—Intel, AMD, HP, Agilent and Motorola—all have nano R&D programs, covering chips and components for PCs, laptops, cellphones and PDAs.

Other nano initiatives could bring brighter and cheaper flat-panel TVs, stronger tires, cheaper and more efficient gasoline, and self-repairing engines. Boeing and Caterpillar are even exploring nanotech to improve airplanes and earth movers.

Top Chemical Firms Safeguard Nano's Promise. Beyond the flashy research, getting nano-inventions to market also means ensuring nano does no harm.

BASF, DuPont, Dow, P&G, and a dozen more of the world's largest chemical companies are collaborating with U.S. and international

■ ■ Nanotechnology Matters

Government, academic and corporate R&D open doors to better medicine, faster PCs and a cleaner environment.

Written by Vance McCarthy

Thousands of nanotechnology experts—researchers, engineers and product specialists—are quietly cracking long-unseen codes about how the universe works at the tiniest scale.

Over the past 3 years, the government's National Nanotechnology Initiative (NNI) and other programs have poured \$2 billion-plus into nanotech exploration. Now, we have thousands of new nano discoveries—building blocks for nano's future, some as small as one or two molecules.

In 2007, R&D spending is intensifying. The U.S. Departments of Energy (DOE) and Defense (DOD) will spend another \$3 billion-plus on pure nano-related projects by 2010. This should attract more commercial R&D money. At decade's end, it's predicted most Global 500 firms will make, buy, or have investments and/or partnerships in nanotechnology.

This section is designed to help *BusinessWeek* readers get their bearings on nanotech opportunities, and how nano could affect their lives, finances, careers and even their company's future. Let's get started.

Sizing Up Nano. Nanotechnologists work at the molecular scale. To give you some perspective, a sugar granule is about 1-millimeter wide. Zoom down 1-million times smaller and you get a single sugar molecule, which measures 1.0 nanometer.

Nanotechnology encompasses materials, chemicals, devices, structures and processes at scales between 0.1 nanometers to

agencies under the mantle of The American Chemistry Council's Nanotechnology Panel, www.americanchemistry.com. Their goal: to ensure nanotechnology advancements move forward while protecting the environment, human health and safety (EH&S).

ACC's Nanotechnology Panel boasts 16 companies, and is encouraging governments to set priorities for conducting EH&S research. The Panel also works with scientists to discover, measure and evaluate potential risks that might arise from production, use and disposal of nanomaterials.

"Right now, many of our [members] are engaged in nanotech R&D. They know the value of having this kind of research in place early," said Bill Gullledge, Manager of the American Chemistry Council's Nanotechnology Panel and Managing Director of ACC's Chemical Products and Technology Division. "What would be a chilling effect on early stage [nanotechnology] R&D would be the uncertainty that may be associated with a whole new set of marketplace regulations for nanotechnologies," prior to a thorough review and the application of today's regulatory framework for nanomaterials and their related bulk chemicals.

Wanting to be included in any groundbreaking nano-initiatives, ACC's Nanotechnology Panel members are cooperating on projects to ensure strong EH&S practices for nano. Among ACC's aims is to work with others to: **(1)** identify multi-national EH&S research strategies; **(2)** identify "representative" nano-materials for further investigation, and **(3)** develop health and environmental test methods for assessing "representative" nano-materials.

Lessons from Current Practices. ACC's Nanotechnology Panel members continue to apply to their nano work current hazard identification and risk assessment principles, developed from their bulk chemical "product stewardship programs," Gullledge said. "Lacking specific measurement techniques in the nano-range, some companies are using experience gained in managing the bulk material." ACC members are eager, meanwhile, to participate in research that will develop the specific nanoscale measurement techniques, he added.

Meanwhile, to capture the necessary strong approaches and good data, ACC's Nanotechnology Panel wants to leverage its vast experience to help **(1)** gather technical information; **(2)** evaluate the specific characteristics of nanomaterials in order to adequately characterize potential hazards, and **(3)** measure potential health and environmental impacts throughout the product life cycle and ultimate disposal. [To "characterize" is to test and analyze to identify and categorize attributes and properties of chemicals under various conditions.]

"Many [ACC] Panel members participated in generating hazard information for the High Production Volume chemical assessment programs [from the U.S. Environmental Protection Agency]. From this experience, they have a lot of knowledge in characterizing chemicals," Gullledge says. "But, our members would benefit from ongoing and future research on characterization of nanomaterials, and possible future information that agencies will be looking for."

So, ACC is asking EPA to make identification and characterization of nanomaterials a research priority. Gullledge is hopeful the gov-



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ernment's FY2008 discretionary budget will fund these programs. ACC members are also encouraging EPA to implement a voluntary nanomaterials stewardship program. "We participated in an advisory capacity as EPA developed their early draft for the program, and we are very excited for it to get off the ground," Gullledge said.

While ACC members await a formal EPA program, they are working on EH&S nano programs with other groups.

With the Organization for Economic Co-operation and Development (OECD), ACC, working within an international industry coalition, is working towards establishing a comprehensive database of nanomaterials and related EH&S information. In a program Gullledge called "very aggressive," OECD is also identifying research strategies for working with nanomaterials, and sharing common national approaches for evaluating risk and conducting risk assessments.

With the National Institute of Occupational Safety and Health (NIOSH), ACC panel members are helping to conduct research to measure and control potential workplace exposure to nanomaterials. ACC is also watching ongoing implementation of a voluntary nanotechnology program recently launched in the U.K.

Asked whether ACC's work is simply an effort to preempt harsher nano regulations, Gullledge is candid. "There is nothing on the radar at this time that suggests Congress or federal agencies want new or special regulations for nanomaterials. I hope as an industry we will go through information collection and analysis efforts, such as these voluntary programs, before governments here or abroad, make any rash decisions

about the need for more regulations for the nanotechnology industry."

"That said," Gullledge adds, "our challenge is to continue to demonstrate the [chemical] industry's commitment to safety and the protection of human health and the environment. Applying product stewardship principles, such as ACC's Responsible Care Program, to nanomaterials could help ensure that EH&S issues do not become potential problems, and is the proper approach, I believe." ■



NSTI

Nano Science and Technology Institute

The Nanotech for Investors Summit (May 21, 2007 in Santa Clara, CA) offers executive-level advice and perspective from the world's leading investors, along with access to top nanotech business and technology execs. "The Summit will provide attendees a financially focused outlook on how nanotechnology is affecting global investments across various markets, and candid discussion on opportunities and risk," said Dr. Aymeric Sallin summit co-chair, and co-founder of NanoDimensions a pioneering nanotech VC firm. The summit is co-hosted with NSTI. (508) 357-2925 www.nsti.org/nanotech2007/nanoinvestor

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Nanotechnology Pioneers

QuantumSphere, Inc. (Santa Ana, CA) is a leader in bringing nanotechnology to battery and clean-energy applications. In 2007, this maker of high-quality nano catalysts revealed two new nano-based fuel cell and hydrogen generation technologies, which will boost power and cut manufacturing costs.

Founded in 2002, the company has a growing IP portfolio of processes and applications. Alongside its in-house engineering staff, led by a former aerospace scientist, QuantumSphere works closely with U.S. national labs and leading universities on nano-scale catalyst materials. QuantumSphere has a unique ability to produce ultra-pure, highly uniform nano-metals and alloys in high volume.

"By enabling low-cost, portable power and efficient renewable energy production with high-performance nano catalysts, QuantumSphere is delivering on its promise to alleviate our nation's over dependency on conventional sources of energy today," said QuantumSphere's CEO and co-founder Kevin D. Maloney.

QuantumSphere aims to be a leading provider of high-performance catalyst materials and electrode devices for clean-energy applications, including batteries and micro fuel cells for portable power, and hydrogen generation through electrolysis. Analysts estimate today's global catalyst market at \$10+ billion a year. **(714) 545-6266; www.qsinano.com**

Advanced Diamond Technologies, Inc. (Romeoville, IL) makes diamond one carbon atom at a time. ADT's UNCD® (ultra-nanocrystalline diamond), born of U.S. Department of Energy research, has the smallest grains of any form of diamond. This makes UNCD purer, smoother, and more uniform than traditional diamond and suitable for electronics. Soon, ADT's diamond will power cellphones and biosensors. "We turn 50 cents worth of natural gas into \$500 of diamond by rearranging the carbon atoms," said ADT's president Neil Kane. UNCD won Frost and Sullivan's 2006 Product Innovation of the Year Award. **(815) 293-0900; www.thindiamond.com**

MEMSCAP Inc. (Durham, NC) solutions include components, component designs, manufacturing and related services. MEMSCAP's Custom Products Business Unit's US operations are located in RTP, NC, where one of the largest MEMS intellectual property portfolios, standard processes and a TL9000 quality system are leveraged to support customers from development to production. "We let our customers leverage MEMS and nanotechnologies to create new products, improve existing products, and accelerate design and manufacture," says MEMSCAP Custom Products Business Unit General Manager, Ron Wages. **(919) 314-2200; www.memscap.com**

Ambios Technology Inc. (Santa Cruz, CA) is a leading manufacturer of surface measurement, visualization, and characterization instruments in the industrial and academic nanotechnology marketplace. "Our recent acquisition of Quesant Instrument Corp. has allowed us to extend our initial market successes in high resolution contact and non-contact profilometry to the nano-scale with atomic-scale imaging systems," says Ambios President and CEO Patrick O'Hara. With a compounded annual revenue growth rate of 35% since the installation of their first instrument in 2001, Ambios is poised to be a significant contributor to the growing nanotech tools sector. **(877) 429-4200; www.ambiostech.com**

Pennsylvania NanoMaterials Commercialization Center (Pittsburgh, PA), a non-profit, promotes commercializing nanomaterials research for U.S. business and defense. The Center's industry partners include Alcoa, BayerMaterial Science, PPG Industries, Plextronics, U.S. Steel and Pittsburgh Technology Council. Partnering universities are Carnegie Mellon University, Pennsylvania State University, and University of Pittsburgh. Funding comes from the U.S. Department of Defense and the Commonwealth of Pennsylvania. The Center's focus includes low-cost solar cells, enhanced polymers, and improved heat exchangers. "We want to commercialize promising nanotechnology research within Pennsylvania's businesses and academia," says Center Executive Director Dr. Alan Brown. **(412) 918-4205; www.pananocenter.org**

mPhase Technologies (Norwalk, Conn.), trading OTC as XDSL, is working with the U.S. Army at Picatinny, Rutgers, The State University of New Jersey and leading research organizations on two blockbuster projects. "Our job is to drive MEMS and nanotechnology R&D into leading-edge products," says mPhase CEO Ron Durando. mPhase's two current projects are: a battery built with nanostructures to last longer, store more energy and be safer to discard; and a family of magnetometers made from MEMS structures smaller than the date on a penny. It would detect magnetic fields disturbances, and could be used for security applications and to augment GPS and GPS-denied electronic devices, and even help guide smart munitions. **(973) 256-3737; www.mphasetech.com**

Nanotech Ventures and Cleantech 2007 Ventures (May 22-24 in Santa Clara, CA), will provide investors and corporate partnership and business development execs an ideal opportunity to meet and evaluate more than 100 early-stage public and pre-IPO companies in the nanotech and cleantech sectors. "The combined Nanotech/Cleantech Ventures event will bring together executives from these pioneering companies with industrial users, funders, technology providers and analysts," says Dr. Matthew Laudon, Executive Director of the Nano Science and Technology Institute, the events' producer. **(508) 357-2925; www.nsti.org/nanotech2007 and www.cleantech2007.org**

