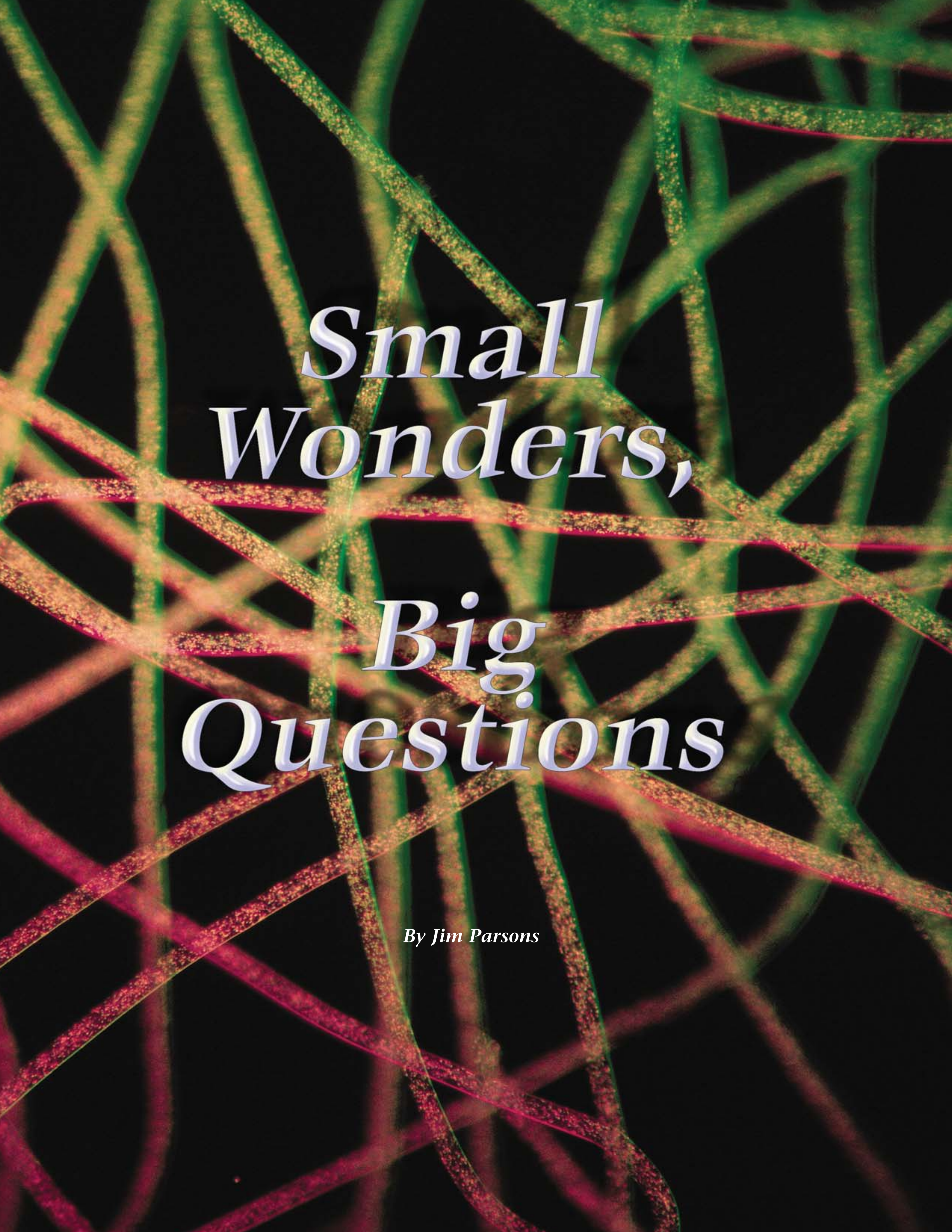


Small Wonders, Big Questions

By Jim Parsons

Nanotechnology

has been called the next industrial revolution, a technology poised to change the way we work, communicate and care for ourselves. Although many of its virtually invisible products have yet to reach the marketplace, experts see a future filled with exciting opportunities and applications (see sidebar, p. 39). Worldwide government investment in nanotechnology has accelerated dramatically since the mid-1990s, setting the stage for what may well become a multitrillion-dollar global industry in the next decade.

Along with its promising benefits and economic potential, nanotechnology also presents many workplace health and safety concerns. To be sure, dealing with submicroscopic health hazards is nothing new to industrial hygiene. A host of monitoring and protective strategies are already in place to safeguard the U.S. workers exposed to nanometer-diameter particles on a regular basis—more than 2 million people, according to the U.S. Department of Labor.

That figure is expected to double as nanotechnology-related industries proliferate around the world, raising fears that the growth may outpace the development of appropriate safety protocols. What's more, those workers will be dealing not simply with microbyproducts of certain processes, but "uniquely engineered materials with novel sizes, shapes and physical and chemical properties, at levels far exceeding ambient concentrations" according to NIOSH.

Speaking before ASSE's 2004 Professional Development Conference and Exposition, NIOSH Director John Howard noted that nanotechnology's materials and devices "are so far from our current understanding that we can not easily apply our existing paradigms to protecting workers. Perhaps for the first time, we need to characterize the quantum properties of exposure."

A recently completed study by Great Britain's Royal Society and Royal Academy of Engineering echoes those thoughts. Cambridge University professor Ann Dowling, who chaired the working group that produced the study, recently told a *Washington Post* reporter that, "Nanoparticles can behave quite differently from larger particles of the same material and this can be exploited in a number of exciting ways. But it is vital that we determine both the positive and negative effects they might have."

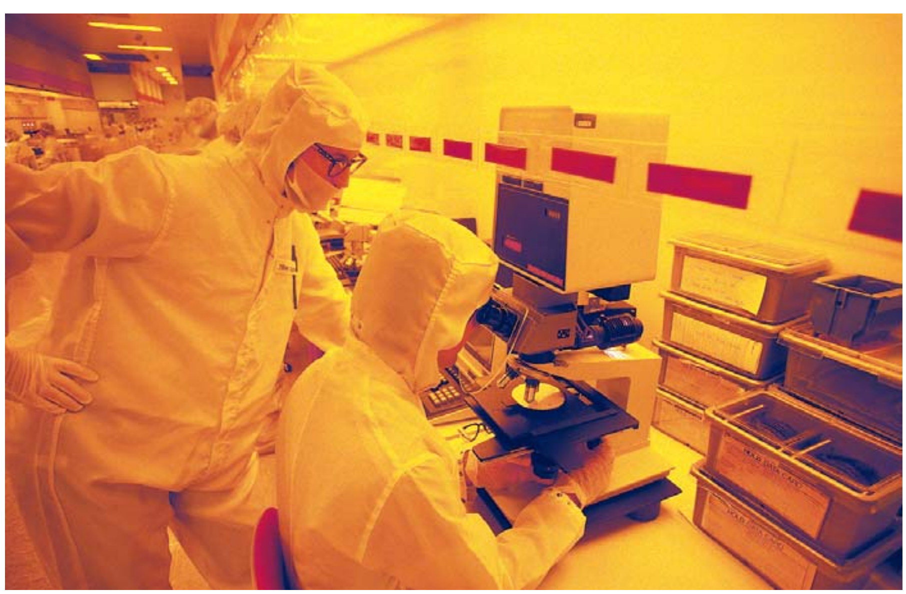
Nano-Basics

Fortunately, IHs are not starting from scratch. Andrew Maynard, a senior service fellow in NIOSH's Division of Applied Research and Technology, says existing toxicology studies from known ultrafine particles and incidental nanoparticles (e.g., byproducts of combustion or welding) offer some clues as to how their manufactured counterparts might behave.

"We know that certain mass concentrations of inhaled nonsoluble nanomaterials can be harmful, which provides a good analogy for other nano-size particles," he explains. "The surface area and chemistry appear to be the key metrics, and there are indications that some materials can affect health. But we couldn't predict how from current understanding."

James Rock, a past president of AIHA, senior lecturer in IH at Texas A&M University and director of the Texas Occupational Health and Safety

(Continued on p. 38)



(Continued from p. 37)

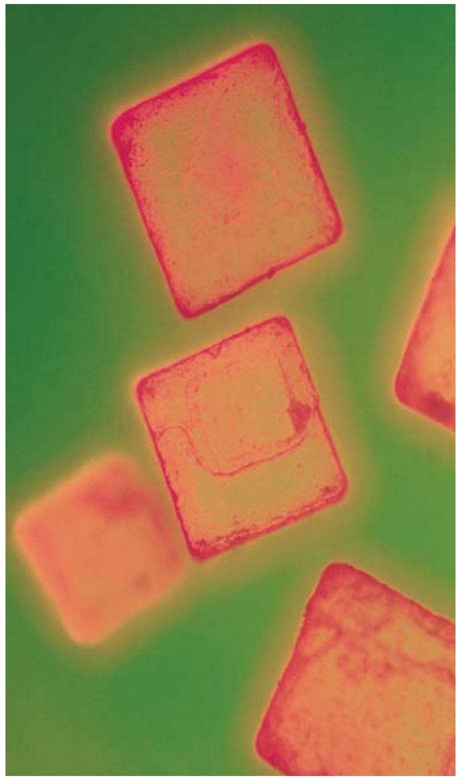
Institute, agrees. "Ultra-fine particulate exposures are reasonable analogs to engineered nanoparticles. We know how they behave in the environment, how they move through airways and how they deposit on surfaces. Now, we need to characterize their behavior and other attributes to see if there are different toxicological effects."

Still, Kenneth L. Williams, a physical scientist at NIOSH's National Personal Protective Technology Laboratory in Pittsburgh, Pa., speaks for many when he concedes, "There is far more that we don't know about nanoparticles than we do know when it comes to health effects and the performance of personal protective equipment."

A number of efforts are under way on several fronts to help fill those gaps. NIOSH's multidisciplinary Nanotechnology and Health & Safety Research Program is exploring a wide range of toxicity and health risks associated with workplace nanoparticle exposure. "We'll establish a common basis for identifying and characterizing nanostructures, their physical attributes and health impacts," says Maynard, one of the program's key participants.

Other NIOSH research programs seek to consolidate new and established research into guidance for workplace health and safety professionals. For example, Eileen Kuempel, a senior health research scientist for the Institute's Risk Evaluation Branch, is leading the development of a risk assessment for exposure to nanoparticles of titanium dioxide.

"We're in the process of developing a current intelligence bulletin using rat data for cancerous and noncancerous responses," she says. "The bulletin will provide a quantitative description of



dose relationships using human dissymmetry models."

NIOSH is also a participant in the National Nanotechnology Initiative (www.nano.gov), which is coordinating research and development programs across 18 federal agencies. The National Toxicology Program of the U.S. Department of Health and Human Services also has several nanotechnology studies under way "to evaluate the toxicological properties of major nanoscale materials classes which represent a cross-section of composition, size, surface coatings and physico-chemical properties," according to an agency fact sheet.

Preparing for Tomorrow Today

While the research community works to turn questions into answers, IHs in existing or potential nanotechnology industries should not hesitate to begin crafting their H&S strategies. Maynard admits that this will not be an easy task.

"We can speculate on what control methods will be effective with nanoparticles, but we have no direct evidence of how the technologies will work," he says. "Respirators with HEPA filters that are good for 300 nm-diameter particles may well be effective, but we still need to research this. We have only theory now."

Rock sounds a more confident note about current technologies. "The business of protecting workers and the environment by engineering systems to prevent the release of undesirable stressors will remain top priority, but I don't foresee different kinds of protection," he says. "HEPA filtering may become more important, but it's still an offshoot of existing technology. Detection will require new sampling methods, but agencies such as [the U.S. Environmental Protection Agency] are already working on it."

On the other hand, Williams says that as particles approach molecular size, "they may be subject to thermal rebound theory, in which they literally bounce through a filter." Though he cites a University of Minnesota research project for the U.S. Department of Energy that suggests thermal rebound is not an issue at room temperature, nothing should be taken for granted. "In lieu of anything else, the sensible person would pursue classic IH practices," he says.

Another pressing concern is communicating both nanotechnology's knowns and unknowns to workers. "This is a major area of emphasis, with the National Nanotechnology Initiative and others," says Maynard, who co-chairs an interagency working group developing best practices guidelines for nanomaterial handling and management. "We need to get occupational health aspects right as quickly as possible. There could be dire consequences 20 to 30 years down the road if we miss something. That could result in a major backlash against nanotechnology."

ANSI Establishes Nanotechnology Standards Panel

ANSI has formed a Nanotechnology Standards Panel, a new coordinating body for the development of standards in the area of nanotechnology. The panel's first meeting was held Sept. 29-30, in Gaithersburg, Md.

The U.S. Office of Science and Technology Policy in the Executive Office of the President asked ANSI to address this area of standardization in support of academia, industry, the investment community and government agencies that utilize nanotechnology.

A Steering Committee is being formed and will be co-chaired by Clayton Teague, director of the National Nanotechnology Coordination Office; Vicki Colvin, professor of chemistry at Rice University and director of the National Science Foundation-sponsored Center for Biological and Environmental Nanotechnology; and David Bishop, vice president of nanotechnology research at Lucent Technologies and president of the New Jersey Nanotechnology Consortium.

The ANSI-NSP is open to all interested parties. AIHA has already been in contact with ANSI about potential participation in the group.

For more information, please visit the ANSI website at www.ansi.org/nsp.

Defining the Future

Although the advent of nanotechnology is a certainty, no one can predict just how the technology will unfold. As the Royal Society/Royal Academy of Engineering report notes, "Nanotechnologies have the potential to impact on a wide range of applications in many industries in the medium- and long-term. However, some people exaggerate potential benefits, whereas others exaggerate the risks. Overstated claims about benefits and risks, neither of them based on sound science, are doing a disservice to these emerging fields."

Williams puts it another way, likening nanotechnology to asbestos. "It was supposed to be this 'wonder material' that would solve all kinds of problems," he says. "Nobody understood the threats until much later, and only now are we catching up. We have the opportunity to investigate the possibility of occupational health risks from nanoparticles early in the game."

Rock believes that IHs can and should take a leading role in ensuring the safe use of nanotechnology applications from concept to customer, and beyond. "We need to anticipate, recognize, evaluate and control first," he says. "We can do a better job of designing engineering controls into the laboratory and manufacturing processes. And, we need to be alert to the need for public education for the safe use of nanomaterials, particularly as they become more widely used in everyday life."

True, nanotechnology's hopes and hazards present a formidable task, but one that Rock says IHs should willingly embrace. "Few other professions would attack this challenge," he says. "We should."

Parsons is a freelance writer in the Washington, D.C. area.

Nanotechnology Resources

NIOSH Nanotechnology Page:
www.cdc.gov/niosh/topics/nanotech

Royal Society and Royal Academy of Engineering (U.K.) Study on Nanotechnology:
www.nanotec.org.uk/index.htm

National Nanotechnology Initiative:
www.nano.gov

NNI Links to Nanotechnology Resources:
www.nano.gov/html/res/links.html

ANSI Nanotechnology Standards Panel:
www.ansi.org/nsp

There's a Small World Coming

How can something so small be so powerful? At a length scale of 1–100 nanometers (the accepted "yardstick" for nanotechnology), certain materials begin to exhibit unique properties that affect physical, chemical and biological behavior. That opens the door to a variety of new and exciting applications.

Nanoscale particles are already being used in the electronic, magnetic and optoelectronic, biomedical, pharmaceutical, cosmetic, energy, catalytic and materials industries. Areas producing the greatest revenue for nanoparticles reportedly are chemical-mechanical polishing, magnetic recording tapes, sunscreens, automotive catalyst supports, biolabeling, electroconductive coatings and optical fibers.

Most computer hard drives contain giant magnetoresistance heads that, through nano-thin layers of magnetic materials, allow for a substantial increase in storage capacity. Other electronic applications include nonvolatile magnetic memory, automotive sensors, mine detectors and solid-state compasses.

Additional products, available today, that benefit from the unique properties of nanoscale materials include:

- Paints and coatings to protect against corrosion, scratches and radiation
- Protective and glare-reducing coatings for eyeglasses and cars
- Metal-cutting tools
- Sunscreens and cosmetics
- Longer lasting tennis balls
- Lightweight, stronger tennis racquets
- Stain-free clothing and mattresses
- Dental-bonding agents
- Burn and wound dressings
- Inks

In addition, the National Nanotechnology Initiative is funding a variety of projects exploring new applications for nanomaterials. Among the recent achievements:

- Use of the bright fluorescence of semiconductor nanocrystals (quantum dots) for dynamic angiography in capillaries hundreds of micrometers below the skin of living mice—about twice the depth of conventional angiographic materials and obtained with one-fifth the irradiation power.
- Nano-electromechanical sensors that can detect and identify a single molecule of a chemical warfare agent—an essential step toward realizing practical field sensors.
- Nanotube-based fibers requiring three times the energy-to-break of the strongest silk fibers and 15 times that of Kevlar fiber.
- Nanocomposite energetic materials for propellants and explosives with more than twice the energy output of typical high explosives.
- Prototype data storage devices based on molecular electronics with data densities more than 100 times that of today's highest density commercial devices.
- Field demonstrations of iron nanoparticles that can remove up to 96 percent of a major contaminant from groundwater at an industrial site.

Sources: NIOSH, National Nanotechnology Initiative