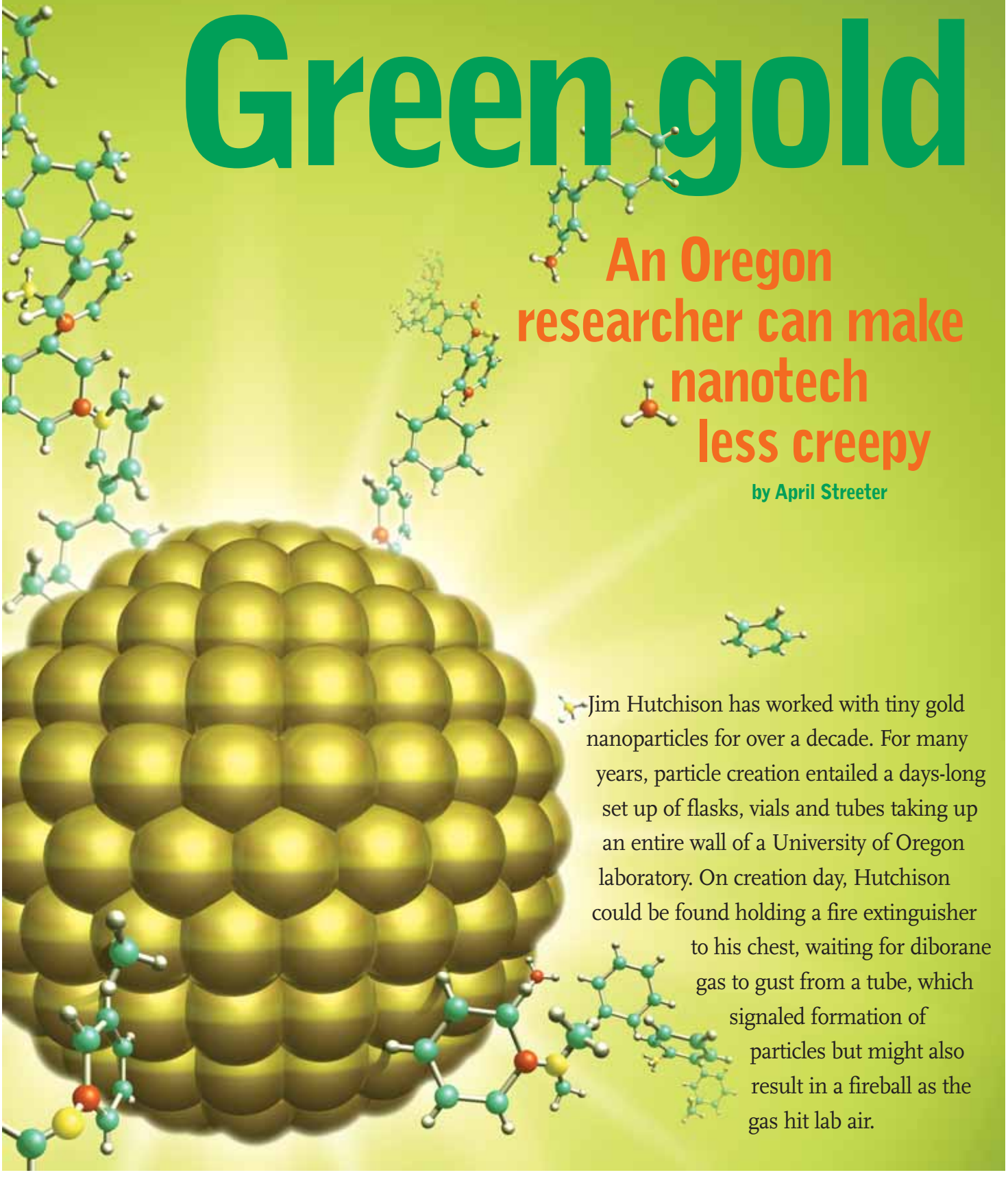
Green gold

An Oregon researcher can make nanotech less creepy

by April Streeter



Jim Hutchison has worked with tiny gold nanoparticles for over a decade. For many years, particle creation entailed a days-long set up of flasks, vials and tubes taking up an entire wall of a University of Oregon laboratory. On creation day, Hutchison could be found holding a fire extinguisher to his chest, waiting for diborane gas to gust from a tube, which signaled formation of particles but might also result in a fireball as the gas hit lab air.

Through a stroke of scientific serendipity, Hutchison and researchers at the University of Oregon recently received a patent for a novel way to make gold nanoparticles using only a test tube and less-toxic reactant chemicals.

Hutchison's particles are some of the raw building blocks of the emerging field of nanoscience. The new process is also an example of what Hutchison calls "green" nanoscience. A melding of nanotechnology and green chemistry, the new discipline is where fast-paced nanoscience should be headed, Hutchison said, especially if scientists want to stave off the consumer fears that have dogged facets of biotechnology.

"I view green chemistry as a way to help nanotechnology responsibly develop," Hutchison said. "The best time to introduce green chemistry is always at the beginning."

Gold rush

Nanotechnology has the potential to generate new materials and products that add up to a trillion-dollar market in the next decade, according to the National Science Foundation. Scientists are jazzed about the tiny structures called nanoparticles, nanotubes and nanowires because novel features they exhibit allow for the redesign (at molecular levels) of everything from sweat socks to drug delivery systems.

Among other experiments, Hutchison is using his particles, which measure in at just 1.5 nanometers (a nanometer is one billionth of a meter), to try and build tiny transistors.

It is nanostructures' unique reactivity at miniscule sizes that make them useful. Researchers from Oregon Health Sciences University and Pacific Northwest National Laboratories (PNNL) have worked with iron nanoparticles that can neutralize persistent pollutants in hard-to-reach natural environments, for example.

And alternative energy enthusiasts are charged about the possibility for nano-sized cells to make solar power incredibly efficient.

The potential for nanostructures to be the miniature Lego blocks of a whole new era of chip-making and electronic device design has caused a burst of research dollars and focus.

Instead of chiseling away at chunks of silicon with lithography, nanoscience opens up a potentially more effective way to create a chip by simply grouping together the right particles to create a transistor.

Scientists like Hutchison must find a way to get the Legos to bind together predictably in a process called self-assembly. Once they do, possible pay-offs include smaller, more materials-effective, energy-efficient transistors and faster data transmission across computer networks.

Through equipment and lab space donations, Hewlett Packard (NYSE: HPQ) is a major supporter of the research pursued by UO, Oregon State University, PNNL and other regional schools working with the Oregon Nanoscience and Microtechnology Institute (ONAMI). HP has said nanotechnology is one way to surmount the wall chipmakers are beginning to hit trying to get more transistors onto ever-smaller pieces of silicon to increase performance.

"It shouldn't be a surprise that we're preparing for the commercialization of these technologies,"

Brian J. Back

"We all really want the highest performance of materials and the lowest detrimental effects."

—Jim Hutchison, University of Oregon

said Jim Stasiak, an HP scientist in Corvallis, Ore. "We're interested in exploiting unique properties at the nano scale in electronic devices. In order to achieve these goals clearly there's a lot of physics, chemistry, and engineering required. It's an emerging area that's not that well understood."

Particle self-assembly is more a concept than a reality at this juncture, and particle creation is still a small-scale affair, to name only two challenges. Each day, however, new reports emerge as scientists work feverishly to solve the problems and bring the technologies to fruition.

Angstrom angst

To the layperson, nanotechnology can be a slightly scary and incomprehensible technology where atoms and molecules demonstrate novel but sometimes sinister or even catastrophic effects.

Consider the buckyball, one of the first nanoparticles to get major notice. Composed of 60 carbon atoms arranged together in a sphere, buckyballs are amazingly strong and resilient. Researchers claim buckyballs hold great promise in materials, lubricants, and coatings.

Named for their resemblance to the geodesic domes created by architect R. Buckminster Fuller, buckyballs also hold promise for medicine delivery vehicles. The nanoparticles can also cause largemouth bass to suffer damage to the fat membranes in their brains. A study at Southern Methodist University showed brain cell damage to bass swimming around for a couple of days in buckyball-infused waters.

More recent studies at Rice University hypothesize that coating the buckyballs with certain molecules can modulate toxic potential. Other studies suggest the size and shape of the nanostructures greatly affect bioavailability, and thus potential to harm humans.

Hutchison said of the two approaches, designing appropriate sizes and shapes or finding less-harmful coatings for nanostructures, he favors the former. "Encapsulation is an end-of-pipe approach," he said.

Nanoscience entered popular culture through Michael Crichton's 2002 novel "Prey," in which tiny robots called nanobots run amok, creating an oozing grey goo that is the stuff of nightmares.

"'Prey' did a disservice to nanoscience by portraying it in a negative way," said Stasiak. "Clearly scientists in this area are aware that these materials are different and have potentially hazardous properties. If groups like the UO demonstrate safer protocols then clearly those are the types of processes we're most interested in."

Thus far, the attitude of most governments around the ethical and environmental dangers of nanotech has been to study now and regulate later, partly because of the intense competition and market interest in nanomaterials.

The United States currently leads the rest of the world in nanoresearch by spending the most and reaping both more published scientific papers and the highest number of patents granted — about 1,000 in 2003. Other countries — Korea, India and the United Kingdom — are rushing to catch up.

Some simple nanomaterials are already a reality. Metal oxide nanoparticles, for instance, are showing up in sunscreens, and carbon nanotubes are showing up on car exteriors.

Green chemistry's ground rules

Prevention

Atom economy

Less hazardous

Designing safer chemicals, solvents, auxiliaries

Design for energy efficiency

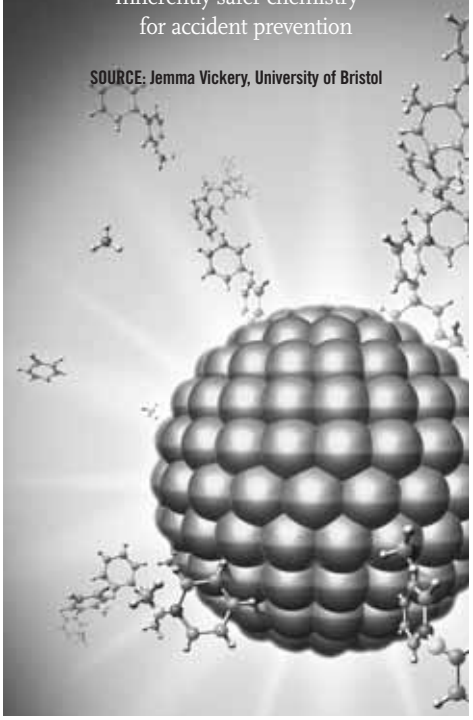
Use of renewable feedstocks

Design for degradation

Real-time analysis for pollution prevention

Inherently safer chemistry for accident prevention

SOURCE: Jemma Vickery, University of Bristol



Allowing nanoparticles into the environment is ludicrous given how little researchers know about their harmful effects, according to the Ottawa, Canada-based think tank ETC Group. The group called for a moratorium on research in 2002.

"It's nonsensical to put these products on people's bodies," said Pat Mooney, executive director of the group.

Mooney said ETC knew its quest for a global moratorium was likely impossible. But the group hoped media exposure would lead to widespread realization that ethical guidelines and best practice procedures for nanoscience research are needed.

Mooney said global standards would protect both scientific lab workers, who have a much lower life expectancy than other scientists, and consumers, who currently have no idea where nanoparticles may be lurking.

"Health and environmental concerns are generally put in the second tier," Mooney said. "The moratorium was a way to get people's attention, and because morally it was the honorable thing to do."

ETC was heartened by last summer's report from Britain's Royal Society that Mooney said recommended releasing nanostructures into the environment "be avoided as much as possible." The report stopped short of saying the hundreds of products ready for market be recalled.

Chemistry to the rescue

Barbara Karn of the U.S. Environmental Protection Agency's (EPA) Technology for a Sustainable Environment Program said one of the goals of her work is to make Jim Hutchison's ideas about green nanotechnology more widely known.

"Everybody wants to find out if nanoparticles can cause harm, and everyone wants to prevent any harmful nanomaterials from getting out," Karn said. "But there's very little that's being done. The whole issue is undercovered — both making nanomaterials 'greenly' and using nanomaterials to 'green-up' the environment. Jim is one of the few who actually gets it."

Green chemistry's inherent principles and goals [see list this page] are already fairly well known. EPA has given a decade's worth of Presidential Green Chemistry Challenge Awards. Dow Chemical (NYSE: DOW), for example, received an award in 2002 for its corn-based polylactic acid plastic known as NatureWorks.

Last year, Bristol Myers Squibb (NYSE: BMY) received the award for a new way to derive a compound for its Taxol anti-cancer drug from the roots and leaves of a European yew tree. The method eliminated the need to kill trees and also reduced the number of steps and hazardous chemicals used to synthesize the compounds.

Hutchison said he wants these examples of organic chemistry to be linked with the ongoing research in nanoscience.

"What green chemistry strives to do is to consider the hazards of the materials that you make and the efficiency of the process in the design phase," Hutchison said. "This is the time ... because societal concerns over the potential negative impacts of nano are causing scientists to take a closer look at how to develop the technology responsibly."

What neither Hutchison nor anyone else seems to know, however, is how to get companies to latch onto green chemistry's ideas as industries pour money into nanotech research and development. Hutchison said he's trying to dispel the myth that green chemistry might be more expensive than traditional approaches.

"In many cases it may still be perceived that a green chemical approach costs more," he said. "The Presidential Green Chemistry Challenge has shown it's commercially viable."

Pharmaceutical companies, he added, have been the first to discover that in drug-making, there is ongoing pressure as a product commercializes to find cheaper ways to produce larger quantities of a compound. The earlier green chemistry is incorporated, the earlier the potential pay dirt of simpler, more cost-effective and possibly less-toxic procedures occurs.

One problem unique to the electronics industry, according to Hutchison, is that a mature company which has already spent billions to construct a semiconductor fabrication plant won't want to go back and retrofit for a green nanotech approach unless there are significant cost savings and competitive advantages. This may mean smaller companies are uniquely positioned when green nanomanufacturing emerges.

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"Lots of green processes have not been commercialized because of the capital costs of changing the plants," he said. "Since there aren't any nanomanufacturing plants yet, that barrier is missing right now."

Ultimately, it is the partnerships fostered by ONAMI that scientists such as Hutchison and Stasiak trust will produce the success stories to foster green nanoscience.

"It's pretty much a wait and see," Stasiak said. "If there are demonstrated routes by Hutch[ison] or anyone else, those are the ones we are most interested in."

Hutchison added while there's no guarantee green nanotechnology will gain mainstream acceptance, it does have a fighting chance.

"We all really want the highest performance of materials and the lowest detrimental effects," he said.

For Hutchison, green chemistry is a naturally more elegant and more efficient approach to nanomaterials design. It's also allowed him to retire the fire extinguisher. ●