Construction Under the Microscope

Nanotechnology makes construction materials work harder

By Peter Kenter

Nanotechnology is the art of manipulating matter larger than one nanometer to achieve worthwhile results without resorting to simple chemistry. At least that's the definition used by Dr. Jon Makar, an officer at the Institute for Research in Construction, a group formed under Canada's National Research Council to make construction materials work harder.

"Chemistry happens at the atomic level, so this is all of the stuff that happens at the next step up from atoms," says Makar. "What we're discovering is that one atom behaves differently from 200 atoms or one million atoms."

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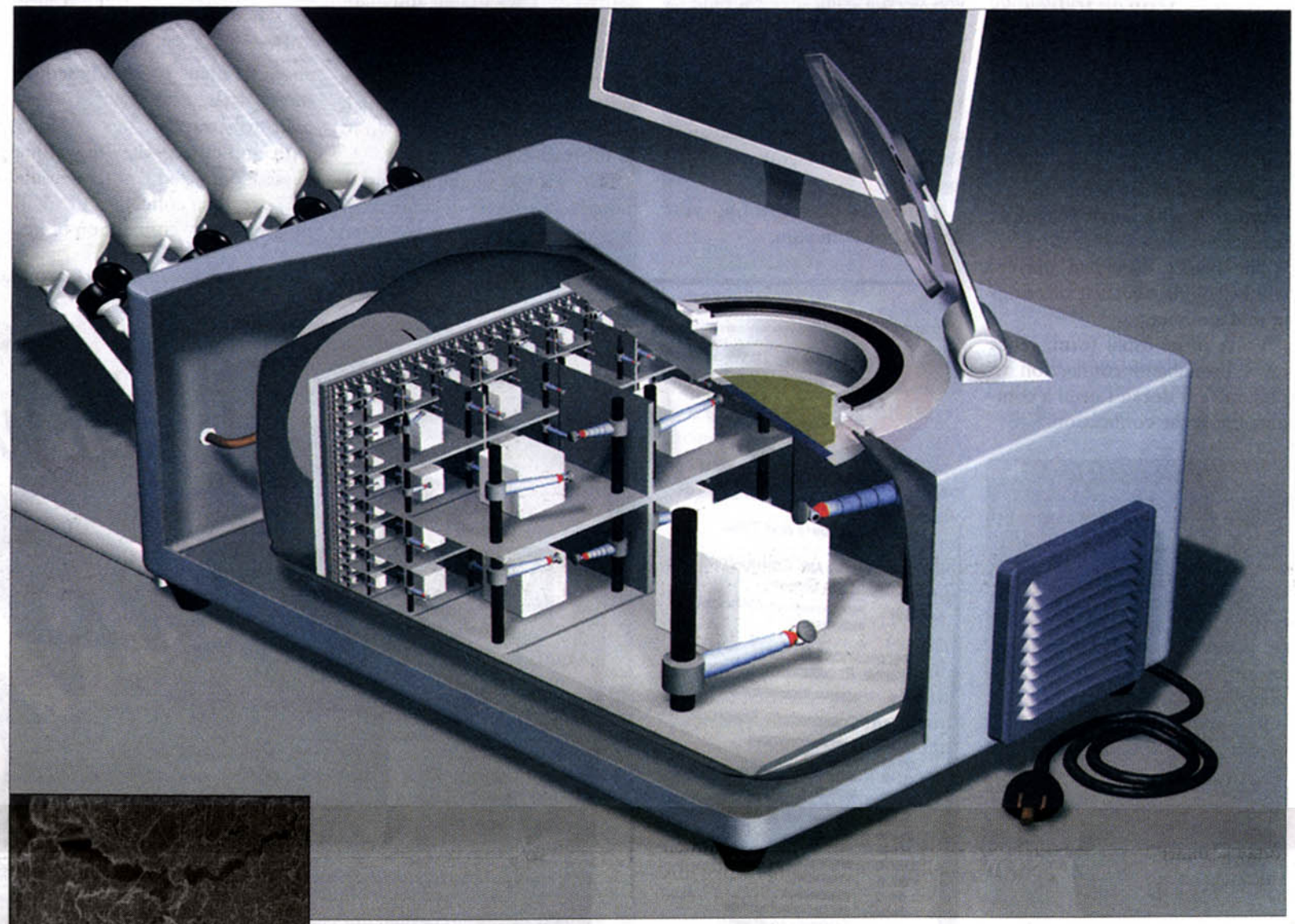


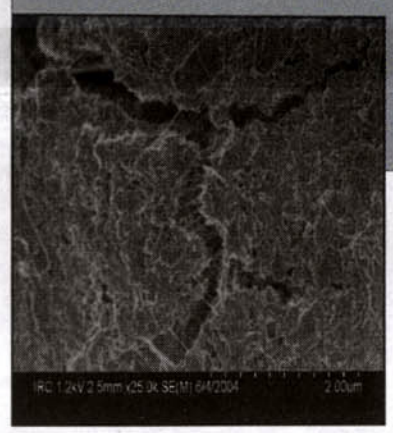
A proposed desktop-scale molecular manufacturing appliance. Tiny machines join molecules, then larger and larger parts, in a convergent assembly process that makes products using a billion nanoprocessors. The manufactured materials are represented as white cubes.
Image by John Burch, courtesy of Foresight Institute.

The construction industry already exploits nanotech in products that have become commonplace, in the use of titanium-dioxide as a self-cleaning surface coating on tiles, and lighting fixtures for example. So what else is new?

"Kitchen counters impregnated with silver nanoparticles for anti-bacterial effect," says Makar. "Anti-graffiti paint developed in Mexico that resists oil and spray paint, and a U.S. steel product that provides the corrosion resistance of stainless steel at a lower cost."

But that's just the beginning, says Makar. Increasingly accurate computer modelling techniques combined with the ability to manipulate smaller particles more effectively means that theoretical applications are translating to usable products at record speed.

"What we'll see fairly quickly is LED lighting systems for common building applications and traffic signals. They use one-tenth the energy of current lighting systems and you won't be stuck with the standard light bulb shape — the light will be made up of tiny components shaped to any design, even spread out over a surface." Makar and his team are currently working to improve the properties of concrete. "When you mix cement, the admixtures have already been released and chemical reactions begin before it leaves the plant. We want to delay those chemical reactions for a half-hour or an hour so the material will arrive at the construction site in better shape, using less chemical additive."



Carbon nanotubes are used to reinforce hydrated cement.
Image courtesy of National Research Council of Canada.

Makar's group is also working on the world's smallest rebar — the carbon nanotube. "Concrete is strong in compression, but weak in tension," says Makar. "Carbon nanotubes a few nanometers across help to provide tensile strength, intercepting cracks and providing stronger reinforcement." The upshot? Stronger bridges using less material for one.

Some of Makar's predictions for the next decade include nanosensors built right into construction materials. "As the cost of sensors comes down and the ability to handle data improves, we'll see sensors in bridges, water mains and building structures." By monitoring and dealing with structural problems as they occur, structures will last considerably longer.

Makar also envisions cost-effective solar panels, the development of superior insulating materials and paints that improve indoor air quality using nanoparticle additives that break down pollutants.

Wood products could also benefit from nanotechnology, says Dr. Theodore Wegner, assistant director of the USDA Forest Service's Forest Products Laboratory. Working with the tree's own DNA, 'intelligent wood' would incorporate nanosensors to measure loads and temperature, or to detect fungus or termites. "Wood-and-plastic composites use wood flour as an ingredient because only smaller particles of wood will bond to plastic. We could take advantage of the strength of wood fibre by altering its structure to attach to plastic matrices."

What other nanotech developments might we see within a lifetime?

"Desktop nanofactories," says Mike Treder, executive director of the Center for Responsible Nanotechnology in New York. "We'll likely see nanofactories ranging from hand-held to the size of a garage, capable of producing construction materials 100 times as strong as steel, but only one-tenth the weight, using simple raw materials like carbon or graphite."

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— Christine Peterson, founder and vice president of Public Policy of Foresight Institute

Nanofactories will start out being very expensive, says Christine Peterson, founder and vice president of Public Policy of Foresight Institute, a nanotech public interest group in Palo Alto, CA. "Over time, people will learn to do things more cheaply, creating atomically precise materials at a fraction of the cost — the machinery itself will sort out the molecules it needs for construction and discard what it doesn't need." Eventually, building specifiers and architects could create their own construction materials on-site.

Peterson predicts building materials will alter themselves on command, starting with surfaces that change colour according to lighting conditions or personal preference. "We could develop materials that change their shape and properties as quickly as we move our muscles. Let's say I'm looking at a wall and I think I'd like a shelf there. I press a button and say 'I want a shelf in the middle of the wall'--and the shelf protrudes from the wall. We'll likely see buildings where the walls themselves are going to move according to our instructions."

Another important component of the nano-revolution will be design, says Treder. "There's going to be a real demand for good design. Just because you can make materials that can go from opaque to transparent doesn't mean you will use them well. Very little work has been done on software like advanced CAD programs that can specify where individual molecules should be placed. The new materials will require smart designers and programmers."◆