Nanotech: Bigger Isn't Better

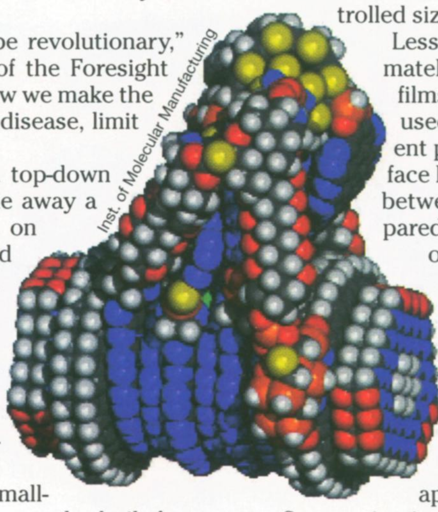
By CORINNA WU

Over the years, scientists haven't settled for merely observing worlds existing on grains of sand, they've also created them.

Once, all motors, engines, or pumps were noisy iron masses that could only be moved with great difficulty. Now, some are delicate wisps that can only be seen under an electron microscope. When researchers at AT&T Bell Laboratories carved early microdevices out of silicon in 1987, they moved one step closer to realizing people's dreams of using tiny robots to perform a multitude of tasks.

In fact, "microscopic" no longer accurately describes the objects that scientists are now creating. Only the word "nanoscopic" will do. For example, carbon nanotubes, first created in 1991, have been tapped as potential super-thin wires, miniature test tubes, and tiny sensors. Some scientists hope to construct working machine parts so small they contain only a few thousand atoms.

"We believe that nanotechnology will be revolutionary," says Chris Peterson, executive director of the Foresight Institute in Palo Alto, Calif. "It will affect how we make the physical objects around us, how we cure disease, limit pollution."



Inst. of Molecular Manufacturing

So far, scientists have usually taken a top-down approach to nanotechnology. They whittle away a chunk of material, leaving small features on the surface. This technique has worked marvelously well, says Peterson. After all, "the whole computer industry is based on this." The tiny wires and electronic circuits on computer chips are etched into slices of silicon. Miniature motors and engines carved with top-down methods, however, have yet to find practical applications.

To break through to the next level of smallness, a new generation of devices will have to be built from the bottom up.

By using atoms, molecules, or nanometer-size aggregates as building blocks, scientists hope to exercise the ultimate control over the devices they construct. Materials made in this way could possess unusual properties, an approach that has "exciting potential," says Ronald Breslow, past president of the American Chemical Society. New nanocomposites, in which nanometer-size particles of one component are mixed into another material, can be vast improvements over their conventionally made counterparts.

One strategy for bottom-up construction is known as self-assembly, a process by which components come together without human intervention to form an ordered, functioning system. Nature abounds with self-assembled objects. The water molecules in a raindrop automatically aggregate to form a smooth, curved surface. A cell is more complex, but it, too, contains all the information it needs to assemble itself. The key challenge for scientists in coming decades will be to cause self-assembly to take place "rationally and by design," says George M. Whitesides, a chemist at Harvard University. Then, the right initial components, carefully chosen, will put themselves together while the humans sit back and relax.

So far, biologists and biochemists have done much of the work in describing self-assembly, says Whitesides. Long chains of amino acids twist and turn back onto themselves to form three-dimensional proteins. Over the years, scientists have deduced the structures of many such proteins, trying to connect their functions to their shapes. Biochemists have also observed how biological membranes self-assemble from their lipid components.

Even common industrial materials can be said to perform a kind of self-assembly. In steel, for example, heating and cooling causes atoms to move around and clump together, which changes the metal's strength and flexibility. Zeolites, inorganic particles used as filters and industrial catalysts, structure themselves around templates that give them pores of a controlled size.

Lessons learned from existing systems could ultimately be applied in developing new ones. Thin films that assemble like a membrane could be used for lubrication. Long molecules with different properties on either end can line up on a surface like the bristles of a brush, easing the friction between one machine part and another. Compared to materials in use today, self-assembled ones could be more robust, perhaps even able to fix their own defects, Whitesides says.

What makes self-assembly an attractive strategy for constructing nanodevices is that in a test tube, billions of interactions take place at the same time. Miniature devices could assemble themselves quickly and in large quantities, but that approach might entail some loss of control.

Some scientists don't want to relinquish that control; they prefer to be part of the assembly line. The microscopes that now enable them to see nanometer-scale objects offer this opportunity. The tiny probe of a scanning tunneling microscope flies above the surface of an object, sensing individual atoms. The same probes can give scientists a "hand" to push the atoms around.

One futuristic application of nanotechnology might produce tiny surgical robots to repair the body from the inside, improving on its natural healing machinery. These tiny medical teams could even "do a search-and-destroy on a virus," Peterson proposes.

Currently, the sweetest fruits of nanotechnology still live in the world of dreams, but scientists are not slumbering. Soon, they will move their human-made nanoworlds out from under the microscope to invigorate the macroscopic world. Then, nanotechnology's benefits—and pitfalls—will be visible to the naked eye. □

1930 Freon and polyvinyl chloride invented

1930 Superfluidity in liquid helium discovered

1930 Amateur astronomer discovers Pluto

1931 Kurt Gödel's proof of incompleteness of arithmetic

1932 Discovery of neutron

1934 Hormones found to regulate insect molting and metamorphosis

1934 Mitochondria isolated

1935 Nylon, first synthetic fiber, invented

1935 Earthquake strength scale developed

1936 Invention of radiometric dating method

1937 Turing machine developed as model of computation