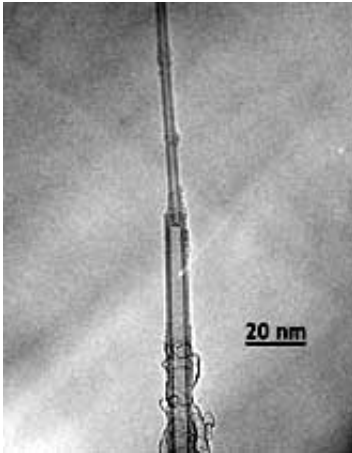


The Tinkertoys of Nanotechnology

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Alex Zettl is an expert builder with the tinkertoys of nanotechnology, carbon nanotubes. By altering the properties and formation of these rolled-up crystalline sheets of atoms, the UC Berkeley physicist has forged some of the world's smallest bearings, switches, diodes, and sensors.

"The most exciting thing is that a lot of structures we are now making in the laboratory and studying are very relevant to everyday life, from being used as structural materials, to electronic materials, to chemical sensing," says Zettl, who is also a researcher in the Materials Science Division of Lawrence Berkeley National Laboratory (LBNL). "In almost any technological application you want to think of, nanotubes probably will have an impact."

Discovered by a Japanese scientist in 1991, nanotubes form naturally during the vaporization of carbon rods. Resembling a roll of chicken wire fused at the seam, the tubes of carbon atoms are less than two nanometers in diameter and can be stretched to lengths of several thousand nanometers. The real magic is in the properties: they're excellent conductors of heat and electricity and are about ten times stronger than steel at one-sixth the weight.

One of the biggest potential payoff for nanotubes will likely be in the arena of molecular electronics. Scientists predict that within ten years, silicon scaling will hit its physical limits. In the post-silicon age, carbon nanotubes may help realize the science fiction dream of supercomputers the size of sugarcubes.

Research toward this distant goal is still in its infancy, but Zettl and his colleagues have made significant strides. Previous work at LBNL showed that depending upon geometry or diameter, single-walled carbon nanotubes can either be metallic or semiconducting, key properties when constructing electronic components. By precisely depositing tubes with dissimilar properties in a crossed formation, Zettl and his collaborators built a nanoscale transistor, the basic building block of computer circuits.

Rather than building nanoscale circuits one component at a time, Zettl hopes someday to build a "tube cube" randomly packed with billions of nanotubes that form a jumbled network of electronic components. The cube, he says, could potentially configure itself to perform desired tasks.

In the nearer term, Zettl's nanotubes will help advance the functionalities of micro-electromechanical systems (MEMS), tiny devices mass-produced in a process similar to the way integrated circuits are fabricated. One major engineering challenge faced by MEMS researchers is the frictional wear that occurs when their tiny contraptions

— pistons and bearings, for example — actuate thousands of times each second. To solve the problem, Zettl devised a system of telescoping nanotubes that slide in and out like a car antenna. Because all of the bonds of the carbon molecules that make up a nanotube are satisfied, there is literally no friction when the shaft moves within its sleeve.

In addition to functioning as a piston or bearing, Zettl has shown that nested nanotubes could also act as electromechanical switches. When an inner tube is extended, he explains, it could bridge the gap between two metals to close a circuit. When triggered though, the telescoped tube could snap back into its sheath in less than ten billionths of a second, almost instantly breaking the circuit.

Last year, Zettl and UC Berkeley collaborator Marvin Cohen founded Nanomix (formerly Covalent Materials), a company dedicated to commercializing nanotube technology. The firm's first product will likely be nanotube-based sensors for biochemical diagnostics, medical monitoring, and the detection of toxic gas leaks and other chemical and environmental hazards. A nanotube's conductivity, Zettl explains, changes when a specific particle binds to it, not unlike barnacles glomming on to the hull of a ship. By measuring the variance in conductivity, the device will be able to identify a specific particle in the sample. According to Zettl, an array of nanotubes integrated onto tiny Smart Dust sensors could enable the detection of trace levels of many molecules much more cheaply and efficiently than current technologies like mass spectroscopy.

"With nanotubes, we're not seeing the beginning of something that might lead to something 25 years down the road," Zettl says. "These are things that are crying out to be exploited in the near future. Nanotubes are on a venture-capital timescale."

Please find the original release by David Pescovitz on [U.C. Berkeley](#)

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