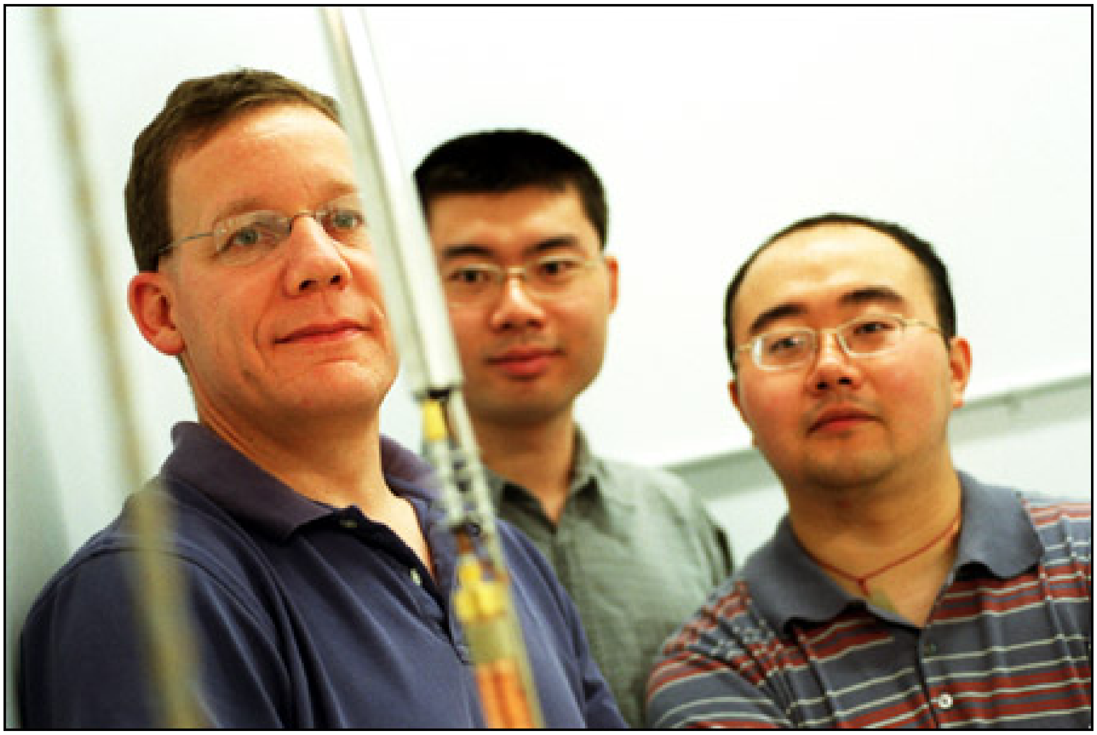
Harvard University Gazette



Charles Lieber (left) and graduate students Jie Xiang and Yue Wu have developed a technique to make wires and switches only tens of atoms in size. The process could affect all the electronic circuits in the world. (Staff photo Rose Lincoln/Harvard News Office)

HARVARD GAZETTE ARCHIVES

A giant step toward miniaturization

Nanotechnology makes the right connections

By William J. Cromie
Harvard News Office

Dabs of metal too small to be seen could start the next revolution in electronics.

The smaller the wires and switches on those silicon chips that run everything from talking teddy bears to supercomputers, the more efficient and less expensive these things become. Since the 1960s the number of switches and other elements on a fingernail-size chip has doubled every 18 months from dozens to tens of millions. But there's got to be a limit.

Two-week listing of upcoming events

The new field of nanotechnology can now produce wires with diameters a scant few hundreds of millionths of an inch in diameter, a hundred or so atoms across. You can't even see wires that small; you need a sophisticated electron microscope.

What keeps such state-of-the-art wires out of laptops and cell phones is contacts. Contact points on the switches and other circuit parts are chunks of metal hundreds of times bigger than nanowires that could connect them together. In a basement laboratory at Harvard University, Charles Lieber and his students have solved this problem. They have taken the first step toward making chips with billions instead of millions of components, nanoelectronics instead of microelectronics.

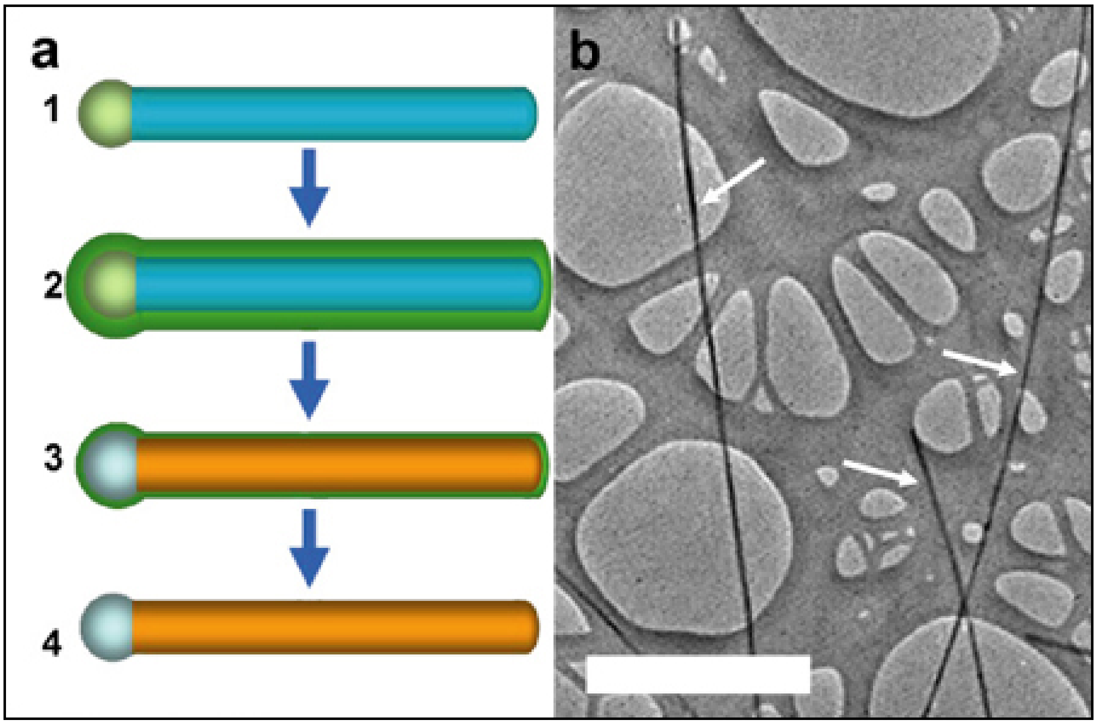


Figure 1. Silicon nanowires (blue at left) are coated with nickel, then heated to form a bond (3). The wires are then etched chemically to remove excess nickel. Images (right) taken through an electron microscope show three nanowires (arrows) with a diameter of about 20 nanometers, or 200 atoms, across.

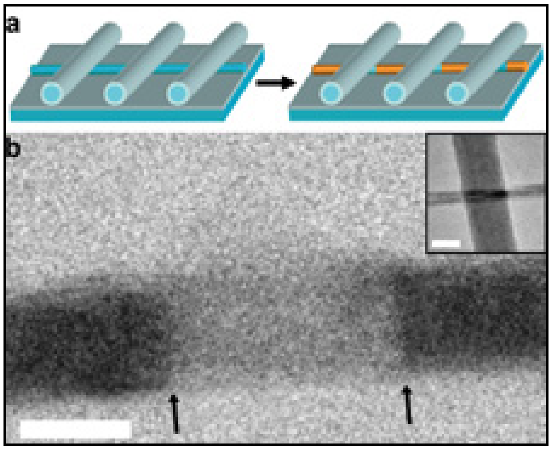
"Nano" refers to nanometers, one billionth of a meter, four hundred millionths of an inch, hundreds of thousands of times thinner than a hair, about 10 small atoms in width. Using chemical processes developed at Harvard's Department of Chemistry and Chemical Biology and Division of Engineering and Applied Sciences, Lieber and his team have made wires as thin as 3 nanometers, tens of atoms thin. What is more, the nanotechnologists have built switches right into the wires, solving the tedious problem of connecting the switches, amplifiers, and other devices that, in today's integrated circuits, are so much bigger than the nanowires.

Such integrated circuits could have applications well beyond faster, smaller computers and cell phones with features only fantasized about today. For example, nanocircuits might make possible sensors that can detect a single virus in your blood.

"It could turn manufacturing of high-end technology upside down," says Lieber, Mark Hyman Jr.

Professor of Chemistry. "It could affect all electronic circuits in the world. And that's really cool."

Beyond thinkable



A silicon nanowire (blue) is crossed by three nanowires of a different composition (top). The dark regions in this electron microscope image (bottom) are composed of one nickel-silicon composition and the light ones of another. The intersection of the two wires (insert) serves as a gate or switch to turn electric currents off or on.

This is the first time that bridging two different types of materials has been done at the nanometer level. The implications for more efficient electronics and sensing devices are obvious. Lieber is already working with Intel Corp., the world's largest producer of electronic chips. But both of them recognize that a great deal more work must be done before the new technique can get from the basement of a building on the Harvard campus to the floor of a factory manufacturing chips to power the next electronic revolution.

Lieber, however, is already looking beyond the products that others are thinking about. "What motivates us most is a fundamental understanding of interactions that occur at the nanometer level between metals and nanostructures made from semiconductors like silicon," he says. Semiconductors can, under different conditions, conduct or block electric current, making them ideal switches. But does the behavior of electric currents change when metal junctions shrink to atomic levels? "That's what we need to understand in order to develop entirely new technologies, technologies we cannot even predict today."

Present methods of circuit making involve the etching of semiconductors and metals with energetic beams of X-rays or electrons. As switching devices like transistors get smaller and smaller, their behavior starts to worsen. Edges get rougher, less well defined, and electric currents are slowed as they try to move through different circuit components. Lieber's team uses chemical assembly, evaporating metal coatings on top of silicon nanowires, and then knocking off excess metal with chemical etching. Lieber describes wires and transistors made this way as "essentially perfect. They show enhanced behavior at these vanishingly small scales."

At the outset, it was not obvious that such a thing would work. One of Lieber's colleagues argued strenuously against trying it. The different materials would combine in a way that produced wires containing too many defects to be useful. That would be true with normal-size elements, but at nanoscales, things came together smoothly. "A beautiful transformation," Lieber calls it. "There are no defects between the different materials that would disrupt electric currents."

Contrary to what you might think, atomically thin nanowires can carry currents a hundred times greater than those thin copper wires we are all so familiar with. Best of all, Lieber doesn't think nanowires and transistors made his way will be any more expensive than microdevices used today.

Technical details about how to make these wires and nanodevices were published by Lieber, graduate students Yue Wu and Jie Xiang, and their colleagues in the July 1 issue of the journal Nature.

In an interview, Lieber estimated that manufacturers like Intel will hit a limit of how many elements they can pack on a silicon chip in 2010. Some other way to avoid that roadblock may be found by then. But if not, nanocircuits may debut in the electronic gadgets you use, or the sensors doctors use on you, by 2010.