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The Smallest Computing Systems Yet

Nanowire transistors could run inside microscopic biosensors or environmental sensors.
By Kate Greene

A team led by Charles Lieber, a professor of chemistry at Harvard, and Shamik Das, lead engineer in MITRE's nanosystems group, has designed and built a reprogrammable circuit out of nanowire transistors. Several tiles wired together would make the first scalable nanowire computer, says Lieber. Such a device could run inside microscopic, implantable biosensors, and ultra-low-power environmental or structural sensors, say the researchers.

For more than a decade, nanowires and nanotubes have promised to shrink computing to scales impossible to achieve with traditional semiconductor materials. But there have been doubts about the practicality of nanowires and nanotubes as actual computing systems. "There had been little progress in terms of increasing the complexity of circuits," says Lieber.

One big problem has been reproducing structures made from nanowires and nanotubes reliably. Each structure needs to be virtually identical to ensure that a circuit operates as intended. But now, says Lieber, some of those problems are being solved. His group, in particular, has developed ways to produce identical nanowires in bulk. Because of this, he and colleagues at MITRE have been able to design a nanowire circuit architecture that has the potential to scale up. The details are published in the current issue of *Nature*.

Traditional chips are made using a so-called top-down approach in which a design is essentially exposed like a photograph onto a semiconductor wafer, and excess material is etched away. In contrast, a bottom-up approach is used to make the nanowire circuits. This means they can be deposited on various types of surfaces, and can be made more compact. "You want [sensor] systems that are physically small," says James Klemic, nanotechnology laboratory director at MITRE. "Right now, your only option is to use a chip that dwarfs the sensor."

To make the new nanowire circuit, researchers deposited lines of nanowires, made of a germanium core and silicon shell, on a substrate and crossed them with lines of metal electrodes to create a grid. The points where the nanowires and electrodes intersect act as a transistor that can be turned on and off independently. The researchers made a single tile, with an area of 960 square microns containing 496 functional transistors. It is designed to wire to other tiles so that the transistors, in aggregate, could act as complex logic gates for processing or memory.

The nanowire transistors maintain their state-on or off—regardless of whether the power is on. This gives it an instant-on capability, important for low-power sensors that might need to collect data only sporadically and also need to conserve power.

According to Das, the circuits could also be 10 times more power-efficient than circuits made of traditional materials. One reason is the nanowire's electrical properties, which don't allow electric current to leak, unlike traditional transistors. Another reason is that the circuit design uses capacitive connections instead of resistive ones, which are less efficient. "We don't burn a lot of power driving resistors," says Das.

"This is a significant milestone on several fronts," says André DeHon, professor of electrical and system engineering at the University of Pennsylvania. Reprogrammable transistors made of nanowires are "the building block I was hoping for," he says.

The researchers' work represents "a leap forward in complexity and function of circuits built from the bottom up," says Zhong Lin Wang, professor of materials science and engineering at Georgia Institute of Technology. It shows that the bottom-up method for manufacturing "can yield nanoprocessors and other integrated systems of the future," he says.

More work needs to be done to make nanowire processors practical for use in electronics systems, Lieber says. His group needs to demonstrate thousands of transistors on a tile—many times more than the current 496 transistors his group has so far achieved. In addition, they need to scale up to multiple tiles. The researchers are in the process of finding the best way to link a 16-tile system together. Lieber says that, realistically, manufacturing these circuits is still several years down the road.