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Nanowire Transistors Faster than Silicon

Advances in nanowires show they can be fast enough to use as ultrasmall transistors in cheap, high-performance electronics.
By Kevin Bullis

Researchers at Harvard University have shown that nanowire transistors can be at least four times speedier than conventional silicon devices. The principal researcher, chemistry professor Charles Lieber, says this could lead to inexpensive, high-performance, flexible electronic circuitry for cell phones and displays. It could also save space and further increase speed, he says, by allowing memory, logic, and sensing layers to be assembled on the same chip.

Nanowires have been considered a promising contender for use on future logic chips because of their very small size (about 10 nanometers wide) and because they can be made without complicated lithography, says Peidong Yang, professor of chemistry at University California, Berkeley. Until now, though, the performance of nanowire-based transistors has lagged far behind that of other potential nano devices, such as carbon nanotubes, and even conventional devices. But the new Harvard research suggests that nanowires have surpassed conventional transistors and nearly caught up with nanotubes.

This may give nanowires an edge over carbon nanotubes (see "Carbon Nanotube Computers"). Nanowires are made with regular crystal structures and uniform electronic properties -- a level of predictability essential for manufacturing high-performance electronics. Nanotubes, however, come in batches of different sizes and structures, each of which can perform very differently -- so until a good sorting method can be found, it will be difficult to use nanotubes in high-end processors.

The first applications for nanowires will likely be ultra-sensitive sensors for single molecule detection (when molecules bind to the nanowires they create a detectable change in the current flowing through the wires). Such applications could be ready in two to three years, Lieber says (see "Drugstore Cancer Tests").

Nanowire transistors may never replace more conventional devices in computer chips used in laptops and personal computers -- the cost of developing large-scale manufacturing would probably not be justified by a 4 to 5 times improvement in performance, Lieber says. But, he adds, the new performance figures suggest it will be well worth scaling up the technology to manufacture them for applications where the ability to assemble nanowire transistors at room temperature on various surfaces, including plastic, will bring an added advantage. For instance, in flexible displays nanowire transistors could be used to embed information-processing in the screen itself.

The technology might also be useful for extremely compact devices, since it would be possible to layer memory, logic, and even sensing circuitry on top of each other, rather than side by side or on separate chips. The nanowires are applied to chips and connected to the source, drain, and gate using room-temperature processes, allowing consecutive layers to be applied without damaging previous layers. "If you can put ultra-high-performance materials into 3-D structures, through layer by layer assembly, it allows you to put a lot more stuff into an area," says Lieber. The proximity of the layers, a mere 100 nanometers apart, could also speed performance, he says.

One of the qualities that distinguishes this current work from earlier nanoscale electronics research, including his own, Lieber says, is that the measurements used are industry standards, which makes it possible to compare how nanowires would perform in real devices.

The key to the improved performance is a "core-shell" structure of the nanowires, which confines electrons, or their counterparts, electron holes, in a small space. That allows electrons to zip through the wires quickly, which is key to the speed improvements. In a recent paper in the journal *Nature*, Lieber made nanowires with a germanium center

surrounded by a thin coating of crystalline silicon. And in work described in Nano Letters, the researchers showed the versatility of nanowires by using gallium nitride, which could be useful for high-power, high-temperature applications.

"These two papers come up with very interesting ideas for using this core-shell structure to enhance the performance of these transistors and basically make them much more robust and reliable," says Berkeley's Yang. With nanowires, he says, "you get very small features and different compositions, and you also have access to all these nonconventional heterostructures, like these core-shell structures, that enable you to engineer the electronic structure. These are not things you can do easily with conventional technology."