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Practical Nanowire Devices

A way to align nanowires could lead to better sensors and flexible displays.

By Kevin Bullis

Researchers at Harvard University and the University of Hawaii have developed an easy way to align nanowires and carbon nanotubes over areas 100 times larger than is possible using existing methods. The researchers are also able to fabricate the nanowires on a number of different surfaces. The advance potentially paves the way to mass production of electronics devices based on these promising nanostructures.

The technique, based on high-volume manufacturing methods used to produce plastic bags, could make it practical to employ nanowires and carbon nanotubes for controlling pixels on large, flexible displays and for accurately detecting multiple chemicals, viruses, and biomarkers for diseases. (See "Drugstore Cancer Tests.") The results were published online this week in the journal *Nature Nanotechnology*.

Researchers had previously developed small-scale prototype devices based on nanowires and carbon nanotubes. But moving beyond prototypes to commercial products requires a fast and easy way to arrange the tiny structures over large areas, says Charles Lieber, professor of chemistry at Harvard. "The lack of large-scale alignment and organization strategies has forced researchers to make small chips in a one-by-one process," he says. "This is the antithesis of economical manufacturing." Whereas previous methods could arrange nanowires over areas of only about a square centimeter, Lieber's new technique works on areas of hundreds of square centimeters, and it could be used to produce many chips at once. Or it could be used to make large arrays of transistors needed to control pixels on displays.

The new technique involves blowing bubbles made of an epoxy polymer mixed with either nanowires or carbon nanotubes. The researchers pour the mixture onto a circular surface equipped with a small hole; the polymer-nanowire mixture forms a membrane over the surface. The researchers then force nitrogen gas through the hole, expanding the membrane until it forms a bubble about 25 centimeters wide and 50 centimeters tall. A metal ring stabilizes the bubble as it grows, with the polymer material stretching to become a 200-to-500-nanometer-thick film containing evenly spaced nanowires or carbon nanotubes lined up and facing in approximately the same direction. The researchers speculate that sheer forces caused by the growth of the bubble make the nanowires line up.

The resulting film can be transferred to a number of surfaces, including silicon and flexible plastic. To do this, the researchers position silicon wafers or other materials so that when the bubble inflates, the surface of the bubble presses against them.

To demonstrate the usefulness of the technique, the researchers transferred the films to silicon wafers, then used conventional techniques to deposit electronic contacts on the films. The nanowires bridged the contacts, serving as semiconducting channels for working transistors.

Lieber says that early applications could include accurate home tests for illnesses such as cancer, influenza, and sexually transmitted diseases. In such a device, a protein biomarker for prostate cancer, for example, would connect to the nanowires, changing the wires' conductivity and registering the protein's presence. Nanowires provide three-orders-of-magnitude-greater sensitivity than current tests, Lieber says. And because the nanowires directly detect the proteins by generating an electronic signal, such tests would provide results right away, making it unnecessary for researchers to wait for results to come back from the lab. What's more, tests for multiple biomarkers can easily be combined on a chip. An array of hundreds of nanowires, each chemically modified to react with a specific protein, could be used to create a highly accurate cancer test.

The nanowires could also be used in flexible displays to turn pixels on and off. Conventional high-speed transistors require fabrication temperatures that would melt the plastic substrates used in flexible displays. But nanowires can provide the same performance without the need for high temperatures.

The researchers are now studying the process to find ways of packing the nanowires closer together, which could allow for applications beyond those for sensors and displays, such as for memory. Before the process can be used for manufacturing, though, it will need to be automated, possibly in ways similar to the blown-bubble techniques now used for high-volume production of plastic bags. Lieber says that the method could be used in nanodevice manufacturing within one to two years.
