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Researchers develop technique that could open doors to faster nanotech commercialization

An innovative method allows silicon nanowires and carbon nanotubes to grow directly on microstructures in a room temperature chamber

07/04/2003 - Engineers at the University of California, Berkeley, have found an innovative way to grow silicon nanowires and carbon nanotubes directly on microstructures in a room temperature chamber, opening doors to cheaper and faster commercialization of a myriad of nanotechnology-based devices.

The researchers were able to precisely localize the extreme heat necessary for nanowire and nanotube growth, protecting the sensitive microelectronics - which remained at room temperature - just a few micrometers away, or about one-tenth the diameter of a strand of human hair.

The new technique, described in the June 24 online issue of the journal Applied Physics Letters, bypasses the cumbersome middle steps in the manufacturing process of sensors that incorporate nanotubes and nanowires. An image of the technique will be featured on the cover of the journal's June 30 print issue.

Such devices would include early-stage disease detectors that could signal the presence of a toxic agent using an ultra-sensitive biochemical sensor triggered by mere molecules of a toxic agent.

"One very big problem right now is figuring out how to assemble these nanowires or nanotubes on a microchip in a way that is commercially feasible," said Liwei Lin, associate professor of mechanical engineering at UC Berkeley.

Lin tested the new technique for processing nano-based microelectromechanical systems (MEMS) with his graduate students Ongi Englander, lead author of the paper, and Dane Christensen, co-author of the paper.

Shown above are oblique and closeup views of silicon nanowire growth. The nanowires are 100 to 35 micrometers long and 100 micrometers long. (Courtesy Bob Prohaska and Orin Brattain)

The steps used in creating nanowires and nanotubes are essentially the same, though different temperatures may be used. "It's like a recipe," said Englander. "Different ingredients are used depending on whether you want to make a chocolate chip muffin or a banana nut muffin, but the steps are the same."

The UC Berkeley researchers, in this case, used a gold-palladium alloy with silane vapor to create silicon nanowires, and a nickel-iron alloy with acetylene vapor to create carbon nanotubes.

The typical nanowire or nanotube production process occurs in a furnace at temperatures of 1,112 to 1,832 degrees Fahrenheit. The procedure begins with a 1 square centimeter wafer that is coated thinly with a metal alloy. A vapor is then directed towards the substrate, and the alloy acts as a catalyst in a chemical reaction that eventually forms billions of nanowires or nanotubes.

The nanomaterials are harvested by being placed in a liquid solvent, such as ethanol, and by ultrasonic waves to loosen them from the wafer surface. Researchers must then sort through nanowires or nanotubes to find the few that meet the specifications they need for their sensors.

Correctly orienting a nanowire onto a 5 square millimeter microchip would be like sticking a pin in a football field with an accuracy of a few micrometers.

"If I had the right pair of tweezers, I could pick out the nanowire that I wanted and manipulate it, but tweezers don't exist," said Englander.

So instead of finding a way to produce nanomaterials separately and then connecting them to systems, the researchers decided to grow the silicon nanowires and carbon nanotubes directly on the microchip board.

The challenge was in protecting the sensitive microelectronics that would melt in the tremendous temperatures needed to create the nanomaterials.

Resistive heating provided the answer. "It's the same idea as the wires in a toaster," said Englander. "Electrical current flows through the wire to generate the heat."

The researchers passed the current through a wire to the specific locations on the microchip where they wanted the nanowires or nanotubes to grow. In one experiment, an area was heated to 700 degrees Celsius while another spot just a few micrometers away sat comfortably at 25 degrees Celsius. The chip was placed in a vacuum chamber for the tests.

"It's the immediate integration of the nanoscale with the microscale," said Christensen, who has done carbon nanotube experiments.

The experiments yielded silicon nanowires from 30 to 80 nanometers in diameter and up to 1 micrometer long, and carbon nanotubes that were 10 to 30 nanometers in diameter and up to 5 micrometers long.

"This is a very unique approach," said Lin. "This method allows the production of an entire nanoscale device in a process similar to creating computer chips. There would be no post-assembly required."

The researchers are continuing experiments to fine-tune the temperatures and length of heat to produce the desired lengths of nanowires and nanotubes.

The California State Nanotechnology Fellowship and the GAANN Fellowship helped support the research.



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