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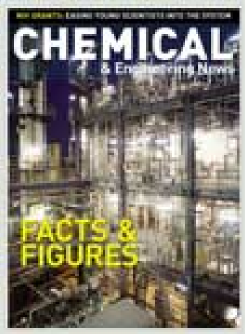

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MATERIAL SCIENCE

METALLIC CONTACTS TO THE NANOWORLD

Method fashions nanosized electrical leads on nanoscale semiconductors

MITCH JACOBY

Ever try connecting speakers to a stereo receiver using automobile jumper cables? Of course not. The mismatch in size makes the task clumsy. Yet researchers who study nanoscale electronics usually wire up the nanometer-sized circuit components—carbon nanotubes, for example—using electrical contacts that are enormous compared with the nanotubes. They accept the size disparity because no one has developed a viable way to avoid it. Until now, that is.

Courtesy of Christopher Navin

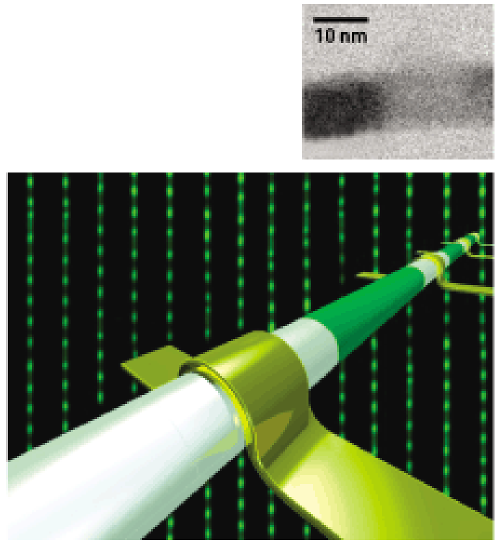
Scientists at Harvard University have devised a method for making electrical contacts to nanometer-sized semiconductor circuit elements using metallic wires of the same dimensions as the semiconductor. The technique may lead to new strategies for integrating nanoscale components in electronic circuits and new ways of studying electron transport on the nanometer scale.

Recently, researchers have made enormous progress in increasing the complexity of nanoscale electronic devices. Nanowires and carbon nanotubes, for example, have been fashioned into transistors, logic devices, and basic computing circuits. The work has been driven principally by a desire to further miniaturize today's already small electronics. But as small as the nanotube and nanowire circuits may be, they could be smaller still—and many more of them could fit in a tiny space—if the metal pads that are generally used to wire up such circuits could be shrunk to the nanometer scale. The metal contacts, which are fabricated via lithographic methods, are often hundreds of times larger than the nanotubes or nanowires.

The Harvard research team has gotten around this problem by demonstrating a reproducible procedure for attaching metallic nanowires to semiconducting nanowires with fine spatial control. The group, which includes chemistry professor Charles M. Lieber and coworkers Yue Wu, Jie Xiang, Chen Yang, and Wei Lu, brings the nanosized entities together by selectively converting segments of a silicon nanowire (a semiconductor) to metallic nickel silicide [*Nature*, **430**, 61 (2004)].

Using that approach, the team prepared NiSi/Si field-effect transistors

and showed that the devices' electrical performance is controlled by the contact between the nanoscale regions of metal and semiconductor. Elsewhere in the circuit, however, larger leads are used to connect the device to the macroscopic world.



TWO-TONE A chemical procedure converts a silicon nanowire into alternating silicon (semiconducting) and NiSi (metallic) segments, as shown in an optical micrograph (background of schematic, where Si is bright green) and an electron micrograph (at top, dark regions are NiSi). Courtesy of C. M. Lieber

To make the nanostructures, the Harvard group prepares silicon nanowires using gold nanoclusters (as catalysts) and silane (SiH_4) in a chemical vapor deposition process. Then they coat the silicon wires with a photoresist material and pattern the wires using lithography. Next, a thin film of nickel is deposited on the patterned regions of the wire and reacted at about 500 °C to form alternating nanometer-sized segments of NiSi and Si. High-resolution electron microscopy studies show the NiSi/Si interface is atomically sharp. The procedure has been used to make wires measuring a few tens of nanometers in diameter and can be extended below the 10-nm scale without using conventional lithography, the researchers say. They also note that they have used a similar approach to convert germanium nanowires into metallic single-crystal NiGe nanowires.

Describing the work as "landmark progress," Zhong Lin Wang, director of the Center for Nanoscience & Nanotechnology at Georgia Institute of Technology, comments that the outstanding electrical performance of NiSi nanowires coupled with the new method for making arrays of metal-semiconductor heterojunctions "opens the possibility of fabricating multifunctional and complex nanoscale electronic and optoelectronic devices."

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