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First All-Nanowire Sensor

Researchers integrate nanowire sensors and electronics on a chip.

By Lauren Rugani

Researchers at the University of California, Berkeley, have created the first integrated circuit that uses nanowires as both sensors and electronic components. With a simple printing technique, the group was able to fabricate large arrays of uniform circuits, which could serve as image sensors. "Our goal is to develop all-nanowire sensors" that could be used in a variety of applications, says Ali Javey (http://nano.eecs.berkeley.edu/) , an electrical-engineering professor at UC Berkeley, who led the research.

Nanowires make good sensors (http://www.technologyreview.com/Nanotech/18127/) because their small dimensions enhance their sensitivity. Nanowire-based light sensors, for example, can detect just a few photons. But to be useful in practical devices, the sensors have to be integrated with electronics that can amplify and process such small signals. This has been a problem, because the materials used for sensing and electronics cannot easily be assembled on the same surface. What's more, a reliable way of aligning the tiny nanowires that could be practical on a large scale has been hard to come by.

A printing method developed by the Berkeley group could solve both problems. First, the researchers deposit a polymer on a silicon substrate and use lithography to etch out patterns where the optical sensing nanowires should be. They then print a single layer of cadmium selenide nanowires over the pattern; removing the polymer leaves only the nanowires in the desired location for the circuit. They repeat the process with the second type of nanowires, which have germanium cores and silicon shells and form the basis of the transistors. Finally, they deposit electrodes to complete the circuits.

The printed nanowires are first grown on separate substrates, which the researchers press onto and slide across the silicon. "This type of nanowire transfer is good for aligning the wires," says Deli Wang (http://nano3.ucsd.edu/) , a professor of electrical and computer engineering at the University of California, Santa Barbara, who was not involved in the research. Good alignment is necessary for the device to work properly,since the optical signal depends on the polarization of light, which in turn is dependent on the orientation of the nanowires. Similarly, transistors require a high degree of alignment to switch on and off well.

Another potential advantage of the printing method is that the nanowires could be printed not only onto silicon, but also onto paper or plastics, says Javey. He foresees such applications as "sensor tapes"--long roles of printed sensors used to test air quality or detect minute concentrations of chemicals. "Our next challenge is to develop a wireless component" that would relay the signals from the circuit to a central processing unit, he says.

But for now, the researchers have demonstrated the technique as a way to create an image sensor. They patterned the nanowires onto the substrate to make a 13-by-20 array of circuits, in which each circuit acts as a single pixel. The cadmium selenide nanowires convert incoming photons into electrons, and two different layers of germanium-silicon nanowire transistors amplify the resulting electrical signal by up to five orders of magnitude. "This demonstrates an outstanding application of nanowires in integrated electronics," says Zhong Lin Wang (http://www.nanoscience.gatech.edu/zlwang/) , director of the Center for Nanostructure Characterization at Georgia Tech.

After putting the device under a halogen light and measuring the output current from each circuit, the group found that about 80 percent of the circuits successfully registered the intensity of the light shining on them. Javey attributes the failure of the other 20 percent to such fabrication defects as shorted electrodes and misprints that resulted in poor nanowire alignment. He notes that all of these issues can be resolved with refined manufacturing methods.

The researchers also plan to work toward shrinking the circuit to improve resolution and sensitivity. Eventually, says Javey, they want everything on the circuit to be printable, including the electrodes and contacts, which could help further reduce costs.
