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Tuesday, February 05, 2008

Tuning In to Nanotube Radio

Researchers have made analog electronics out of carbon nanotubes.

By Duncan Graham-Rowe

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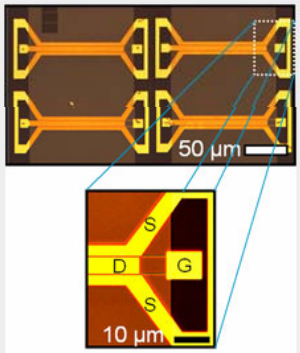

Transistor radio: A micrograph shows an array of four nanotube transistors.
Credit: John Rogers, UIUC

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- See a schematic and electromicrograph of the technology.
- Listen to a recording of the radio using the nano radio.

Carbon nanotubes have long been a contender for future electronic devices because of their potential to scale down the size of components and their excellent electronic properties. But building practical circuitry out of carbon nanotubes has proved challenging. Now researchers at the University of Illinois at Urbana-Champaign report having made scalable radio-frequency analog electronics in which all of the transistor-based devices, including the antennas and amplifiers, are built out of nanotube transistors.

The goal is to establish carbon nanotubes as a realistic competitor with conventional analog electronics, says John Rogers, a professor of materials science and engineering at the University of Illinois. Rogers found a novel way to make transistors using parallel arrays of nanotubes. (See "A Breakthrough in Nanotube Transistors.") By way of demonstration of the ability to use the method in electronics, he has made a radio receiver out of which each of the active components is created from nanotubes. To test the electronics, the researchers say that they tuned the nanotube radio to a commercial station in Baltimore to hear the traffic report.

"It's a very significant advance," says Peter Burke, head of the nanotechnology group at the University of California, Irvine. "They have been able to make the first radio-frequency amplifier out of nanotubes."

Indeed, other groups have already demonstrated the use of single nanotubes in radio circuits. (See "The World's Smallest Radio.") "What we have done is a bit different," says Rogers. The previous research has involved using a single carbon nanotube to act as a radio receiver. "In our

radios, every single active component is based on nanotubes, all the way up to the point where the headphones plug in," he says.

Employing single nanotubes in this way would not normally be feasible because of the relatively high currents used in analog circuits, such as amplifiers. To get around this, Rogers's nanotransistors consist of arrays of thousands of nanotubes in parallel, in such a way that they spread the current, while collectively behaving like a semiconductor material.

Rogers says that the fabrication method used to build the analog lends itself to current manufacturing processes. "With these arrays, we can build our devices, device arrays, and integrated circuits in wafer scale processing sequences that are fully compatible with established approaches to building semiconductor devices," says Rogers.

A crucial factor in making these transistors lies in Rogers's ability to grow the carbon nanotubes in such uniform arrays. But by growing the nanotubes on a single crystalline quartz substrate, using a standard chemical vapor deposition process, Rogers and his coworkers were able to fabricate "aligned arrays that are completely parallel," he says.

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Once the arrays have been grown, Rogers makes a transistor using existing patterning techniques to lay source and drain electrodes over both of the ends of all the nanotubes, and by placing a gate across their collective width. "From that point on, the process is just like making silicon on insulator devices," says Rogers.

"As silicon transistors become smaller, inherent limitations become more critical," says Alex Zettl, a physicist at the University of California, Berkeley. "Nanotubes as a material are an exciting alternative material for forming extremely small, stable transistors," he says.

But while the original interest in nanotubes for electronics lay in their nanometer size, there has been an increasing amount of interest in their use for analog electronic devices, says Burke. There are now predictions that nanotubes will actually outperform conventional analog transistors, he says.

Rogers's radio is relatively big, with each transistor consisting of thousands of carbon nanotubes. But he says that there is plenty of room to scale them down, not least because there are relatively large gaps between some of the nanotubes. So it should be possible to pack them in more densely. "Ideally, you would want the nanotubes to be sitting right next to each other," Rogers says. He and his colleagues are now working on creating integrated circuits containing up to 100 of these transistors.

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