Research uncovers reliability issues for carbon nanotubes in future electronics

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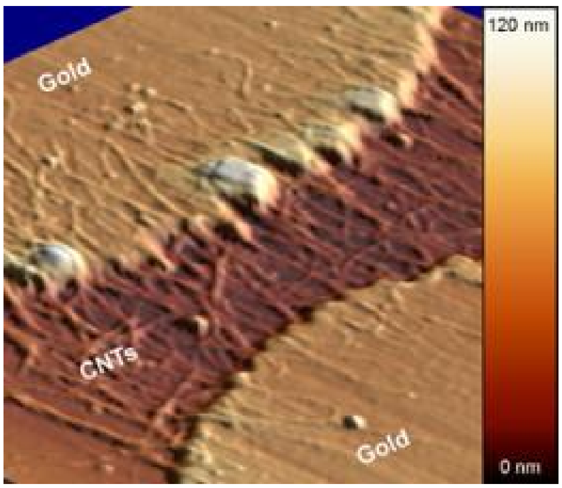

Micrograph of recession and clumping in gold electrodes after NIST researchers applied 1.7 volts of electricity to the carbon nanotube wiring for an hour. The NIST reliability tests may help determine whether nanotubes can replace copper wiring in next-generation electronics. Credit: M. Strus/NIST

(PhysOrg.com) -- Carbon nanotubes offer big promise in a small package. For instance, these tiny cylinders of carbon molecules theoretically can carry 1,000 times more electric current than a metal conductor of the same size. It's easy to imagine carbon nanotubes replacing copper wiring in future nanoscale electronics.

But -- not so fast. Recent tests at the National Institute of Standards and Technology (NIST) suggest device reliability is a major issue.

Copper wires transport power and other signals among all the parts of integrated circuits; even one failed conductor can cause chip failure. As a rough comparison, NIST researchers fabricated and tested numerous nanotube interconnects between metal electrodes. NIST test results, described at a conference this week,* show that nanotubes can sustain extremely high current densities (tens to hundreds of times larger than that in a typical semiconductor circuit) for several hours but slowly degrade under constant current. Of greater concern, the metal electrodes fail—the edges recede and clump—when currents rise above a certain threshold. The circuits failed in about 40 hours.

While many researchers around the world are studying nanotube fabrication and properties, the NIST work offers an early look at how these materials may behave in real electronic devices over the long term. To support industrial applications of these novel materials, NIST is developing measurement and test techniques and studying a variety of nanotube structures, zeroing in on what happens at the intersections of nanotubes and metals and between different nanotubes. "The common link is that we really need to study the interfaces," says Mark Strus, a NIST postdoctoral researcher.

In another, related study published recently,** NIST researchers identified failures in carbon nanotube networks—materials in which electrons physically hop from tube to tube. Failures in this case seemed to occur between nanotubes, the point of highest resistance, Strus says. By monitoring the starting resistance and initial stages of material degradation, researchers could predict whether resistance would degrade gradually—allowing operational limits to be set—or in a sporadic, unpredictable way that would undermine device performance. NIST developed electrical stress tests that link initial resistance to degradation rate, predictability of failure and total device lifetime. The test can be used to screen for proper fabrication and reliability of nanotube networks.

Despite the reliability concerns, Strus imagines that carbon nanotube networks may ultimately be very useful for some electronic applications. "For instance, carbon nanotube networks may not be the replacement for copper in logic or memory devices, but they may turn out to be interconnects for flexible electronic displays or photovoltaics," Strus says.

Overall, the NIST research will help qualify nanotube materials for next-generation electronics, and help process developers determine how well a structure may tolerate high electric current and adjust processing accordingly to optimize both performance and reliability.

More information: * M.C. Strus, R.R. Keller and N. Barbosa III. Electrical reliability and breakdown mechanisms in single-walled carbon nanotubes. Paper presented at IEEE Nano 2011, Portland, Ore., Aug. 17, 2011.

** M.C. Strus, A.N. Chiaramonti, Y.L. Kim, Y.J. Jung and R.R. Keller. Accelerated reliability testing of highly aligned single-walled carbon nanotube networks subjected to dc electrical stressing. *Nanotechnology* 22 pp. 265713 (2011).

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