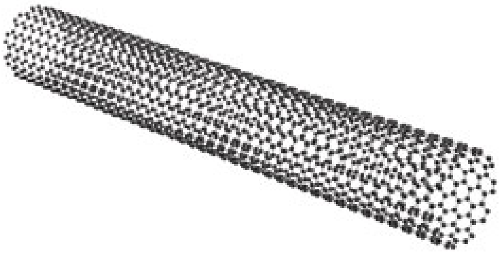
Improved Superconductivity in Multi-Walled Carbon Nanotubes



A group of researchers from several institutions in Japan has observed superconductivity — a phenomenon in which electrons flow with no resistance — in billionth-of-a-meter sized cylindrical carbon molecules known as "multi-walled carbon nanotubes." The nanotubes' ability to superconduct adds to their many intriguing electrical and physical characteristics. Moreover, it increases the likelihood that carbon nanotubes will one day drastically improve electronics, building materials, and many other products.

To be fair, observing a supercurrent through carbon nanotubes is not a new discovery. But past studies, which have used ropes made of single-walled carbon nanotubes (those consisting of just one cylinder rather than several nested cylinders), have only been able to achieve superconductivity by deep-freezing the nanotubes down to about 0.4 degrees Kelvin (K). Such an ultra-low "critical temperature," as it's called — just fractions of a degree away from 0 K, the coldest temperature possible — is very difficult to achieve and maintain in a laboratory.

"In our study, the nanotubes superconducted at a much more manageable critical temperature of 12 K," said Aoyama Gakuin University scientist Junji Haruyama. Haruyama is the lead author of the paper describing the work, which appears in the February 10, 2006, online edition of *Physical Review Letters*. "While 12 K is still extremely cold by everyday standards, it requires far less work to sustain. Also, in terms of potential applications of superconducting nanotubes, such as quantum molecular computing, this higher temperature is far more promising."

The scientists measured the supercurrent through the nanotubes by creating arrays of nano-sized electric "junctions" — very thin conducting layered structures. They began with a layer of aluminum, prepared such that it contained a grid of nanoscale pores. On top of this they deposited a layer of MWNTs, which inserted themselves vertically into the aluminum pores. Finally, they topped the nanotubes with a layer of gold.

The group created three of these arrays. By carefully cutting off part of the nanotube layer, they created an array in which the nanotubes were flush with the aluminum surface and another in which the nanotubes jutted out slightly above the surface. For the third array, no cutting was done. As a result, each nanotube remained longer than the depth of each pore, and thus "spilled" over onto the aluminum.

These three cases correspond to a different degree of nanotube-gold contact, referred to as "end bonding." In the first array the nanotubes are only slightly end bonded with the gold, while in the third they are fully end bonded.

End bonding turned out to be one important factor affecting the nanotubes' ability to superconduct. Only the array containing entirely end-bonded MWNTs exhibited superconductivity at 12 K. Because the nanotubes were folded over, the gold could only make contact with the outer shell of each nanotube, rather than also bonding with the inner shells. However, in this third case the gold touched far more nanotube surface area.

“We concluded that being entirely end bonded with the gold electrically activated all the shells in each nanotube,” said Haruyama. “In the other two arrays, only some of the shells were activated. This indicates that superconductivity in MWNTs is strongly related to the number of electrically active shells and, by extension, that electric interactions between shells play a large role.”

Haruyama and his colleagues are planning several follow-up studies. These include an experiment that will attempt to increase the critical temperature of the nanotubes, as well as an investigation into how coupling neighboring nanotubes in the array’s MWNT layer could affect their superconductivity.

Citation: "Superconductivity in Entirely End-Bonded Multiwalled Carbon Nanotubes", Phys. Rev. Lett. 96, 057001 (2006)

By Laura Mgrdichian, Copyright 2006 PhysOrg.com