Discovering new properties in carbon nanotubes

The trend in science is moving toward smaller devices. Indeed, single electron devices are considered one way for computing and other electronic applications to become ever smaller in size, while still providing large operating capacities. Single electron devices can also provide a fundamental probe to quantum states in a controllable manner.

One group of scientists in Korea may have found a precursor to such a single electron device. Their work details a quantum dot device fabricated as a carbon nanotube with a double wall by focusing on some of the unexplored electronic structures found in carbon nanotubes. “Eightfold Shell Filling in a Double-Wall Carbon Nanotube Quantum Dot” is published in *Physical Review Letters* and details the electrical transport properties of such a device.

“There are many different ways to fabricate quantum dots,” Mahn-Soo Choi, a scientist at Korea University, tells *PhysOrg.com*. “We chose to use a carbon nanotube not only because of its small size and how easy it is to fabricate, but also because it shows highly symmetric structures of electronic transport.”

The experimenters group at Korea University, Sunkyung Moon and Soon-Gul Lee, and the group at the Korea Research Institute of Standards and Science, Woon Song, Joon Sung Lee, Nam Kim lead by Jinhee Kim, and theorist Choi wanted to explore some of the properties of a nanotube with a double wall, as opposed to a single wall. Choi explains that his main duty in the project was to provide interpretation of the experimental results found by Jinhee Kim’s group.

“Before, with so-called multi-wall nanotubes,” Choi says, “people assumed that inner walls did not contribute the electric current.” However, he continues, “the data I interpret from the experimental results my colleagues in this group brought me, shows that the inner wall could contribute.”

Choi explains that the cylindrical symmetry and the strong electron-electron interaction in a carbon nanotube provides each wall with a four-diamond structure. “In the single wall, this makes beautiful symmetry, and shows interesting quantum mechanical electronic structure.” But until now scientists could observe this only in single-wall carbon nanotubes. Choi speculates that this is probably due to defects in multi-walled carbon nanotubes.

“We, however, observed this same symmetry in the inner wall of a double wall carbon nanotube,” Choi says. He says that the quantum dot device his team fabricated shows an eight diamond structure – four from each wall. “The patterns from the inner and outer walls arrange so that we observe only one such structure.”

The scientists working in Korea found that the inner and outer walls of the carbon nanotube interact with each other. Using a back gate to tune the number of electrons in the carbon nanotube, they were able to test its electrical properties. “The patterns on the walls shift when you change the gate voltage,” Choi explains. “The outer wall pattern follows intently the change, but the inner drags behind. This is why sometimes the patterns on the walls shift so that they no longer appear to match.” He goes on to point out that it is the interaction between the walls that offers interesting possibilities.

“By now it’s quite easy to fabricate a quantum dot into a nanostructure electric circuit. This could lead to a single electron tunneling device.” Even though current technology is not where it needs to be, Choi thinks that at some point it will be possible to explore further, continuing the work he and his peers have advanced.

“If we could observe this from a realistic setup,” he says, “we can explore it and then probably manipulate this quantum state in the nanostructure to control the quantum mechanical state of electrons. At the moment it is not possible with our present technology, but our work shows promise to pave the way to quantum engineering in single electron devices.”