Using superconducting probes to get a picture of what it's like inside CNTs

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(PhysOrg.com) -- "Carbon nanotubes are exciting for fundamental physics, and for potential technological applications," Nadya Mason tells *PhysOrg.com*. "However, we are generally limited in the way that we can study them. Many of these limitations have to do with controlling tunneling, or the way electrons move on and off the nanotube." In order to overcome this limitation, Mason, a scientist at the University of Illinois at Urbana-Champaign, participated in an experiment using a superconducting tunnel probe in a carbon nanotube to observe spectroscopic features.

Mason worked with Travis Dirks and Yung-fu Chen at the University of Illinois, as well as Norman Birge at Michigan State University, to develop a technique to map out changes in conductance through a carbon nanotube quantum dot. “We’re hoping to see what is happening in the interior, rather than what is influenced by the contacts,” Mason explains. “Then we can get at the fundamental electronics of quantum dots, which may be a key to future quantum technologies.” The results of the team’s work can be seen in *Applied Physics Letters*: “Superconducting tunneling spectroscopy of a carbon nanotube quantum dot.”

There are three elements to the technique, according to Mason. “First, there is a carbon nanotube quantum dot, which can act as a model “particle-in-a-box” with quantized energy states. Next, we tunnel to the interior. The non-invasive probe allows us to study the bulk electronics, and also to separately test the effect of voltages across the length of the tube .”

The third element is that the tunneling probe is a superconductor. “The superconductor enhances spectroscopic features. But it also shows how this technique is very flexible,” Mason says. “We can try different materials, multiple probes, or magnetic fields, for example.” Some of the spectroscopic features observed with the superconducting probe include signals from cotunneling and unusual scattering processes.

Mason points out that elements of this technique have been accomplished before. “However,” she continues, “I think that we are the first to put all the elements together to work as one system, by adding a third terminal and a superconducting probe.” Mason also points out that this set-up works with standard fabrication techniques. “We used lithography, which is common in industry, and easily scalable.”

For now, most of the work is focused on fundamental properties of carbon nanotubes. “We are interested in seeing how these nanotube quantum dots work, and tracking what happens in them. We’ve already seen some unexpected features, such as an unusual energy exchange. Using our probe, it is possible to see these features, and explore them in greater depth.”

In the future, though, Mason sees the potential for technological applications. These types of quantum dots are being considered for quantum computers and even single electron transistors. There are a number of potential applications for this work, perhaps a decade or so down the road. And the first step is looking into the tube. We want to understand this system so that it might be used in future advanced technologies. Our superconducting tunnel probe will help us do just that.”

More information: Dirks, et. al., “Superconducting tunneling spectroscopy of a carbon nanotube quantum dot,” Applied Physics Letters (2009). Available online:

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