Theoretical Investigations of Quantum Transport through Carbon-Nanotube Devices

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Carbon nanotubes are perhaps one of the most interesting of the new materials to emerge this past decade, displaying outstanding mechanical and electronic properties. From a device point of view, they are important not only because of their potential for microelectronic applications, but also as a fundamental testing ground for transport at the nanometer length scale. By combining the Keldysh nonequilibrium Green's function analysis with a standard tight-binding model, we have investigated transport through carbon nanotube devices. For finite-size armchair nanotubes, we find that transport is dominated by resonant tunneling with the conductance being strongly dependent on the length of the nanotube. Turning to nanotube devices, we have investigated spin-coherent transport in nanotube-ferromagnetic devices [1] and nanotube-superconductor devices [2]. The former shows a significant spin-valve effect of up to 20%, in good agreement with the experimental results [3]. Transport through superconductor-nanotube devices are dominated by resonant Andreev reflections such that for high transparency device on-resonance, the Andreev current is characterized by a large value and a resistance dip, while low-transparency off-resonance devices give the opposite result. We also show that the observed low-temperature anomalies appear to be the natural result of the Andreev reflection processes [4]. Finally, the dynamic or AC conductance of carbon nanotubes will be discussed [5]. Because of the induced displacement currents, the dynamic conductance of nanotubes differs significantly for the DC results, displaying both capacitive and inductive behavior. The important role of photon-assisted transport through nanotubes is revealed and some implications for experiments discussed.

1. H. Mehrez, J. Taylor, H. Guo, J. Wang and C. Roland, Phys. Rev. Lett. **84**, 2682(2000).
2. Y. Wei, J. Wang, H. Guo, H. Mehrez and C. Roland, submitted to Physical Review Letters.
3. K. Tsukagoshi, B. Alphenaar and H. Ago, Nature **401**, 572 (1999).
4. A. Morpurgo, J. Kong, C. Marcus and H. Dai, Nature **286**, 263 (1999).
5. C. Roland, M. Buongiorno Nardelli, J. Wang and H. Guo, Phys. Rev. Lett. **84**, 2921 (2000).