Low-temperature electronic transport in one-dimensional hybrid systems: metal cluster embedded carbon nanotubes

by

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An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the degree of

DOCTOR OF PHILOSOPHY

Major Subject: Physics

The original of the complete thesis is on file
In the Rensselaer Polytechnic Institute Library

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November, 2007
(For Graduation December 2007)

ABSTRACT

The investigation of the electronic and magnetotransport properties at low temperature in individual MWNT with embedded clusters are here presented. The majority of studies of transport in MWNT reported in literature has been carried out on arc-discharge grown tubes, generally considered “clean” and defect-free. In this project, individual MWNT grown in alumina template are used; these tubes are highly disordered compared for example to arc-discharge ones, conditions that dramatically will impact the charge transport. As-fabricated devices are in general highly resistive. A large decrease in the value of the device resistance can be achieved through a controlled and fast high-bias sweep method (HBT) across the sample. Scanning electron microscopy analysis shows that this method induces a metal (platinum) decoration of the MWNT surface as a consequence of the large amount of Joule heating developed during the sweep.

Temperature dependence study ($5<T<300K$) reveals a slow power law dependence of the conductance as a function of the temperature for all investigated devices. Large value of power law exponents are found for the conductance in all pristine devices, suggesting that the transport mechanism takes place through tunneling between adjacent graphene flakes. Platinum-decorated devices show a Lüttinger liquid behavior in the high temperature regime and a large suppression of the conductance at low temperature due to *e-e* interactions. Transport properties are studied in light of a recently proposed model for disordered multi-channel quantum wires. DFT calculations show that the enhancement in conductance can be explained in term of enhanced density of states around the Fermi energy due to presence of platinum on the wall. Magneto-

transport measurements carried out up to a value of magnetic field up to |5|T show a clear dependence from the energy (i.e. applied bias). A nearly symmetric and monotonically increasing positive magneto-conductance is observed in the range of the applied field, confirming the presence of weak localization in the system. A small but distinct Rashba spin-orbit scattering effect in the magneto-conductance in the low-field regime (|B|<.5T) is found and attributed to the surface decoration. Electronic and magnetotransport measurements independently confirm the 1D nature of the transport in the system.

"Zero-field" measurements were performed on magnetic cluster-embedded MWNT-based devices (FM-MWNT). Temperature dependence of the conductance reveals a Lüttinger liquid type of behavior in the range of investigated temperatures but no conductance suppression at lower temperatures, as seen platinum-decorated devices. Direct differential conductance measurements for discrete applied magnetic field show the appearance of random fluctuations, which amplitude is field-dependent. The properties of the FM-MWNT were found to change permanently under the application of a magnetic field, indicating that the charge transport is sensitive to the relative magnetic orientations (random or aligned) of the nanoclusters. Measurements and relative analysis are hence presented in a chronological order, as the investigation was performed, which brings out the difference between charge transport in a Lüttinger liquid under the influence of "random" and "ferromagnetically aligned" impurities.

The present thesis is organized as follows:

Chapter 1 presents a general overview on carbon nanotubes; various transport mechanisms and related issues are also introduced.

Chapter 2 presents a detailed description of alumina template grown multi wall nanotubes together with the high-bias treatment (HBT), a novel *in-situ* technique to tune the device resistance. Outcome of this process is analyzed in terms of scanning electron microscopy.

Chapter 3 describes the experimental set-up and various measurement techniques used in this project.

The last two chapters present a detailed characterization of the electronic and magnetotransport in pristine (or as-fabricated) and platinum-decorated (chapter 4) and ferromagnetic clusters embedded multi wall carbon nanotubes (chapter 5).