ELECTRICAL AND STRUCTURAL PROPERTIES OF CARBON NANOTUBES

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The rapid progress of interest in carbon nanotubes research have been improved with a development of sensitive tools for their observation and characterization. In this work Raman spectroscopy and atomic/electric force microscopy (AFM/EFM) have been successfully applied for studying electrical and structural properties of multiwall carbon nanotubes (MWNT). The combination of these methods (Raman spectroscopy and AFM/EFM) of characterization of MWNT gives a new wider approach to the understanding properties of carbon nanotubes.

A method of separation of nanotubes has been developed which allows to work on a single nanotubes [fig.1]. Different surfaces has been tested and the results shows that this is one of crucial points during of this study. I designed special, metal masks for this surfaces, done with e-beam lithography [fig.1]. That gives opportunity to perform different experiment on the same single nanotube and there is no problem to find this particular nanotube whenever it is needed.

Raman experiments have been performed on bundles of nanotubes [fig.2]. The micro-Raman spectra of the objects were taken with 514,5nm wavelength excitations and in the temperature range 4K – 400K. Basically the spectra are quite similar to the well known single wall carbon nanotube spectra [1], with the exception of the absence of low frequency band. The major Raman bands, that are observed in single wall nanotubes are found in the spectra. There is also new feature in Raman spectra at 843 cm^{-1}, which was not observed in other Raman spectra studies but it was theoreticaly calculated. Metallic and semiconducting type of conductitivity is distinguished through an analysis of the G (LO) mode at ~1600 cm^{-1}.

The nanotubes were characterized with AFM (fig.1) in tapping mode (Nanoscope IIIa, Digital Instruments) to obtain shape parameters (length, diameter and curvature). Additionally a successful experiments was also performed to estimate the adhesion forces between nanotubes and the surface. Using the same Nanoscope equipment in EFM mode completely new kind of measurement has been performed, where electrons are injected in the single nanotube [fig.3]. Interesting phenomenon after charge injecting was observed depending on diameter and electronic structure of nanotube. Two different type of behavior of charges was noticed: when injected charges disperse along nanotube and very quickly go out from nanotube or the charges stays inside the nanotube much longer time (tens of hours).

In the last part of this studies, using the EBPG (Electron Beam Pattern Generator) and FIB (Focused Ion Beam) the metallic contacts [fig.1] has been made to perform electrical characterization of carbon nanotubes. Contacts were made in two, four and four +1 (gate) terminal set up. Preliminary characterization have been made in low (4 K) and room temperature (300 K), and the results shows good agreement with work of oder groups [2].

During all this work few interesting potential application ideas came up, mainly in nano-electronics (fast, low-energy memory devices) and in optics (field electron emission devices).

References:

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[2] "Single- and multi-wall carbon nanotube field-efect transistors" R. Martel, T. Schmidt, H. R. Shea, T. Hertel, Ph. Avouris; APL 73, 2447-2449, (1998).

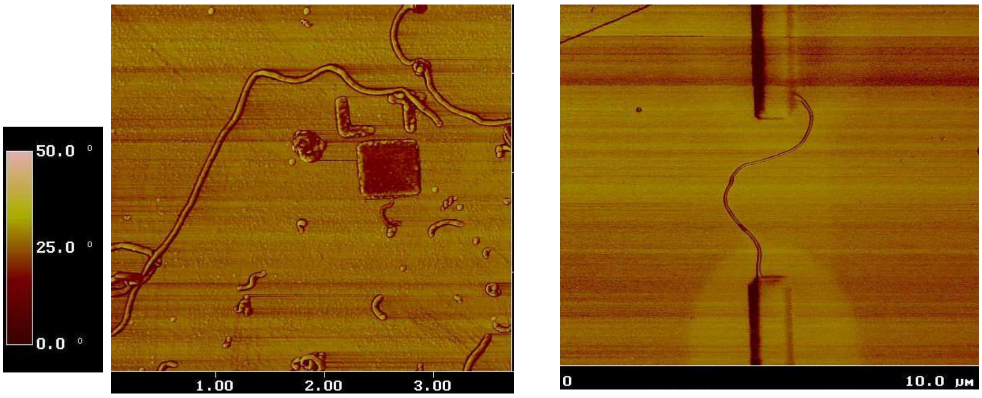

Fig. 1 Left part: AFM scan image (phase mode) of separated multiwall carbon nanotubes on SiO2 surface with part of the metal mask ; right part: view on two-terminal contacted (topography mode) one nanotube.

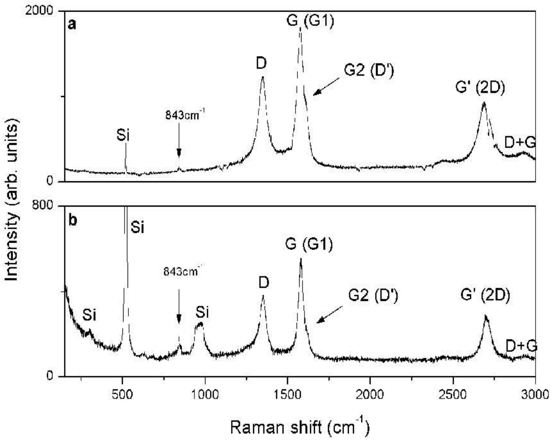

Fig. 2 Raman spectra of a bundle of muliwalled carbon nanotubes

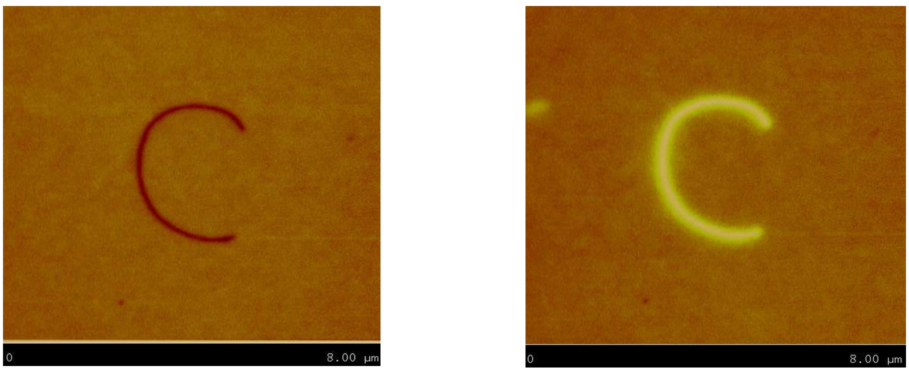

Fig. 3 Left part: EFM scan image (frequency mode) of multiwall carbon nanotubes before charge injecting; right part: after injection.