CHARGING EFFECTS IN CARBON NANOTUBES

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In this contribution , we will describe the issue of electrostatic and emission properties of separated carbon nanotubes (CNTs) deposited on a insulating layer have been investigated by charge injection and Electric Force Microscopy (EFM) experiments [1]. We found that upon local injection charges were delocalized over the whole nanotube length (up to more then 40µm). We will describe the phenomenological behaviours of SWCNTs and MWCNTs upon charging.

We will present experiments aiming to dissociate between *capacitive* charging mechanisms [2] (in which the nanotubes are capacitively put at the EFM tip bias during the charging, and the charge is stored in the nanotube outer shells) and *inner-shell* charging mechanisms, associated with tunnelling processes through the nanotube shells.

Depending on the CNT diameter (number of walls) we observed different discharge behaviours:

- fast (see Fig. 1) and abrubt discharge
- charge storage with long time retention of charge

In addition, the insulating layer supporting the nanotubes is shown to act as a charge-sensitive plate for electrons emitted from the CNTs at low electric fields, thus allowing the spatial mapping of nanotubes field emission patterns. We will present that one of the important factor during field emission from nanotubes is the cap diameter (see Fig.2) and cap structure[3].

References:

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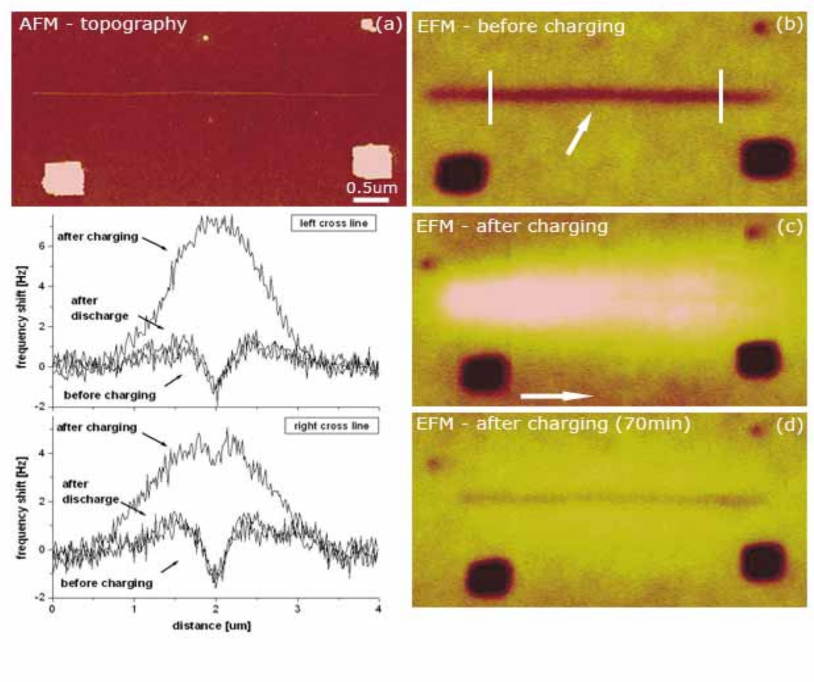

Fig.1 (a) AFM topography scan of 5 µm long SWNT (1.5 nm of diameter). Metal square markers are visible below the nanotube. (b) EFM image before charging. The white arrow indicates the injection point. Both, nanotube and markers remain uncharged (dark features) during this scan. Vertical bars indicate the place where the cross section are taken (see the chart inset). The cross sections before charging are shown on the graph inset. The lift scan height was 90 nm. (c) EFM picture after charge injection (V_{inj} = -5 V for 3 min). The white arrow shows the scan direction. The left part of the nanotube is brighter than the right one, which means that here the nanotube undergoes the discharge process. Two cross-sections are taken from this scan and shown on the graph inset. The left cross-section shows a regular peak shape of the frequency shift of the charged nanotube, while the right cross line already exhibits capacitive effect. Metal markers are still uncharged. (d) EFM scan after 70 min after charging. The nanotube is already uncharged. Cross sections after discharge are shown on the graph inset.

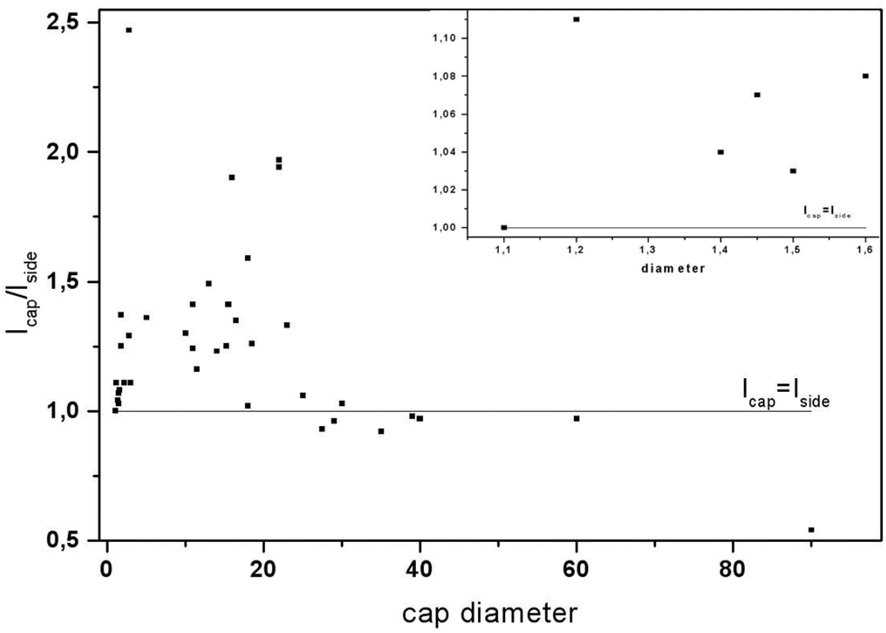

Fig. 2 (a) Comparison of charge emission from the nanotube cap and through the side walls. On the plot we show ratio of frequency shift in front of the nanotube apex and on side of the nantube (I_{cap}/I_{side}) as a function of the nanotube diameter. (inset) Data zoom for single-walled nanotubes.