Electrical Study of 2D Carbon Nanotube Thin Films

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Because of their unique electronic, thermal, optical and mechanical properties [1,2], Carbon Nanotubes (CNTs) have been considered as serious contenders for leading the future of nanosciences. Moreover 2D CNTs films have uniform physical and electronic properties which make them a promising candidate for low cost electronics [3,4]. Here we present a study of 2D CNTs films where a theoretical model and electrical characterization will be presented.

In order to get a microscopic understanding of the transport and noise phenomena, we have developed a model based on the charge transport. In this model, two transport mechanisms are considered: the transport along NTs themselves and the transport between crossed NTs. Considering the large mean free path in CNTs and the weak coupling between NTs, we assume that the contacts between NTs dominate the transport through the film [5]. Using these assumptions, NTs are set randomly on a surface using a Monte-Carlo algorithm, then wide electrodes are defined to form source and drain with a low contact resistance. An equivalent electrical circuit has been drawn where NTs are wire of constant potential and each junction between two tubes in contact is modeled as a dipole with a dynamic resistance. In junction, the hopping from a tube to another is modeled as a perturbation in the transmission probability T(E) in the framework of Landauer formalism. T(E) depends on the CNT charge ρ and on the energy barriers between NTs. Charge inside a tube is calculated using Poisson equation and the density of states D(E). The energy barrier is obtained by a first neighbor tight-binding calculation. The transmission probability is obtained by WKB approximation and the tubes potential are computed using a modified nodal analysis MNA. Figure 1 shows the used algorithm for conductivity and noise simulations.

For a macroscopic validation of the model, high purified HELIX SWCNTs were suspended in aqueous solutions with Sodium Dodecyl Sulfate "SDS" or Bile Salt "BS" with different concentrations. The dispersion of CNTs in the different solutions was studied by MACRO RAMAN, where the spectra are represented in Figure 2. More the RAMAN shift is broad, more the solution is homogeneous.

2D CNTs films with different density of tubes, which is equivalent to different number of deposited layer N_c, are fabricated by spin coating on SiO2/Si substrates. Each film layer was deposited with the same spin-coating parameters. 2D films electrical parameters depend on the homogeneity of the deposited layer.

Conductivity measurements for films deposited with the two kinds of surfactants were extracted using Transmission Length Measurements structures. The results obtained with "BS" show a large conductivity improvement in comparison to the results obtained with "SDS" (Figure 3). In the same way, the contact resistance which is associated to electrodes-NT junctions presents a lower value with "BS". This variations show clearly that films fabricated with "BS" have higher homogeneity in accordance to Raman spectroscopy. Noise measurements were carried out using an HP89410A dynamic signal analyzer with an EGG5182 low noise amplifier. The spectra present 1/f noise, which obeys to the classical equation $K=Si.f/I^2$ [6] for the two kind of surfactants (Figure 4), where Si is the noise current power spectral density PSD, K is the noise amplitude coefficient, f is the frequency, and I is the average current through the sample. The noise is due to fluctuations involving a large number of NT-NT and NT-electrodes junctions. An increase in the density of NTs or a higher homogeneity in the films implies a decrease in 1/f excess noise. Conductivity ($\sigma \propto (Nc-Nc0)^{tc}$) and 1/f noise ($K \propto (Nc-Nc0)^{-k}$) can be fitted by the classical power laws where tc and **k** are the critical exponents. N_{c0} is the percolation threshold value.

In summary we have clearly shown the impact of fabrication process of the devices on the conductivity and on 1/f noise level. Percolation theory is used to describe conduction and noise measurements in 2D-CNT films. The developed model, based on NT properties, on NT-NT junction, and NT-electrodes confirm the experimental results and show that these junctions remains a limiting factor for electrical application.

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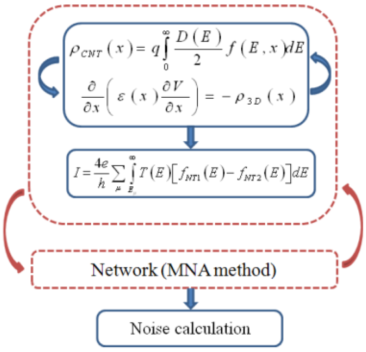

Figure 1: General algorithm.

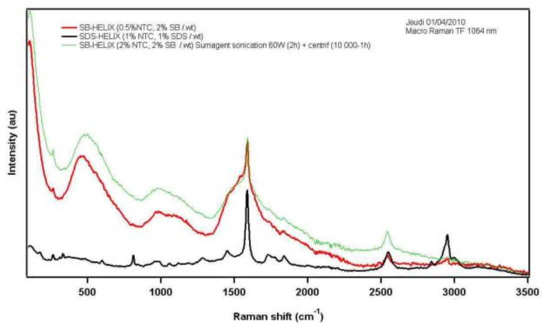

Figure 2: Raman spectra for the different solutions.

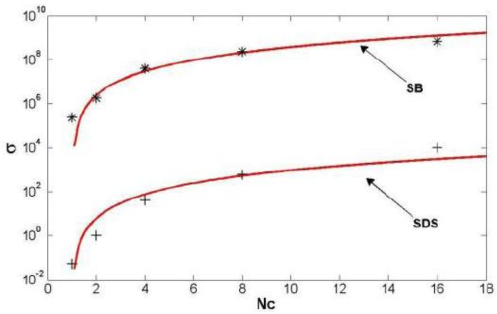

Figure 3: Measured conductivity ($\Omega^{-1}m^{-1}$) and power law versus the number of deposited layer (-).

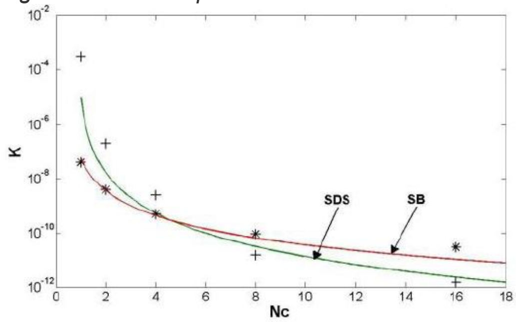

Figure 4: Measured K and power law versus the number of deposited layer (-).

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