Flexible Transparent Electrodes using Carbon Nanotubes

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Flexible conducting thin films are useful for applications in different kind of devices called as "flexible electronics": sensors, transistors, or transparent electrodes that could be used in photovoltaic solar cells.

With this objective we prepared thin single walled carbon nanotubes (SWCNT) networks on a transparent and flexible substrate (PPC) with different SWCNT densities using a very simple spray method [1]. We measured the electric impedance at different frequencies Z(f) in the frequency range from 40 Hz to 20 GHz using two different methods: two-probe method in the range up to 110 MHz and a coaxial (Corvino) [2] method in the range from 10 MHz to 20 GHz, see figure 1. We measured the optical absorption and electrical conductivity in order to optimize the conditions for obtaining optimum performance, films with both high electrical conductivity and transparency, see figure 2. We observe a square resistance from 8,5 to 2 kohm for samples showing 85% to 65% optical transmittance respectively.

For some applications we need flexibility and not transparency: for this purpose we deposited a thick film of single walled carbon nanotubes (SWCNT) on a flexible silicone substrate by spray, from an aqueous suspension of SWCNT in SDS, obtaining a flexible conducting electrode.

The measured electrical resistance is as low as 200 ohm/square, the impedance is constant from DC up to high frequency. Stretching up to 10% and 20% the electrical resistance increases slightly with the stretching, recovering the initial value for small elongations. The stretching is reversible for elongations up to 10%.

We analyzed the stretched and non stretched samples by Raman spectroscopy, and could observe that Raman spectra breathing mode are very sensitive to the stretching. The high energy Raman modes are not changed, then we are not introducing defects when stretching.

In both cases, using selected metallic carbon nanotubes could enhance electrical conductivity by a factor from 5 to 10 [4], increasing the film performance. Also previous carbon nanotubes purification will enhance the transparency. Recent results using graphene to obtain flexible transparent electrodes are much successful [5], their obtained samples show sheet resistances as low as125 to 25 ohm/square for 97,4 to 90% transparency respectively. But in our case the films are obtained just using a very simple spray method, from an aqueous suspension of carbon nanotubes and can be deposited on any kind and shape of surface.

References

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Figures

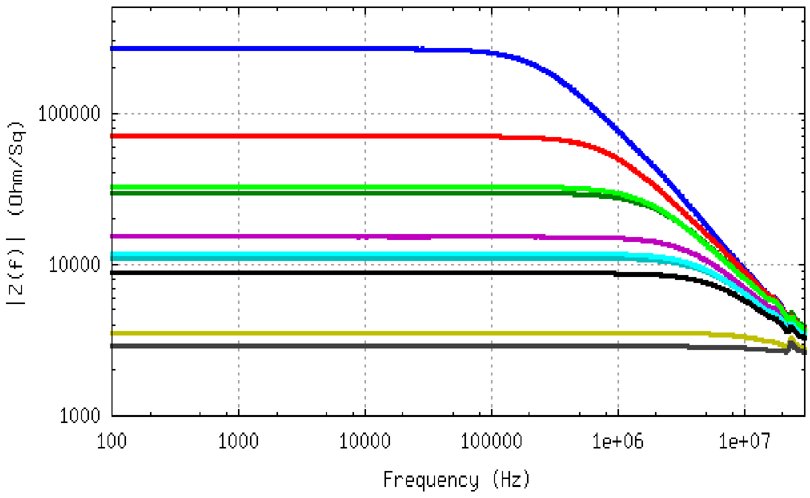

Figure 1 shows the impedance dependence on frequency Z(f). We can define the cut off frequency fo, at which Z decreases abruptly; we observe that fo increases when increasing the SWCNT density on the substrate.

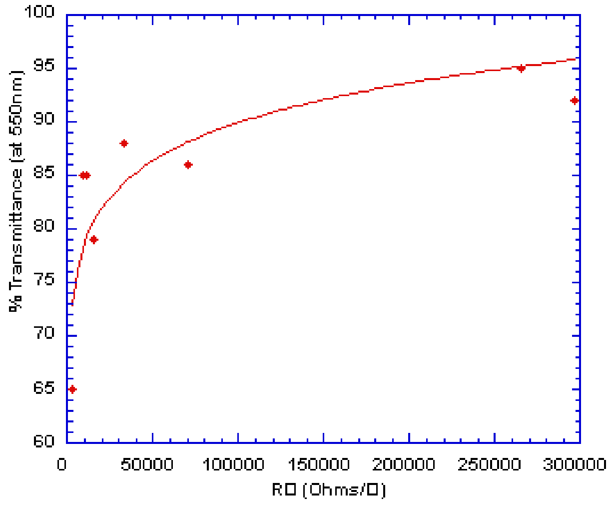

Figure 2 shows the transparency (%Transmittance at 550nm) versus the sheet resistance, R□

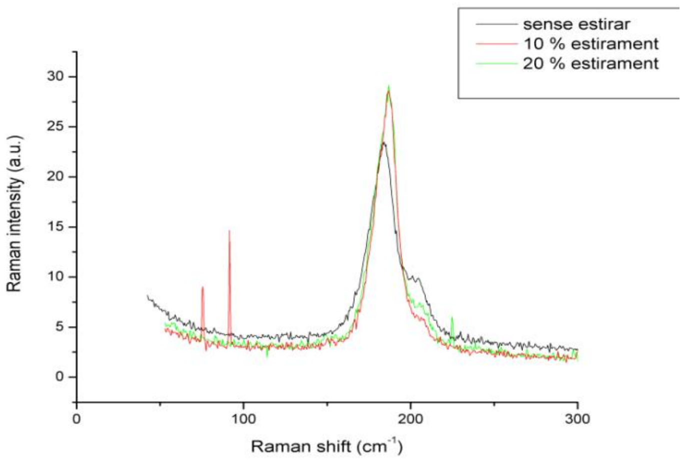

Figure 4 Raman spectroscopy on the unstretched and stretched samples show clear shift on the breathing mode