Compression enhanced conductivity in carbon nanotubes

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The applicability of carbon nanotubes as field effect transistors [1], has stimulated large investigations of the electronic transport in this kind of devices. The understanding of the transport properties goes trough the study of the tunneling phenomena which play a key role.
In this work, we have studied the electronic properties of multi-walled carbon nanotubes (MWCNTs) samples which were produced as continuous, free standing, lightweight, translucent and conducting sheets where nanotubes are preferentially oriented along their longitudinal direction [2]. Continuous stress cycles (between 3 and 10) up to 5 GPa were performed using a sapphire anvil cell [3], shown in the figure, and, at the same time, the resistance and the Raman spectrum of the sample were registered. The combination of both measurements with stress allowed us to identify the different mechanisms invoked to explain the conductivity in CNTs samples [4, 5].
During the first stress cycles some irreversible phenomena could be observed; on one hand with applying stress the original sample is debundled which affects the inter-tube conductivity, on the other hand the stress cycles cause the generation of hopping defects in the graphene lattice leading to a progressive increase of the resistance along the tubes, only after performing enough stress cycles the defect concentration reach a constant value and the resistance stop increasing.
However, the changes of resistance due to the aforementioned phenomena are negligible in comparison with the abrupt and reversible variations observed at around 2 GPa. The large changes of resistance are consequence of variations of the inter-tube distance when the nanotubes are squeezed with the anvil cell, which demonstrate the effect of the tunneling phenomena on the conductivity of carbon nanotubes samples already described in the literature. Interestingly, we have found that the Raman intensity of the D band, as well as other double resonance Raman modes of carbon nanotubes, suffers a similar reversible variation to that observed for the resistance; consequently we can assume that, apart from the defect concentration, other factor such as the inter-tube distance is modulating the intensity of this band. This novelty result clearly indicates that the tunneling phenomena have a strong influence on the electronic band structure of carbon nanotubes.

References

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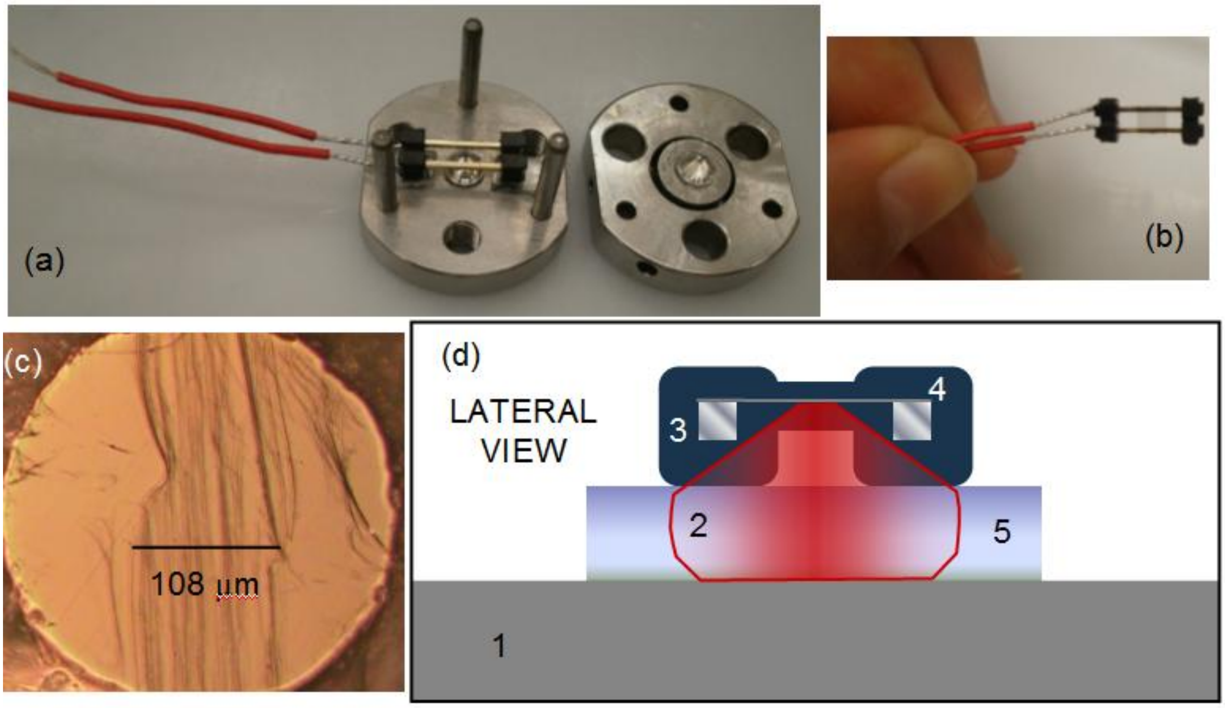
Figures



(a) Photograph of the open SAC coupled with the pin. (b) Photograph of the freestanding MWCNTs sheet supported between the poles of the pin. (c) Photograph of the MWCNTs sheet on top of the sapphire culet after removing some of the sample. (d) Schematic representation of lateral view of the experimental set up used in these experiments; the numbered parts of the device are: (1) cell, (2) sapphire, (3) pin, (4) MWCNT sheet and (5) height adapter.