CARBON NANOSCROLLS FABRICATION BY A MICROMECHANICAL TECHNIQUE

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A simple micromechanical approach (that is, the peeling off) has allowed to extract graphene molecules from a graphite crystal [1]. During the peeling out of the graphite crystal, the applied mechanical stress causes the separation of the graphene layers, contrasting the interlayer interaction forces. Analogously a particular mechanical stress (shear stress) can allow the graphite nanocrystals (graphite nanoplatelets, GNPs) to transform into a new carbon nanomaterial, which is the carbon nanoscroll (CNS). In this case, the applied stress acts on the single carbon sheet, moving and causing a complete graphite crystal exfoliation. However, when this movement of the graphene sheets takes place against a rough surface it causes a rolling-up process because of the effect of the acting friction forces. In particular, when the micromechanical exfoliation takes place against a nano-fibrous surface like bioriented polypropylene (BOPP) this scrolling mechanism results particularly favored. In this study, an alcoholic (ethanol) dispersion of (Few Layer Graphene, FLG) was rubbed on the surface of a bioriented polypropylene (BOPP) film using a low-density polytethylene (LDPE) film. Before to dry the concentrated liquid suspension was removed from the BOPP film by pouring ethanol on it. The resulting dispersion contained a large amount of nanoscrolls. Probably the high roughness and nano-fibrous nature of the BOPP surface helps the rolling process. Nanoscrolls can be separated from the un-rolled and/or partially rolled graphene-based material by sedimentation in ethanol since their Stokes coefficient value is significantly higher than that of graphene. The ability of the shear-stress forces to induce nanoscroll formation has already been observed in the treatment of graphite by ball milling. Carbon nanoscrolls are made of continuous graphene sheets rolled up in a hollow tubular form. They are materials analogous to multi-walled carbon nanotubes, and therefore can be considered as nanotube-like structures. Moreover, there are different ways for the graphene unities to separate from the graphite crystal during the rolling-up process under the effect of the applied shear stress. Cylindrical and fusiform structures typically result in addition to partially rolled, multi-rolled, and other non-regularly-shaped rolled structures. Cylindrical nanoscrolls have a very uniform diameters and tend to form bundles just like carbon nanotubes (CNT) because of the π-π interactions. The average length of cylindrical nanoscrolls obtained by this method was ranging from 0.5 to 2.5 μm, and the diameter was of ca. 100nm. Consequently, each cylindrical nanoscroll should contain from 2 to 8 inner layers ($n=l/\pi D$). Nanoscrolls containing only a few graphene layers result quite transparent (see the TEM - SEM micrographs in Figure 1,2). However, for fusiform nanoscrolls the number of layers resulted of ca. 11 in the equatorial region ($n=l\sqrt{2}/\pi D$). These nanostructures are hollow and therefore particularly useful for many technological applications like hydrogen storage [3-4], drug-delivery systems, etc. Carbon nanoscrolls offer a number of advantages compared to planar graphene. Graphene has a large surface development (2630 m^2/g) but also a certain tendency to aggregate by stacking. Such problem is completely solved in carbon nanoscrolls that may only moderately aggregate. Owing to the very high specific surface area, carbon nanoscrolls can have important application as sorbents and catalyst supports, in addition they are electrically conductive and therefore can be used in the fabrication of electrodes for supercapacitors and batteries [2], where high current densities are required. In addition, these nanostructures are characterized by a temperature-dependent rolling level, and therefore the release by diffusion of molecules contained inside the nanoscroll could behave differently, depending on the temperature. Also a temperature-depending electrical conduction has been observed for carbon nanoscrolls that allow their use as temperature sensors. The interlayer spaces of CNS can be easy intercalated because it is not a closed topological structure. Since the diameter of CNS can be easily expanded by charge injection or intercalation, it could also be used as a nanoactuator in nanomechanical devices [2-5].

References

[1] A. K. Geim, Science, **324** (2009) 1530.
[2] S. F. Braga, V. R. Coluci, S. B. Legoas, R. Giro, D. S. Galvao, R. H. Baughman, *Nano Lett.,* **4** *(*2004) 881.
[3] G. Mpourmpakis, E. Tylianakis, G. E. Froudakis, *Nano Lett*., **7** (2007) 1893.
[4] V. R. Coluci, S. F. Braga, R. H. Baughman, D. S. Galvao, Phys. ReV. B, **75** (2007) 125404.
[5] R. Rurali, V. R. Coluci, D. S. Galvao, Phys. ReV. B, **74** (2006) 085414.

Figures

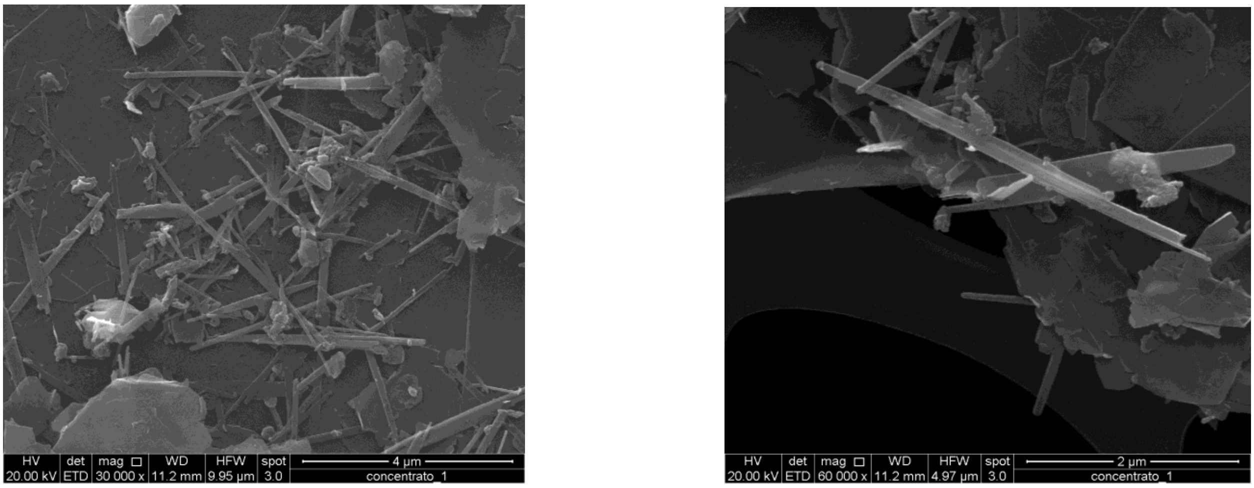

Figure 1: (left side) SEM micrograph of a bundle of scrolled material; (right side) high magnification SEM image of some tubular nanoscrolls.

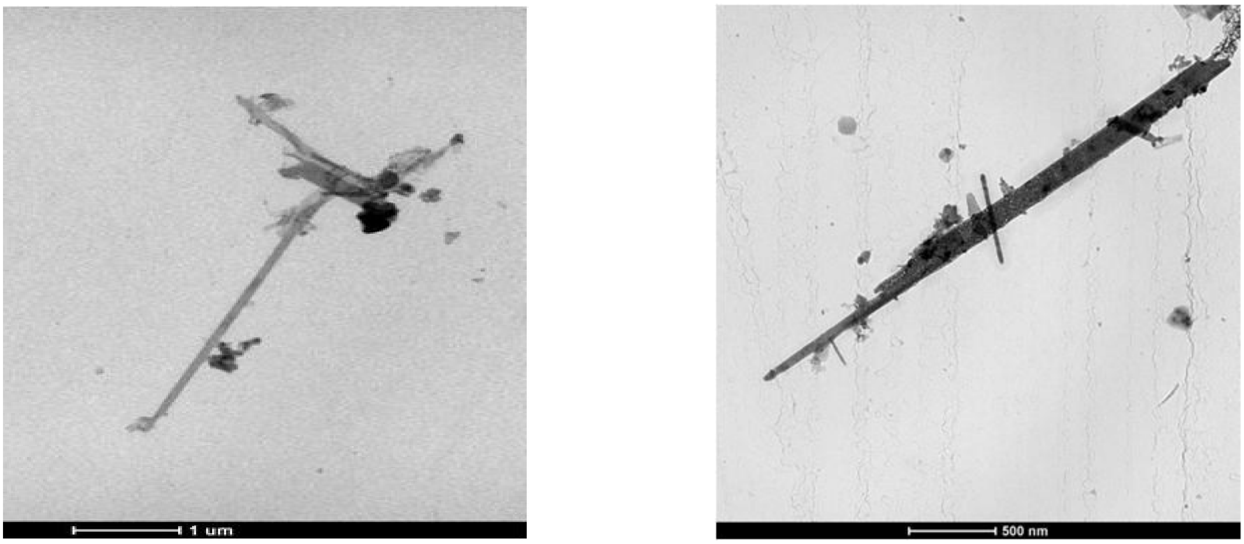

Figure 2: (left side) TEM image of nanoscrolls produced by the mechanical stress ; (right side) TEM image of an isolated carbon nanoscroll.