Atomic Force Microscopy Assisted Graphene 3D-Modification

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Nowadays, graphene occupies a special place among two-dimensional materials due to its unique properties [1]. Nevertheless, graphene has several important drawbacks such as chemical inertness, zero band gap, and its 2D structure which makes it a material that is difficult to manipulate. These limitations can be overcome by tuning graphene's properties at micro- and nanoscales by chemical functionalization, which introduces defects in graphene's electronic structure [2-4], and by mechanical modifications [5], the so-called graphene "origami", which consists in the control of the 3D structure to tune electronic and mechanical properties of graphene and provides better characterization of 3D graphene.
In the present work, we used the atomic force microscope (AFM) tip to form 3D graphene structures. The technique consists in nanomechanical folding of single-layer graphene deposed on Si substrate by means of cut and push zigzag movements of an AFM tip [6]. Graphene was detached at 4x4 µm square zones and compacted at the top of the 4x4 µm squares. Thus, we created a series of folded multilayer graphene (MLG) structures, which were characterized by Raman spectroscopy, AFM, SEM and TEM. Interestingly, the Raman analysis revealed a 100-time increase of the G-band intensity, compared to the pristine single-layer graphene, and a 10-20 cm^{-1} blue-shift of the 2D-band which kept nearly unimodal Lorentzian shape. TEM study of the cross-section of folded structures showed several dozens of well-organized stacked graphene layers with interlayer distance of 0,36-0,40 nm which exceeds one of graphite (0,323 nm). These data evidence the weak interaction of the layers in the folded structures. In order to control the shape and organization of folded graphene, we are exploring the influence of the various cut and push process parameters, such as the tip force, the zigzag motion speed etc.

References

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Figures

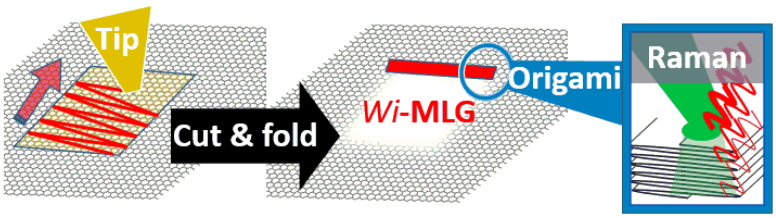

Figure 1: Principle of the AFM tip assisted 3D graphene folding.