Discriminating chemically derived graphene conductivity through Electrostatic Force Microscopy

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In this work we present an Electrostatic Force Microscopy (EFM) study of graphene monolayers obtained by chemical reduction of graphite oxide.

The oxidation-reduction process of graphite is one of the most promising routes for obtaining graphene sheets in large amounts[1]. Once oxidized graphene sheets become highly hydrophilic, thus easily exfoliated in water media. While graphene oxide is a good insulator, deoxygenation leads to a partial recovery of the initial conductivity of graphene[2], indeed controlled reduction allows tuning the conductivity of these sheets[3]. However, dispersion in the published results regarding the conductivity of such obtained layers is very large, probably due to the different preparation methods. The standard procedure to characterize the conductivity of Reduced Graphene Oxide sheets (RGO) usually involves tedious lithography that impedes a quick estimation of the results of the reduction process. This, along with the large scattering in the experimental results, makes highly desirable to develop a fast method for characterizing the conductivity of single layers.

In this work we apply Electrostatic Force Microscopy to measure the electrostatic interaction between chemically reduced graphene oxide monolayers with different levels of reduction (i.e different conductivities) and a metalized EFM tip. Our work is focus on the term of the electrostatic interaction related with the permittivity of the films. The tunable conductivity of the chemically derived graphene layers allows measuring the electrostatic interaction between layers with a wide range of conductivities and a metallic EFM tip. This interaction is found to be dependent on conductivity of the RGO, showing that the electrostatic interaction can discriminate between flakes with conductivities in the range of 0-3 S/m.

Theoretical modeling of the experimental situation[4] allows determining the effective dielectric constant of the layers which span from 5 (for the insulating layers) to 2000. The extreme thinness of graphene combined with its tunable conductivity with chemical reduction is responsible of such an exceptional sensitivity of EFM and represent the limits of the technique. The presented method allows a quick and non-invasive characterization of layers with different conductivities in a wide range without the need of electrical contacts.

References.

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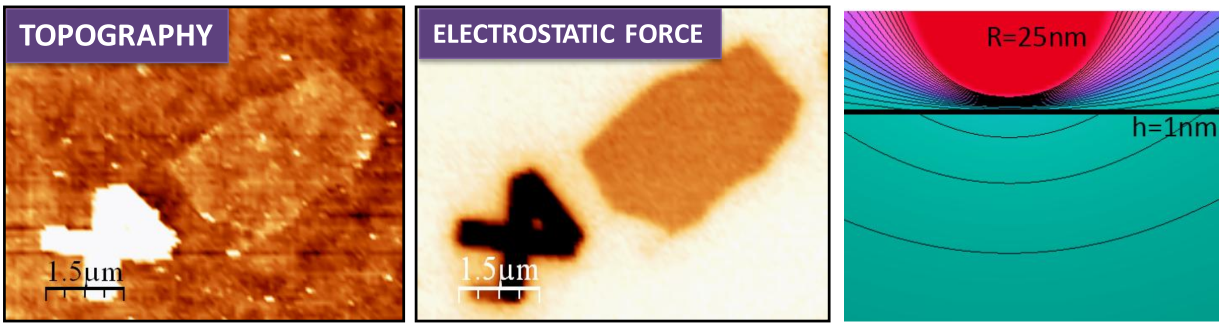

Figure: a) Topographic map of an area including a metal marker and a RGO sheet b) Electrostatic force mapping of the same area depicted in panel a. c) Scheme of a tip near to a graphene sheet on an insulating substrate where the equipotential lines are represented.