Modulated Plasma Treatments for Engineering Graphene

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Abstract
We demonstrate modulated H_2 and O_2 plasma treatments as an effective methodology for engineering graphene properties.
An unprecedented control over the graphene functionalization by hydrogen atoms is demonstrated together with the fine tuning of multi-layer graphene resistivity as well as the transition from metallic to semiconducting behaviour. Experimental results open new perspective for tuning the optical response of graphene in the microwave range where optical and electrical conductivities are strongly correlated [1]. Moreover, modulated hydrogen plasma results in a dry chemical reduction process for healing of the oxygen defects in graphene.
As for the interaction of atomic oxygen with graphene, experimental results suggest the confinement of oxygen modulated plasma functionalization mainly to the outmost graphene layer in a multilayer sample. This makes modulated oxygen plasma an effective route for engineering the surface chemistry of multilayer graphene samples without drastic effects on their conductivity. This finding is important for the application of graphene as transparent conductive layer in photovoltaic devices where high conductivity is needed as well as an engineered surface chemistry for better interfacing other materials [2].

References
[1] M. Grande, G. V. Bianco, M. A. Vincenti, D. De Ceglia, P. Capezzuto, V. Petruzzelli, M. Scalora, G. Bruno, A. D'orazio, Optics Express, 24 (2016) 22789;
[2] L. La Notte, E. Villari, A. L. Palma, A. Sacchetti, M. M. Giangregorio, G. Bruno, A. Di Carlo, G. V. Bianco, A. Reale, Nanoscale, 9 (2017) 62–69:

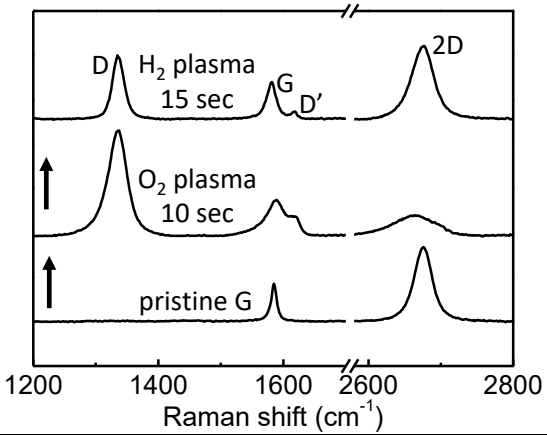

Figure 1: Raman spectra of single layer CVD graphene after controlled plasma oxidation and subsequent reduction by hydrogen plasma treatment.

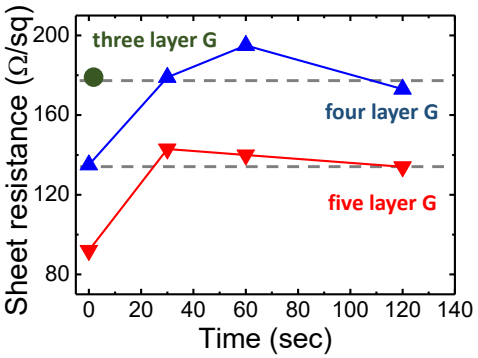

Figure 2: Evolution of the sheet resistance (Rs) of multilayer graphene under plasma treatment for different times. The stabilization of the Rs of a N layer sample to the Rs value of a N-1 layer sample is indicative of the plasma oxidation limited to the outmost layer.

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