Functionalisation of Graphene Surfaces with Downstream Plasma Treatments

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Abstract

Graphene has garnered much interest from the research community due to its unique physical, structural and electronic properties. It has been linked with applications in next generation electronics, sensors and energy storage to name but a few. Central to the realisation of these applications is control over the quality and surface chemistry of graphene. Plasma treatments allow for the introduction of controlled levels of functionalities onto surfaces without the need for wet chemical steps. This makes it a clean, green technique, compatible with industrial processes. Downstream plasmas generate a high density of ionized species, but induced surface damage is minimised due to the absence of an applied bias. Such treatments have previously been reported for adding functionalities to the surface of thin pyrolytic carbon films [1, 2] and for post transfer cleaning of graphene [3].

We report on an adjustable process for the functionalisation of graphene surfaces with a downstream plasma source [4]. The parameters of oxygen plasma treatments are modified such that oxygenated functionalities can be added to the surface of graphene films prepared by chemical vapour deposition in a controlled manner. The nature of induced defects is investigated thoroughly using Raman and x-ray photoelectron spectroscopy. A massive change in the surface properties is observed through the use of contact angle and electrochemical measurements.

We propose the usage of such plasma treatments to facilitate the addition of further functional groups to the surface of graphene. The incorporation of nitrogen in to the graphene lattice by substitution of oxygenated functional groups is demonstrated outlining the validity of this approach for further functionalisation. We show that similar plasma treatments can be applied to other forms of graphene, including graphene oxide powder, allowing for dry functionalisation on a large scale. Preliminary studies indicate that such powders have potential applicability for solar cells and electrocatalysis.

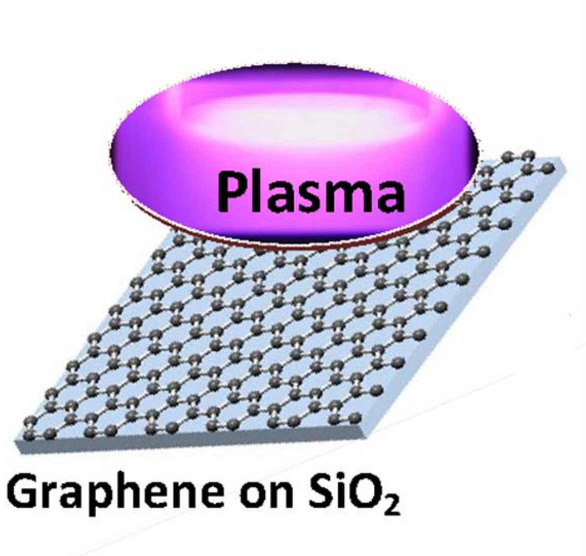
References

[1] G. P. Keeley, N. McEvoy, S. Kumar, N. Peltekis, M. Mausser and G. S. Duesberg, Electrochemistry communications, **8** (2010) 1034-1036

[2] N. McEvoy, N. Peltekis, S. Kumar, E. Rezvani, H. Nolan, G. P. Keeley, W. J. Blau, and G. S. Duesberg, Carbon, **3** (2012) 1216-1226

[3] N. Peltekis, S. Kumar, N. McEvoy, K. Lee, A. Weidlich and G. S. Duesberg, Carbon, **2** (2012), 395-403

[3] N. McEvoy, H. Nolan, N. A. Kumar, T. Hallam, and G. S. Duesberg, Carbon, (2012), accepted for publication, DOI: 10.1016/j.carbon.2012.11.040



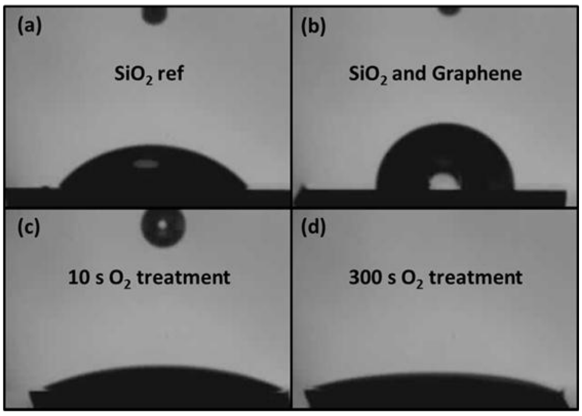
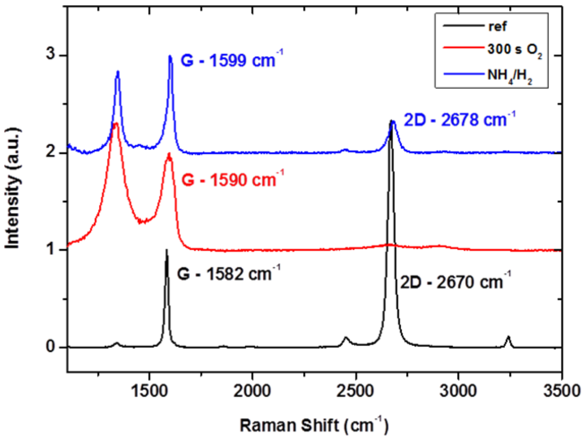


Figure 1: Left – Schematic of graphene plasma treatment, Right – contact angle measurements on as grown and plasma treated graphene samples outlining increased hydrophilicty following treatment.



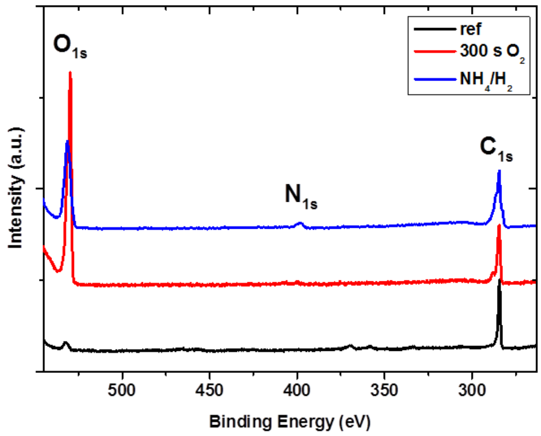


Figure 2: Left – Raman spectra of pristine, oxygen functionalised and partially nitrogen functionalised graphene. Right – corresponding X-ray photoelectron spectra.