Electrochemical Doping of Graphene by Small Molecules

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Background and Significance Field-effect transistors (FET) based on graphene are extremely sensitive to atmospheric gas. This behaviour, also observed in other material systems such as carbon nanotubes and organic semiconductors, is highly unexpected for chemically inert materials. Our work shows that graphene FETs are a sensitive surface probe to electrochemical reactions in aqueous solutions. The conductance minimum at neutrality provides a natural reference to electrically read-out the local electrochemical potential. In the case of nanoscale systems, where cathodic/anodic currents may be exceedingly small, the graphene neutrality point provides increased measurement sensitivity well below the atto Ampere. The use of a hydrophobic substrate, such as parylene, gives improved graphene FET mobility and stability.

Methodology: The graphene-SiO_2 FETs were prepared on a 285 nm thermal SiO_2 on n++ Si. As a first step, a standard photolithography was used to define alignment marks on the substrate, followed by metal evaporation and lift-off. Graphene was then mechanically transferred onto the prepared substrate by exfoliation of natural graphite using an adhesive tape. The graphene flakes were then located and identified as monolayers using a quantitative optical reflection microscopy system. Standard electron beam lithography and lift-off techniques with PMMA as a resist were finally used to fabricate the contact electrodes to the graphene layer. All electrical transport characteristics were measured at room temperature in a variable environment probe station with a base pressure below $5x10^{-7}$ Torr and a gas-handling manifold.

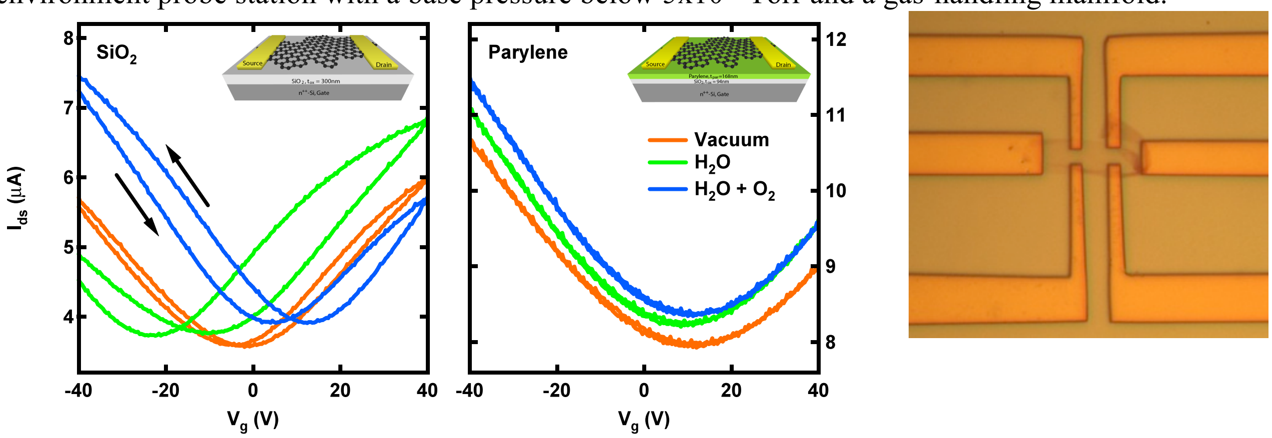

Figure 1: Graphene transistor transfer characteristics in vacuum, in the presence of water and in the presence of water and oxygen for (a) SiO2 substrate and (b) parylene substrate. An optical micrograph (c) of an exfoliated graphene flake contacted by electron beam lithography.

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Selected publications

P.L. Levesque, S.S. Sabri, C.M. Aguirre, J. Guillemette, M. Siaj, P. Desjardins, T. Szkopek, and R. Martel, ``Probing Charge Transfer at Surfaces Using Graphene Transistors", Nano Lett. 11, 132, (2011).

S. Sabri, P. Lévesque, C.M. Aguirre, J. Guillemette, R. Martel and T. Szkopek, ``Graphene Field Effect Transistors with Parylene Dielectric", Appl. Phys. Lett. 95, 242104 (2009).

Conference Talks: S. Sabri, P. Levesque, C.M. Aguirre, J. Guillemette, R. Martel and T. Szkopek, "Graphene Transistors with Parylene Gate Dielectric" Graphene Week, College Park USA, 19-23 April 2010, and others.

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