

Ambient p-doping of CVD graphene

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CVD graphene is a versatile material, which high mobility and large area make it very promising for electronics, touchscreens, optoelectronics, etc. One of the drawbacks of this material is that the transference process always leaves some polymer residues¹. Among other, these defects contribute to shift the Dirac point from 0 V to high voltage. There are several methods for removing those residues, such as heating with Ar/H₂ flux, oxygen plasma treatment or cleaning by an electrical current². In this work, we use the latter procedure of current cleaning in vacuum conditions, and reduce the Dirac point voltage, from high values (above 90 V) to 40 V. We also quantify the p-doping that occurs while removing the sample from vacuum.

The initial material is CVD graphene transferred to SiO₂/doped Si substrate. We use Hall bar structures because they have large area, what is useful for measuring how gases affect the material (fig. 1). The device is then patterned using optical lithography and reactive ion etching (RIE) oxygen plasma. After this step, in some of the samples we deposit a thin layer of aluminum (4 nm thick) via e-beam evaporation under low vacuum conditions. The aluminum is oxidized in ambient conditions after removing the samples from the low vacuum chamber, resulting in an AlO_x layer. Better contrast between graphene and the substrate is achieved after this process. Pads lithography and metal deposition (5 nm Ti/ 50 nm Au) is done for the samples without cap layer. For the samples with cap layer, diluted KOH solution is used after the pads lithography for removing the aluminum oxide layer before the metal deposition. This way we assure that we have a good contact surface. Finally we have two types of sample, very similar except for the cap layer. The doped Si substrate will be used as back gate in both types of samples.

A Janis probe station is used for measuring the different samples at room temperature in vacuum (10⁻⁴ Torr). A 4145B semiconductor parameter analyzer with ICS software is used for programming the time domain measurements as well as the current induced cleaning. A comparison of I/V_G characteristics before and after the current cleaning for two different samples is shown in fig. 2. Once the sample is cleaner, the chamber is exposed to the normal atmosphere. The Dirac point voltage shift is measured in different times. Fig. 3 shows a comparison between capped and uncapped samples. The shift increases very fast until it reaches a saturation limit.

A fit of the data to exponential decay-like functions provides time constants of around 3 minutes for the uncapped layer sample, and 10 minutes for the capped sample, showing that it is more difficult for the gases to contact with graphene when this kind of cap layer is used.

More work is underway to optimize the cap layer (e.g., increasing the thickness of AlO_x), so that graphene may keep the same behavior in vacuum and open air.

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References

- [1] Lin, Y.-C. et al, Nano Letters, **12** (2012) 414-419.
- [2] Moser, J. et al, Applied Physics Letters, **91** (2007) 3.

Figures

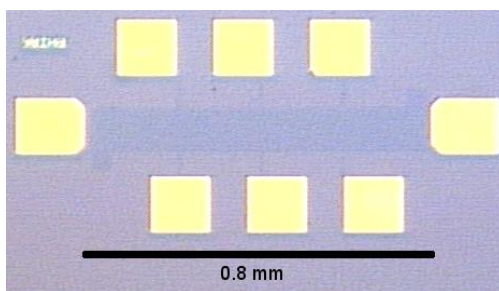


Fig. 1: Device layout

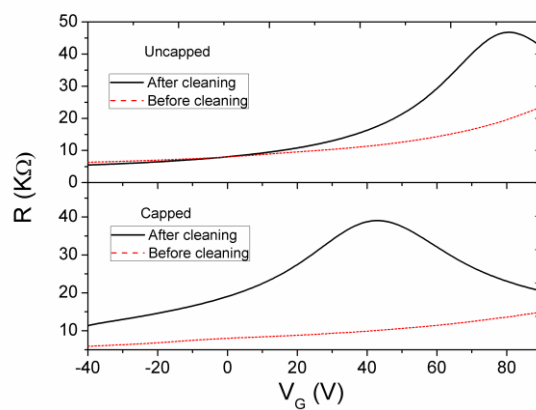


Fig. 2: Comparison before and after the current annealing for the two types of samples

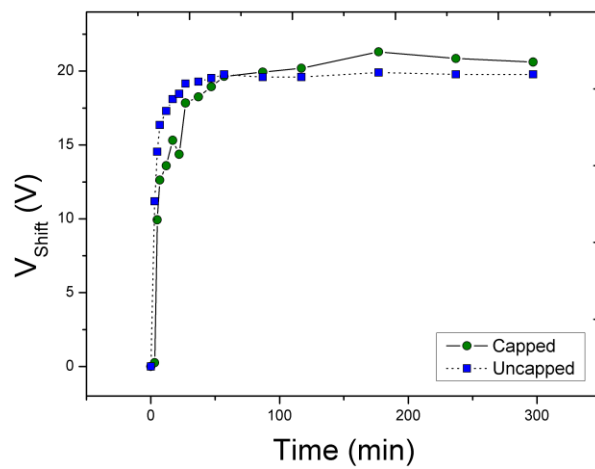


Fig. 3: Dirac Point shift produced by atmospheric p-doping