Graphene nanodevices for environmental and bio-medical sensing

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Graphene devices operating in ambient air face constantly fluctuating atmospheric conditions (*i.e.*, water vapour, CO_2, NO_2, etc.). These polar molecules tend to have a profound effect on the electronic properties and alter the performance of graphene devices. Thus, the combined doping effects from the ambient air and the functionalisation processes must be taken into account when developing graphene based sensor for applications such as food allergen detection.

We perform systematic transport measurement to first investigate the atmospheric doping effects on chemical vapour deposition (CVD) graphene film transferred to silicon dioxide ($Gr/SiO_2/Si$) by changing the environment from vacuum to N_2, relative humidity (R.H.) and ambient air.[1] As shown in Fig. 1a, water vapour and ambient air act as electron acceptors and thus, pristine Hall bar device shows strong p-doping with hole concentration of n_p=1.13×10^{13} cm^{-2} and mobility, μ_p=1600 cm^{2}V^{-1}s^{-1} (Fig. 1b). We then characterise the electronic properties after drop-casting 2M nitric acid, which is a step prerequisite to functionalisation with aqueous solution of 0.02% (3-Aminopropyl) triethoxysilane (APTES). The combined effect of nitric acid and ambient air results in increased hole concentration (n_p=1.31×10^{13} cm^{-2}) with mobility relatively unaffected. However, APTES functionalisation leads to significant reduction in the hole concentration (n_p=0.5×10^{13} cm^{-2}) and increase in mobility (μ_p=2700 cm^{2}V^{-1}s^{-1}). Additionally, heating the sample to 120 °C in ambient air is an effective way of further lowering n_p (0.31×10^{13} cm^{-2}) and can be used to fine-tuning the electronic properties of devices.

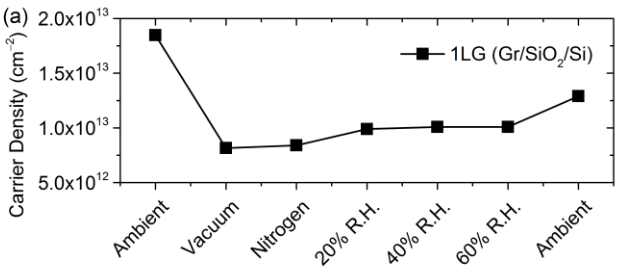
Thus, we systematically demonstrated that environment largely influences the conduction of graphene and the APTES functionalisation process significantly improves the performance of graphene devices. Characterising the impact of air is a crucial step towards developing graphene based environmental and biomedical nanosensors.

References

[1] C. Melios, Carbon, 103 (2016) 273-280

Figures

(a)



(b)

	Hole Carrier Density (cm^{-2})	Carrier Mobility (cm^{2}V^{-1}s^{-1})	Resistance (Ω/□)
Pristine Hall Bar Device (25 °C)	1.13 × 10^{13}	1600	344
2M Nitric Acid Treated (25 °C)	1.31 × 10^{13}	1550	312
0.02% APTES Treated (25 °C)	0.50 × 10^{13}	2720	459
0.02% APTES Treated (120 °C)	0.31 × 10^{13}	2720	740

Figure 1: (a) Carrier density for 1LG in vacuum, N_2, water vapour and ambient air. (b) Table summarising the transport properties of pristine, nitric acid and APTES treated Hall bar devices in ambient air.