Permanent Electrostatic Field-Effect Doping of Graphene

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A graphene transparent conductor in electronic devices could offer broadband transmittance, high mobility and stability, eliminating the need for expensive and unsustainable indium-based alternatives [1,2]. At present, however, graphene's high sheet resistance has limited its use in most applications [2]. Techniques to reduce graphene's sheet resistance have so far resulted in reduced transmittance, mobility and stability [2], or are not viable for large areas [3]. In this work, we present a novel field-effect doping technique that offers the potential for rapid, permanent, stable doping of large-area graphene without impacting transmittance or mobility. Fig.1(a) inset shows the device architecture. CVD-graphene was wet-transferred to a 300 nm SiO_2 dielectric membrane supported by a p-type Si substrate. Positive and negative electrostatic charges were deposited on the SiO_2 membrane in ambient conditions using a point discharge electrode held under constant voltage. Fig.1(a) shows how contact potential difference increases with charging time, suggesting increasing charge density on the membrane. Fig.1(b) shows a 60%abs reduction in graphene sheet resistance after 3 minutes of positive charging. Negative charging was shown to reverse this effect. This implies that the sheet resistance changes due to field-effect doping of the graphene by the charged substrate, shifting its Dirac point. The charge can be permanently embedded in the membrane using K^+ ions, allowing for further reductions in sheet resistance, and multi-decade stability. This could enable monolayer graphene with sheet resistance <50 Ω/□ and transmittance >97%. Moreover, the p-doping effect of negative charge could enable viable p-type transparent conductors, which are currently limited. These innovations offer a clear pathway for graphene transparent conductors in a diverse range of electronic device applications including flexible displays, sensors, next-generation solar cells, and LEDs.

References

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[2] Song, *et al.*, *Nano Today*, vol. 10, no. 6, pp. 681-700, 2015.
[3] W. Shi *et al.*, *Nature Electronics*, vol. 3, no. 2, pp. 99-105, 2020.

Figures

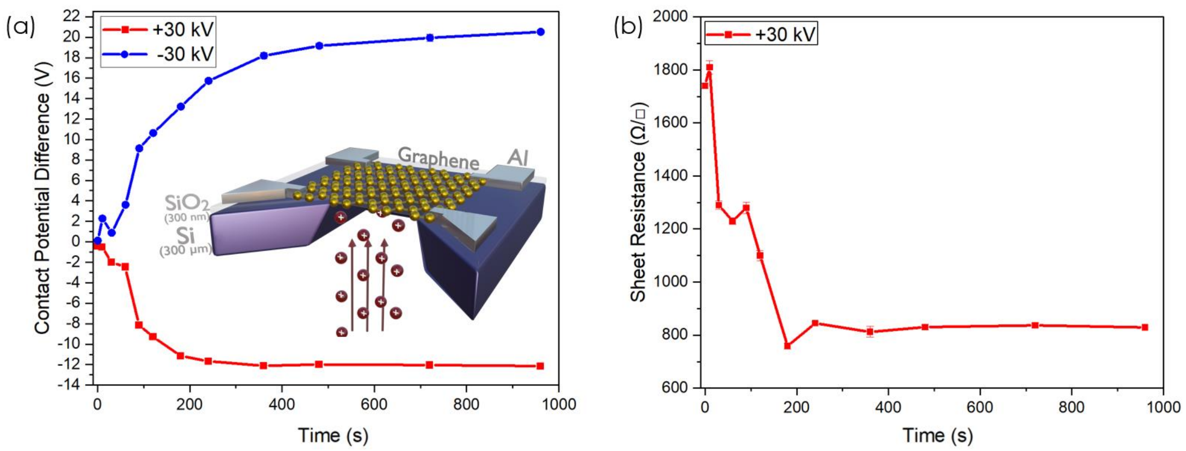

Figure 1: (a) Contact potential difference measured over an SiO_2 membrane as a function of time held under constant ±30 kV voltage. Inset: Schematic of device architecture held under positive charge. (b) Graphene sheet resistance as a function of time held under +30 kV voltage.