Tailoring electrical properties of chemically derived graphene for graphene-based monolithic devices

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Chemically derived graphene exhibits a wide range of electrical and optical properties depending on its chemical structure [1]. The versatile properties of this material suggest that graphene-based monolithic electronic devices can be realized by carefully fine-tuning the chemistry and structure of the material and implementing it into device structures [2,3]. In this contribution, we discuss the dielectric properties of graphene oxide (GO) and its implementation into devices as gate dielectric and non-volatile memory elements.

Graphene oxide is an electrical insulator with large in-plane resistivity (~ 10^{12} Ω/sq) due to strong electronic disorder induced by covalent oxygen functionalization. While many studies have focused on the electrical properties of GO in the in-plane direction, its electrical properties in the out-of-plane direction have received much less attention. Here we show that the out-of-plane electrical properties of GO thin films are highly dependent on film thickness and water adsorption. The dielectric constant was found to vary between 3 and 12 depending on humidity level. The changes in dielectric constant took place immediately when GO was exposed to air from vacuum, reflecting the highly hygroscopic nature of the material. The out-of-plane current-voltage characteristics could be approximated by space-charge-limited conduction and low-bias resistivity increased rapidly with increasing film thickness.

We found that with optimized film thickness, GO thin films exhibit sufficiently high capacitance and low leakage current to be used as a gate dielectric material for field effect devices. We demonstrate operation of monolithic graphene-based top-gated field effect device consisting of partially oxidized graphene (POG) [4] as the channel material and GO as the gate dielectric (Figure 1). We further discuss electrode metal dependence on the electrical behavior of GO thin films and a non-volatile bistable memory effect which we believe arises from electrochemical modification of GO.

Our results demonstrate the viability of using chemically derived graphene as a solution-processable gate dielectric and non-volatile memory material and suggest possibility of further optimization via improved chemical engineering.

References

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Figures

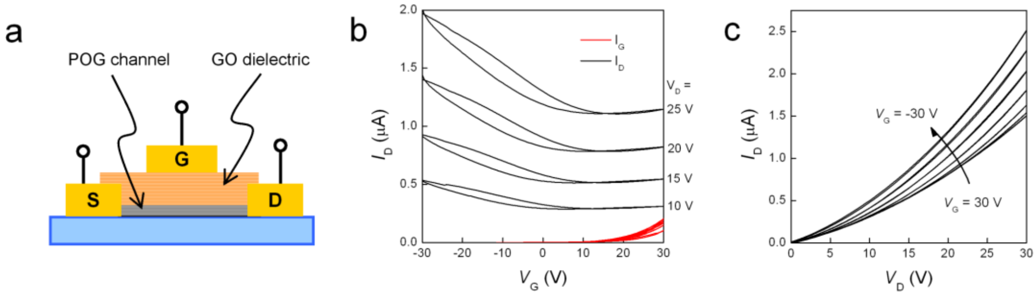

Figure 1 – (a) Structure, (b) transfer and (c) output characteristics of a graphene-based monolithic field effect device consisting of partially oxidized graphene (POG) as the channel and graphene oxide (GO) as the gate dielectric.