Enhancing Electric Field Sensitivity in Graphene Devices by hBN Encapsulation

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Sensing lightning accurately and its early detection is of utmost importance to develop reliable lightning protection systems. Lightning is the discharge of charges accumulated on the cloud to the ground. This accumulation of opposite charges on the cloud and ground results in an electric field between them. Thus to detect lightning, we need to have an efficient electric field sensor. In our previous study, we used graphene device to detect both positive and negative electric fields and established the sensing mechanism [1-2]. In this study, we show that the electric field sensitivity could be enhanced by encapsulating the graphene layer using hexagonal boron nitride (hBN).

The mechanism of electric field sensing lies in the trapping and de-trapping of charge carriers from graphene to the trap sites at the SiO_2/Graphene interface under the application of an external electric field. Such trapping and de-trapping of charge carriers effectively change the carrier concentration in graphene, which in turn changes the drain current. This change in the drain current in the presence of the external electric field is translated as the electric field sensitivity. As one would anticipate, this difference in the drain current with and without the application of the electric field would vary with the strength of the applied electric field. Thus we define the electric field sensitivity (S_{EF}) as the percentage change in the drain current, i.e., $S_{EF} = \frac{|I_{ON}-I_{OFF}|}{I_{OFF}} \times 100$ where I_{ON} is the drain current in the presence of the electric field and I_{OFF} is the drain current in the absence of the electric field. A key strategy to enhance the sensitivity is to increase the mobility of the graphene device. It has already been proved that the encapsulation of graphene with hBN increases mobility [3]. Thus, we fabricated an encapsulated graphene device and tested it for electric field sensing (Fig. 1a). Figure 1b shows the electric field response diagram of the encapsulated device. A clear difference in the drain current is observed in the presence of the electric field. A comparison of the sensitivity of the encapsulated device to that of a pristine graphene device shows that the encapsulation tremendously enhances the sensitivity (Fig. 1c).

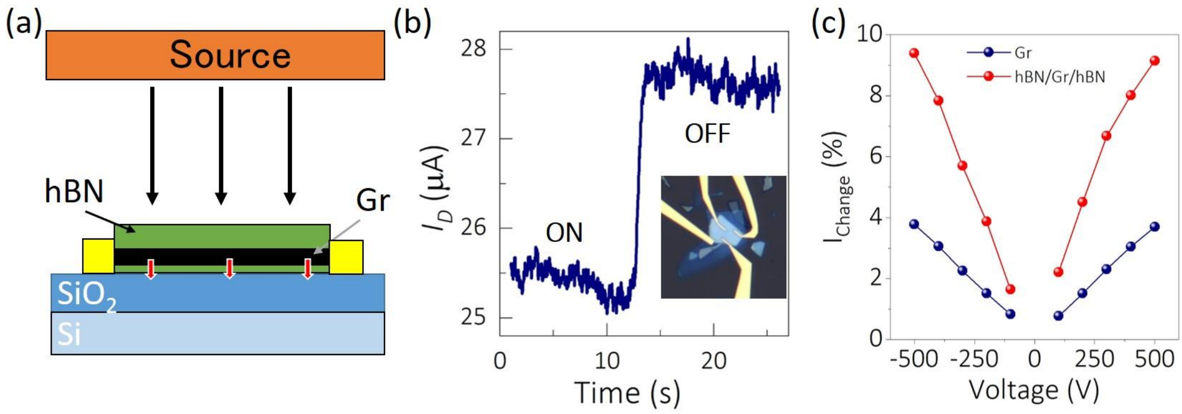

Figure 1: (a) Schematic diagram showing the encapsulated device under an electric field source. (b) Electric field response diagram for encapsulated graphene device. The inset shows the optical micrograph of an encapsulated device. (c) Comparison of electric field sensitivity of the encapsulated device to that of the pristine graphene device. The x-axis shows the potential of the field source at a distance of 3 cm.

References: [1] K. Afsal *et al.*, The 68th JSAP spring meeting, March 16-19, 2021. [2] T. Agari *et al.*, The 68th JSAP spring meeting, March 16-19, 2021. [3] L. Wang *et al.*, Science, 342, 614-617, 2013.

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