Effect of Substrate Doping in Graphene Electric Field Sensor for Thunderbolt Forecast

落雷予知を目的としたグラフェン電界センサにおける基板ドーピング効果

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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 this study, we develop an electric field sensor based on monolayer graphene for both positive and negative electric fields. The mechanism of electric field sensing lies in the charging and discharging of the interface trap states in SiO_2 under the application of an external electric field. Such charging and discharging also changes the carrier density in graphene, leading to a change in the drain current under the application of a drain voltage [1-3].

Figure 1a shows the response of the graphene device for a positive electric field where a field source of 500 V is kept at a working distance of 3 cm. The applied source-drain bias is 100 mV. The application of a positive electric field reduces the drain current as the field shifts the Dirac point towards lower gate voltages resulting in the reduction of the drain current. However, application of a negative electric field increases the drain current as it shifts the Dirac point towards more positive gate voltage, increasing the drain current. We have also found that the sensitivity of graphene electric field sensor varies with the resistivity of the Si substrate. Figure 1c shows the percentage change in the current under a positive electric field for a highly doped Si substrate (resistivity of 1-5 mΩ·cm). Comparing that with the case of graphene electric field sensor fabricated on a lightly doped Si substrate (resistivity of 40-60 Ω·cm). An increase in percentage change of at least one order is observed with the lightly doped substrate. This difference could be due to the change in the number of interface trap states. More details will be presented at the conference.

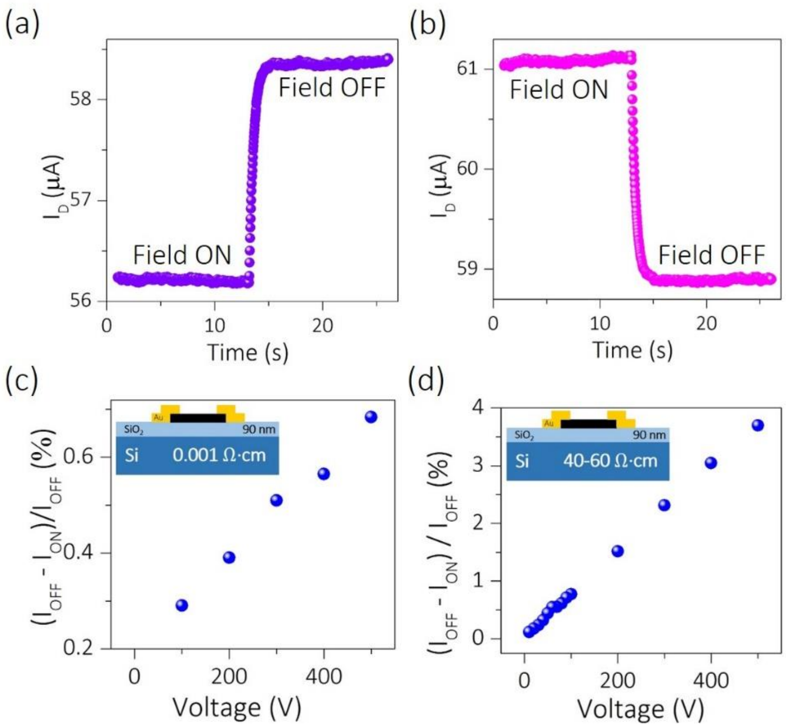

Figure 1: The response of the graphene device for (a) positive and (b) negative electric fields. In both cases, the field source is kept at 500 V with a working distance of 3 cm. Percentage change in the drain current for graphene devices on (c) highly doped Si substrate and (d) lightly doped Si substrate. The source-drain voltage in both the cases in 100 mV.

References: [1] W. Wang *et al.*,IEEE Electron Device Letters, 38, 1136, 2017. [2] Xitao Guo *et al.*,Optica 3, 1066, 2016. [3] L. Tao *et al.*,IEEE Electron Device Letters, 39, 987, 2018.

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