Field Effect Control of Current in Ion Irradiated Graphene and its Application to Transistors

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Abstract

We present a new technique of functionalization of monolayer graphene by applying an ion beam for realization of current on/off switching by gate biasing, which is strongly required for application of graphene to electronics [1]. Atomic size defects are supposed to be generated by applying an accelerated helium ion beam to a graphene sheet (Fig. 1) with a defect density proportional to the applied ion dose [2]. We found that current in the functionalized graphene exhibited exponential decrease as the defect density increased (Fig. 2(a)), and it showed current on/off switching at room temperature with an on/off ratio of two orders of magnitude (Fig. 2(b)). Based on a strong temperature dependence of conductivity and also an exponential dependence of current on the size of irradiated region, we discuss that the mechanism of charge carrier transport control can be understood in terms of transport gap generated by strong localization of electrons due to the scattering of electrons at the defects [3]. We applied this graphene functionalization technique to the channel of dual-gated graphene transistors, in which only graphene between two top gates are irradiated with ion beam (Fig. 3(a)). By controlling the band configuration by independently-biased top gates, we demonstrated transistor operation of current switching with an on/off ratio of almost four-orders of magnitude at 250 K. This device allows fully top-down fabrication process and it can be transferred to the surface of any kinds of substrates, which opens a new way of graphene application to a wide variety of future electronics.

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References

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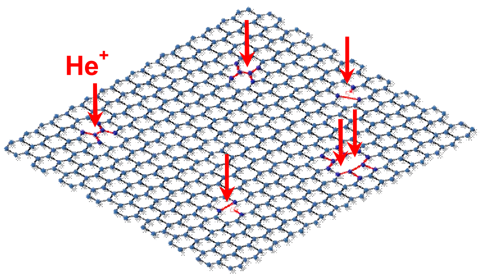

Fig. 1 Schematic illustration of graphene irradiated with helium ion beam with a defect density of 1%.

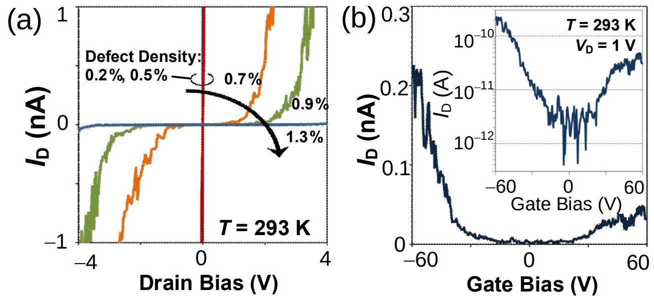

Fig. 2 (a) Drain bias dependence of drain current at different defect density. (b) Back gate bias dependence of drain current. Inset shows a logarithmic plot.

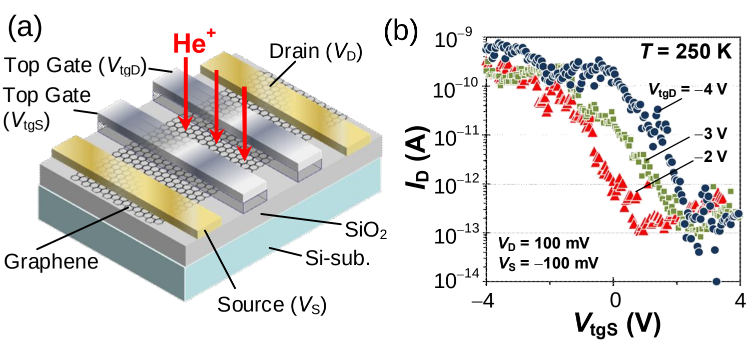

Fig. 3 (a) Device structure of dual-gated graphene transistor. Helium ion beam was applied only between two top gates. (b) Transistor operation at T = 250 K. With fixed bias of the gate of drain side (V_{tgD}), the drain current (I_D) was modulated by the sweeping of the gate bias of source side (V_{tgS}). The maximum on/off ratio was almost four orders of magnitude.