BAND-GAP MODULATION IN GATED BILAYER GRAPHENE

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We present fundamental researches on thin graphite film, with the goal of realizing future nanometer scale electronic applications. The graphite films are expected to be an important element in nano-carbon electronics. For a control of the conduction of the thin graphite channel, gating effect must be fully clarified. Here, we introduce our original gate-structure to efficiently apply gate-voltage to the graphene channel, and discuss energy-gap modulation in gate-electric field.

Our starting materials are thin graphite film (thickness < 10 nm) or bilayer graphene pealed off from bulk graphite on SiO_2/doped-Si substrate. The thin film is connected to two or multiple metallic electrodes. In general, conduction of the graphite can be changed in gate voltage applied to the doped-Si substrate. In this configuration, the gate electric field can be applied from the substrate side (back-gate configuration). Observed resistance in the gate-voltage change shows ambipolar behavior based on clear carrier polarity change.

We also attached a front gate, which was directly formed on the surface of the graphite film. We deposit an Al electrode on the graphite film (Fig.1). The graphite channel and the Al electrode are naturally insulated in air. Then the Al electrode can be used as a front gate. The front gate also changes the conduction of the thin graphite film. A scan of the top gate voltage generates a resistance peak in the ambipolar response. The back gate voltage shifts the ambipolar peak depending on the graphite thickness. The shift is larger in thinner film. The peak shift depending on the thickness is clarified in terms of the inter-layer screening length λ to the electric field in the dual-gated graphite film. We assume that the gate-induced carriers decay exponentially from both surfaces, and that the conductivity in each layer increases proportionally to the induced carrier density. Then the condition for the ambipolar resistance peak in top-gate voltage scan is obtained as a function of back-gate voltage, λ, and the graphite film thickness. Applying this model to the thickness-dependence, we succeeded in estimating a screening length to be 1.2 nm in the thin graphite device.

Based on the screening length obtained in the above experiment, a bilayer film was electrically gated in dual-gate configuration. The effective electric field successfully generated the band-gap depending on the gate-electric field. The observed band-gap depends on the applied electric field, and opens up to 200 meV at 1 V/nm. The existence of the band-gap was confirmed in a conductance measurement depending on the temperature.

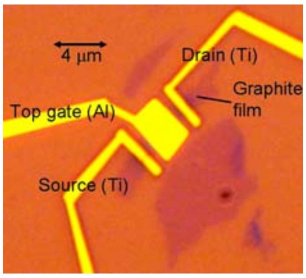

Fig.1 Optical microscope image of a thin graphite film with source-drain electrodes and a Al top gate on SiO_2/Si substrate.