Gate induced band gap for graphene device

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We present fundamental researches on thin graphite film, with the goal of realizing future nanometer scale electronic applications. Because thin graphite films are by nature nanometer scale materials with remarkable electrical conductions, they 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 established an effective gate-structure on graphene channel, and realized band-gap control in gate-electric field modulation.

Our starting materials are thin layers (thickness 1-10 nm) of graphite films 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 by exposed 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 (V_{tg}) generates a resistance peak in the ambiploar response. The back gate voltage (V_{bg}) shifts the ambipolar peak depending on the graphite thickness. The shift is larger in thinner film. The thickness-dependent peak shift 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 V_{tg} scan is obtained as a function of V_{bg}, λ, and the graphite film thickness d. Applying this model to the thickness-dependence, we estimated a screening length of 1.2 nm.

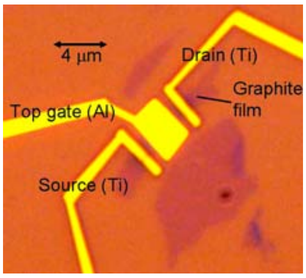

Fig.1 Optical microscope image of a thin graphite film with source-drain electrodes and a Al top gate on SiO_2/Si substrate.

Following the above screening length, 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 gate-tunable band-gap in the graphene will be introduced.