High-performance graphene field-effect transistor and graphene spin-filter with atomically thin MoS_2 tunnel barrier

Nojoon Myoung[1], Kyungchul Seo[1], S. J. Lee,[2] and Gukhyung Ihm[1]

[1] *Department of Physics, Chungnam National University, Daejeon 305-764, Korea*

[2] *QSRC, Dongguk University, Seoul 100-715, Korea*

The excellent electronic properties of monolayer of graphene[1] have inaugurated the way for using layered materials in the post-silicon stage. Various layered structures have been used to fabricate vertical graphene heterostructures as an alternative device flatform based on graphene[2]. Graphene heterostructures with a thin MoS_2 layer are regarded as promising candidate systems for applications. Indeed, high current on/off ratio was observed in graphene/MoS_2 heterostructures. In this report, we present characteristics of tunneling current density through vertically stacked graphene/MoS_2 heterostructure as well as its applications.

We consider heterostructure, which consists of an atomically thin MoS_2 layer sandwiched by graphene as shown in Fig. 1. The MoS_2 layer of the heterostructure becomes a tunnel barrier for Dirac fermions, and both graphene layers play the role of high-quality source and drain electrodes. We can obtain the tunneling current through the MoS_2 insulating barrier as below

$$j\left(V_b, V_G\right) = j_0 \int_{-\infty}^{+\infty} D_S\left(E, V_b\right) D_D\left(E, V_b\right) T\left(E\right) \left[f_S\left(E, V_b, V_G\right) - f_D\left(E, V_b, V_G\right)\right] dE, \quad (1)$$

where $j_0 = \left(qv_F\right) / \left(2\pi L_0^3\right)$. We find the ratio of the tunneling current between an off-state and an on-state up to 10^6 at room temperature.

Moreover, we present not only the improvement in the current on/off ratio of the graphene/MoS_2 heterostructure but also an application of the heterostructure in spintronics by producing spin-dependent transport. First, we show that there emerge current peaks for a graphene/MoS_2/grarphene nanoribbon (GNR) heterostructure. This finding has potential for the use of the current peaks, resulting in the improvement of the current on/off ratio. Second, the existence of magnetic properties in few-layer MoS_2[3] can lead to the spin-polarized current in the graphene heterostructures. We show that the graphene heterostructure can be a perfect spin-filter for holes with the electron-hole asymmetric spin splitting of MoS_2[3].

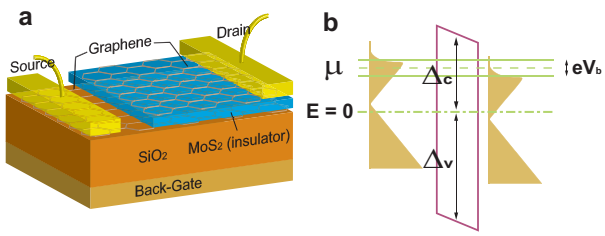

Figure 1: (a) Schematic view of various graphene/MoS_2 heterostructures. (b) Energetic diagram of the quantum tunneling model.

[1] A. H. Castro Neto *et al*, Rev. Mod. Phys. **81**, 109 (2009).
[2] L. Britnell *et al*, Science **335**, 947 (2012).
[3] E. S. Kadantsev, P. Hawrylak, Solid State Commun. **152**, 909 (2012).