**Boltzmann Transport Theory of Graphene Double-Layer Systems**

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**Abstract**

Recent progress in graphene research stimulated the fabrication of new functional electronic devices, which are composed of graphene and atomically-thin materials. One such system is a graphene double layer structure (GDLS), where two graphene layers are separated by a thin dielectric shown in Fig 1 [1, 2]. The GDLS is considered to be a good platform for studying excitonic superfluidity and Coulomb drag effect [3,4,5]. Recently, an optical device using this system was also proposed as an application [6]. These progresses demand to reveal the carrier transport properties on GDLS from theoretical calculation. Our purpose is to find appropriate parameter set which can enhance the carrier mobility.

We have studied the dielectric environment effect on the charged-impurity-limited carrier mobility of the GDLS on the basis of the Boltzmann transport theory [7]. By considering infinite series of the image charges arising from two interfaces at z = 0 and *d* as shown in Fig. 1, we obtained unscreend Coulomb potential which depends on interlayer distance. Moreover, we have taken account of the screening effect within random phase approximation.

We have found that carrier mobility can be enhanced by inserting the high dielectric materials as the middle layer. Figure 2(a) shows the dependence of the mobility on the interlayer distance *d* for three different middle dielectrics. In the large *d* limit, that is $k_F d$ >>1, the carrier mobilities strongly depend on the dielectric constant of middle layer. Figure 2(b) shows $\varepsilon_2$ dependence of the carrier mobility for three different interlayer distances. We can see that the carrier mobility increases with *d* in the region $\varepsilon_2/\varepsilon_3 > 1$, however this trend is reversed when $\varepsilon_2/\varepsilon_3 < 1$. This different tendency can be understood by strong screening effect in $k_F d << 1$. Moreover, we showed that the carrier mobility considerably depend on the carrier density polarization when the dielectric environment are satisfied with $\varepsilon_{1 << } \varepsilon_2 \sim \varepsilon_3$.

Our results reveal that the mobility can be improved by choosing higher dielectric materials as well as the carrier polarization between two layers. These results are served to design atomically thin devices with new functionality.

**References**

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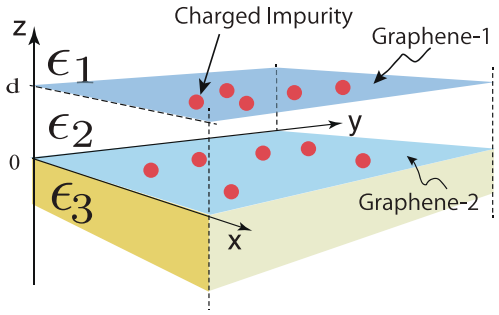


Fig. 1: Schematic of graphene double layer structure with three dielectrics.

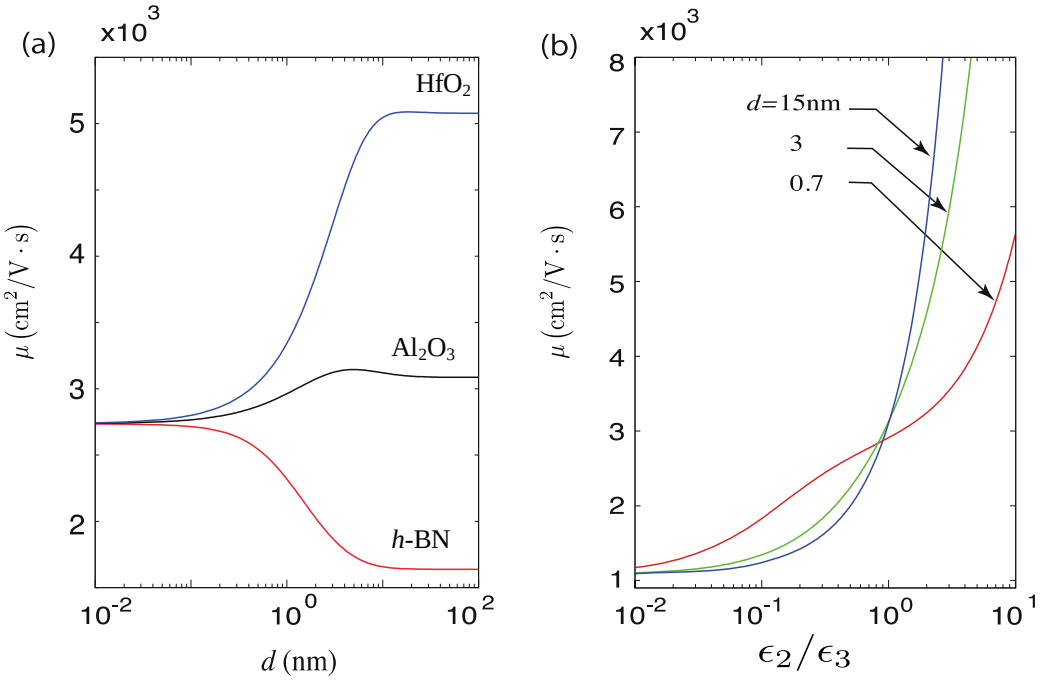


Fig. 2: (a) Interlayer distance of the mobility for three different inner dielectrics, that is, *h*-BN, $Al_2O_3$, and $HfO_2$. (b) Mobility versus inner dielectric constant for different interlayer distance, *d* = 0.7, 3, 15 nm.