Weak Localization and Gas Sensing of Graphene

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Two-dimensional (2D) materials such as graphene and transition metal dichalcogenides have potential applications in electronic devices such as transistors and gas sensors. We have previously developed sensors for the detection of gases such as hydrogen (H_2) and nitrogen dioxide (NO_2) using commercially-available single-layer graphene grown by chemical vapor deposition (CVD). In general, the adsorption of reducing/oxidizing gas molecules onto the p-type graphene surface causes an increase/decrease in the charge carrier density in graphene, which in turn causes a change in electrical resistance. We have also studied the adsorption of gas molecules on exfoliated graphene surfaces by means of the magneto-transport [1] as a powerful tool to study disorder effects and electrical properties of 2D electron systems. The conductance of 2D systems exhibits quantum correction at low temperatures (LT), originating from weak localization (WL). WL is the constructive quantum interference effect produced by electron waves at LT. The interference effect due to time-reversal symmetry is destroyed by application of magnetic field, and a negative magnetoresistance (MR) is observed.

In this study, we examined MR on single-layer CVD graphene, including WL and inhomogeneous charge transport near the charge-neutral point (CNP). Fitting of the negative MR using a theoretical WL expression [2] is performed to investigate the temperature (T) and back gate voltage (V_G) dependence of the inelastic scattering length (L_φ) and intervalley scattering one (L_i). Figure 1 shows the obtained T -dependent L_φ and L_i. The circles and the triangles show L_φ and L_i, respectively. Solid and open symbols represent the results in the electron transport region (V_G = +60 V) and CNP (V_G = -2.9 V), respectively. With increasing T, we observed a decrease in L_φ due to electron-electron (*e*–*e*) interactions. In contrast, L_i did not show significant T dependence. We found that small momentum transfer due to Nyquist scattering was dominant in the CNP region, while large momentum transfer processes of direct *e*-*e* interaction was dominant in the electron transport region.

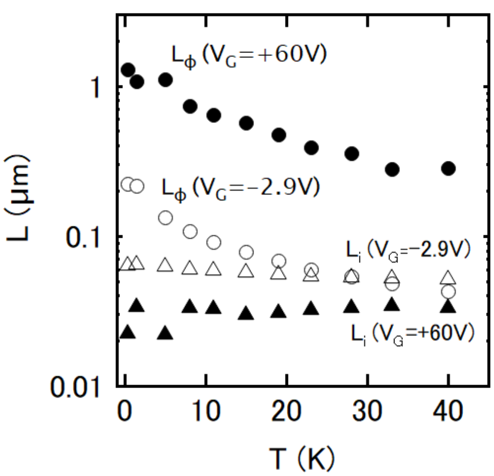

Fig.1. Temperature dependence of the extracted characteristic lengths.

Furthermore, we also investigated the different sensitivities to H_2 gas and NO_2 one for p-type single-layer CVD graphene and MoS_2/graphene van der Waals heterostructures (vdWH). When the *p*-type CVD graphene is exposed to respective H_2 and NO_2 gases, the change rate in resistance was just about 3 % for these gases. These results are consistent with previous study by Schedin *et al.*[3] On the other hand, we found the change rate in resistance of MoS_2/graphene vdWH was approximately 20% for H_2 and NO_2 gases. One of the possible mechanisms of gas adsorption for our vdWH is that MoS_2 acts as an adsorption layer and promotes the change of hole concentration in graphene.

References

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