Quantum Carrier Transport of Highly Disordered Electron System in Epitaxial Graphene on 6H-SiC with As-Grown Defects

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Quantum-mechanical aspects of charge carrier transport in a highly disordered 2D electron system are non-trivial and fascinating in that they can be considered as a measure to estimate the degree of disorder in the system. Graphene is one of the most attractive 2D electron systems to investigate the quantum aspects of carrier transport because its magnetotransport characteristics of pristine high-quality crystalline phase are quite distinct from those of its disordered phase. To date, disordered graphene systems have mostly been prepared by well-defined artificial treatments to produce defects and decorate adatoms on high-quality single crystal. The defects in graphene, however, can also be created during the formation of graphene and their density can be modulated without additional post-treatments provided the graphene synthesis is elaborately controlled. Here, we report temperature-dependent magnetotransport characteristics of disordered epitaxial graphene (EG) films with as-grown defects on 6H-SiC (0001) substrates. The EG films are grown by metal-plate capping method [1], which is a kind of confinement-controlled growth, and the growth parameters are finely adjusted to produce defects with varying densities. The defectiveness and inhomogeneity of grown film are characterized by analyzing D peak (I_D/I_G = ~0.4) in Raman spectrum. Atomic force microscopy (AFM) and scanning tunneling microscopy (STM) images on the EG films present irregular film morphology containing uneven step structures, pits on terraces, and point defects accompanied with relatively small sizes of grains. In magnetoresistance (MR) measurements at temperatures below 250 K, the monotonic negative MRs are observed for a wide range of out-of-plane magnetic field up to 9 T. Remarkably, the analytic fitting of weak localization (WL) correction [2] to the MR data indicates that WL is not completely suppressed even at 3 T below ~120 K despite a quite large carrier density $n > \sim 10^{13}$ cm^{-2}. In temperature-dependent resistivity measurements, the logarithmic increase after passing the minimum resistivity is observed as temperature goes down from room temperature. The temperature of minimum resistivity is T_{min} ~116 K when NO magnetic field is applied. Although the WL correction is considered, the logarithmic behavior still remains with the lowered T_{min} and it is attributed to electron-electron interaction (EEI) or Kondo effect [3]. In the broad temperature range from T_{min} to room temperature, on the other hand, the resistivity is T-linear [4], likely to indicate the dominancy of acoustic phonon scattering. Additionally, we will discuss about how more complex structural irregularity of mono- and bi-layer regions coexisting in an EG film can be manifested in electrical properties of film by proposing an appropriate way for analyzing measured data.

References

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