Correlation between Morphology and Transport Properties of Quasi-free-standing Monolayer Graphene

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Quasi-free-standing monolayer graphene (QFMLG), obtained by intercalating hydrogen at the interface of buffer layer and SiC(0001), is efficiently decoupled from the substrate and a promising material for wafer-scale graphene-based nanoelectronics.[1-3)] However, the mobility of QFMLG (~3000 $cm^2V^{-1}s^{-1}$) is limited to a value lower than exfoliated graphene on SiO_2, and the carrier scattering has not been fully understood. Recently it has been reported that the mobility of QFMLG depends on the substrate temperature during the hydrogen intercalation process, and the highest mobility is obtained at 700-800°C.[4] These measurements suggested that the carrier scattering is mainly caused by charged impurities at 600 and 800°C, and at 950°C defects cause additional scattering. We have used scanning tunneling microscopy (STM), atomic force microscopy (AFM), and transmission electron microscopy (TEM) to study the surface structure of QFMLG formed at several hydrogen intercalation temperatures, and investigated the relationship with transport measurements.

Our STM observations reveal that the QFMLG formed at 600°C and 800°C shows defects (dark spots) with a diameter of 1.5 nm, depth of 15-25 pm (Fig. 1), while samples formed at 1000°C show dark spots with diameter 4-10 nm, depth 250 pm. The dark spots at 600°C and 800°C partially align with a periodicity of 1.8 nm, corresponding to the quasi-(6x6) reconstruction of the buffer layer. This implies that hydrogen intercalation in our samples is not complete at 600°C and 800°C, and the remaining patches of Si dangling bonds are observed as dark spots. Since the depth of the dark spots at 1000°C corresponds to the height of a SiC(0001) bilayer, they are identified as holes in the SiC substrate, probably due to etching by hydrogen at high temperature. In addition, the AFM and TEM observations of the samples formed at 1000°C revealed the formation of wrinkles of graphene. This is consistent with transport measurements and suggests that the incomplete hydrogen intercalation at 600 and 800°C scatters carriers as charged impurities, while the holes in the SiC substrate and wrinkles of graphene at 1000°C act as defects.

A higher mobility of QFMLG could therefore be obtained by optimizing the hydrogen intercalation conditions below the temperature at which holes and wrinkles appear.

References

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