HYDROGEN-INTERCALATED GRAPHENE ON SiC STUDIED BY NONCONTACT SCANNING NONLINEAR DIELECTRIC POTENTIOMETRY

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Graphene can be synthesized on a SiC wafer by a thermal decomposition method. This method has been expected to underlie the fabrication of graphene-based electronic devices, since large-scale monolayer graphene (MLG) can be formed on the wafer. However, the electronic properties of MLG on SiC is different than expected. In particular, the carrier mobility of graphene on SiC has been much lower than an ideal value so far. This is attributed to the existence of a buffer layer between the MLG layer and underlying SiC subsurface. This interfacial layer has a two dimensional honeycomb structure like a graphene layer. The difference is that a part of the carbon atoms in the buffer layer are covalently bonded to the Si atoms on the subsurface. In addition, Si dangling bonds remain at the interface. In this context, hydrogen-intercalation to the interface has been performed in order to obtain quasi-freestanding graphene (QFSG) \(^1\). Hydrogen is expected to decouple the top-layer graphene from the subsurface by eliminating and saturating the interfacial bonds. However, even after hydrogen-intercalation, mobility has not been improved drastically. Recently, it has been pointed out that the charge states at the intercalated interface significantly affect electronic structures and transport in graphene on SiC\(^2\). Therefore, it is important to understand the charge states at the interface in hydrogen-intercalated samples. In this study, we use noncontact scanning nonlinear dielectric potentiometry (NC-SNDP) to investigate the interfacial charge states. NC-SNDP can image topography of a sample surface and potential induced by dipoles in an atomic scale by measuring a tip-sample capacitance\(^3\).

NC-SNDP was used for imaging graphene on a 4H-SiC(0001) substrate. MLG on SiC before hydrogen-intercalation showed a quasi-6×6 super-periodic structure due to the 6√3×6√3-R30° structure of 4H-SiC(0001) subsurface. The potentials were 0.3 to 0.4V. In contrast, after hydrogen-intercalation, flat islands emerged in the topographic image. The heights of these islands were 0.17 nm higher than those of the original super-periodic structure. This height difference is caused by the relaxation of the buffer layer from the subsurface, because this value is almost equivalent to the difference between the interlayer distance of graphene layers and the Si-C bond length. In addition, the flat islands had an almost neutral potential. This implies that the covalent bonds between the buffer layer and subsurface are broken and Si dangling bonds are terminated by hydrogen-intercalation, as expected. However, in a magnified image, we found small shallow depressions on the flat islands. Since these depressions had slightly higher potentials than the surrounding areas, this result suggests that the buffer layer is not perfectly decoupled from the substrate even after hydrogen-intercalation. In addition, there were bright atomic-sized spots in a potential map of the flat islands. The density of these spots are roughly comparable with the estimated density of charged impurities in hydrogen-intercalated samples reported in Ref. 4. Thus, we conclude that the interfacial charge states, which possibly originates from Si dangling bonds persisting after hydrogen-intercalation, can be imaged by NC-SNDP.

References