Nanoscale Analysis of Electronic States of Graphene by using 3D Nano-ESCA

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Devices using graphene as active layers have been actively studied for post-silicon electronics especially in the field of radiofrequency electronics, in order to bridge, so called, THz gap in electrical communications systems. The reason for the choice of graphene as the active layers is its exceptional electronic properties, such as giant carrier mobilities (200,000 cm^2/Vs) and limited density of state near Dirac point.

Unfortunately, however, the principal electronic devices, field-effect transistors using graphene as the channel has never exhibited superior device performances as anticipated. The deteriorated device performances partially originate from unintentional potential variations due to the charge transfer between graphene and substrate or metal electrodes [1].

In the beamtime experiments of the 2011A/B terms, we have focused on the interactions between graphene and substrates, SiC or SiO_2/Si [2]. For instance, epitaxial graphene on SiC is speculated to possesses unintentional potential distribution in lateral directions near the borders between monolayer and bilayer regions, as schematically shown in Fig. 1. This potential distribution arises from electron doping into graphene, which depends on the distance between graphene and SiC substrate. Though this lateral potential distribution is influential to the carrier transport in graphene devices, the details has never been clarified yet.

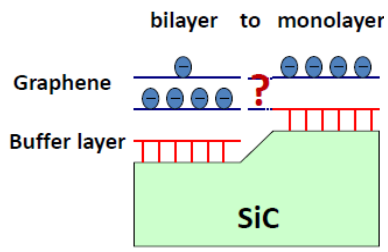

Figure 1. Potential distribution near the boundary.

In order to investigate the local electronic properties, spectromicroscopic techniques are truly powerful tools. Recently, we have developed a new scanning photoelectron microscope (SPEM) system with a depth profiling analysis capability for three-dimensional (3D) spatially resolved electron spectroscopy for chemical analysis (ESCA), called “3D-nanoESCA”[3]. This system is installed at the University-of-Tokyo Materials Science Outstation beamline, BL07LSU, at SPring-8.

In the present study, we have therefore employed nondestructive 3D highly spatial distribution analysis using our 3D-nanoESCA for the definite observation of the interfaces between the epitaxial graphene and SiC.

The epitaxial graphene has been formed on *n*-type 6H-SiC(0001) in Ar-furnace at around 1900 K, following the sample pretreatment in H_2-ambient, which makes the SiC surface flattened. The SiC surface is covered almost by monolayer graphene, but bi- and trilayer graphene also exists, as shown in Fig. 2.

Figure 3 shows C1s line profile across the boundary between monolayer and bilayer regions on 6H-SiC(0001) by using 3D Nano-ESCA. By compairing the deconvoluted C1s core level spectra of monolayer and bilayer graphene, the peaks due to the buffer layer and SiC in bilayer graphene is smaller than those of monolayer graphene. This is of cource explained by the fact that graphene is on buffer layer and SiC [4]. The intensity ratio of buffer layer and SiC is unchanged by the thickness of graphene. This is because the buffer layer, whose thickness is monolayer, is situated between graphene and SiC [4].

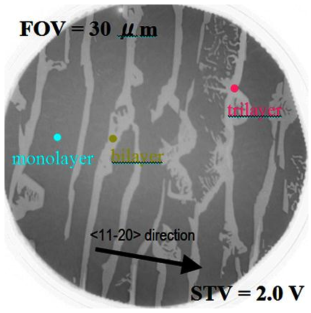

Figure 2. Epitaxial graphene on 6H-SiC(0001) imaged by low energy electron microscopy.

The peak energy of graphene changes across the border between monolayer and bilayer regions, as shown in the right panel of Fig. 3. As pointed out above, this peak shift can be explained by the charge transfers between graphene layers and SiC. There seems to exist relatively long charge transfer region, on the order of μm. The lateral resolution was, however, not good at that time because of the uncertainity of electron energy analyzer and X-ray focus optics. In the next beamtime, we will precisely measure the C1s peak shift with good resolutions.

We are planning to use these results for the precise understanding of field-effect transistor in which the eptaixial graphene fabricated in the same manner is used as the channel, in order to raise the device performance of graphene-based transistors.

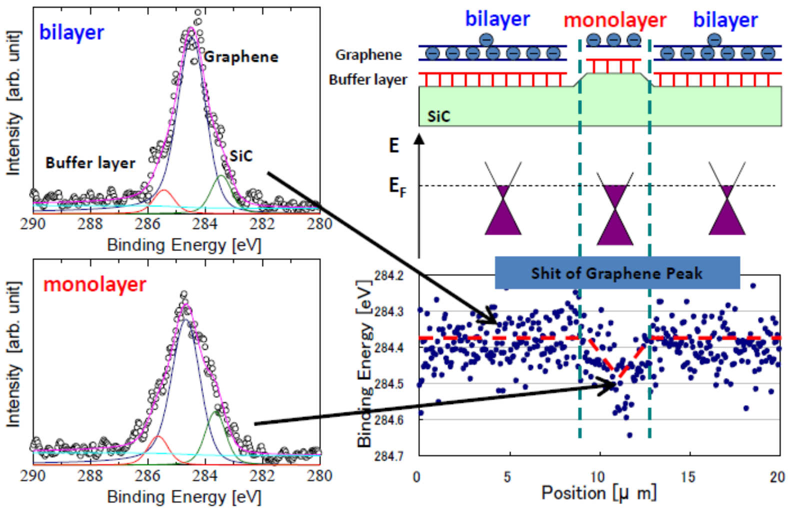

Figure 3. C1s line profile across the boundary between monolayer and bilayer regions on 6H-SiC(0001) by using 3D Nano-ESCA.

References

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