In-situ Observation of Exfoliated-Graphene Transistors by Using 3D Nano ESCA

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Graphene can be the promising material for the next generation devices owing to novel physical properties, e.g. giant carrier mobility (>$10^5 cm^2/Vs$). Graphene-based devices including field-effect transistor (FET) has been extensively studied to succeed the throne of Si in electronics. The current status of device characteristics of graphene FET is, however, restrained from the ideal. One of the reasons for this is on the graphene-metal contact [2, 3]. Mechanistic understanding of the contact, i. e. charge transfer between graphene and metal, is therefore one of the focused issues in graphene device researches. For this purpose, spectromicroscopic studies have been performed. The techniques used in the previous studies, such as scanning photocurrent microscopy [4] and scanning gate microscopy [5] is, however, not adequate means because of the inability to remove the effect of surface carbon contaminations and perform depth-profile analysis [6].

In this study we have employed nanoscale 3D spatial distribution analysis using photoelectron spectroscopy (3D nano-ESCA) for the definite observation of the interfaces in graphene FET, such as graphene-metal [6] and graphene-oxide interfaces.

For the operando analysis of graphene transistors, 3D nano ESCA installed at BL07LSU of SPring-8 was utilized, whose lateral resolution is below 70 nm [7]. In the transistors, exfoliated graphene and Ni thin films were used as the channel and metal electrodes, respectively. The Si substrate with SiO_2 thin film (90 nm) was used as the backgate. In this work, the graphene as well as the backgate were grounded.

The graphene devices are clearly visualized by the elemental mapping (C, Ni, Si) by using 3D NanoESCA, as shown in Fig. 1 [6]. Figure 1(a) shows an optical microscope image of themonolayer graphene sheet attached to Ni electrodes on ahydrophilic SiO_2 thin film (90 nm thickness) on a pt-Si(100)substrate. Figure 1(b) shows the elemental mappingh of the sample taken at the photon energies of 1000 eV. The colored contrast reflects the X-ray photoelectron spectroscopy (XPS) intensity of C 1s peak (graphene, red region in Fig. 1(b)) and Si 2p peak(green in Fig. 1(b)). We can thus distinguish the graphene clearly from the metal electrodes and the SiO_2 substrate region by using the 3D nano-ESCA. The Ni electrode is also clearly visualized as yellow region.

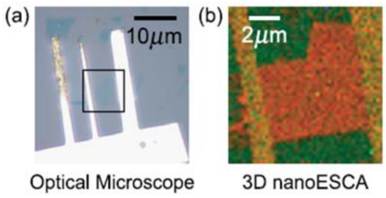

Figure 1 (a) Optical microscope image and (b) elemental mapping of the exfoliated-graphene transistor.

The wide charge transfer region can be formed near the graphene-metal contact owing to the limited density of states of graphene near the Dirac point where the conduction and valence bands touch each other [3, 6]. The charge transfer region is investigated by 3D Nano ESCA, as shown in Fig. 2. On the hydrophilic SiO_2/Si, the wide charge transfer region with a remarkable hole-doping is formed, while the very narrow region with a slight electron-doping is observed on the hydrophobic SiO_2/Si. The results suggest that the charge transfer region is determined by three-dimensional charge transfer consisting of graphene-metal interfacial charge transfer and graphene-oxide interfacial charge transfer.

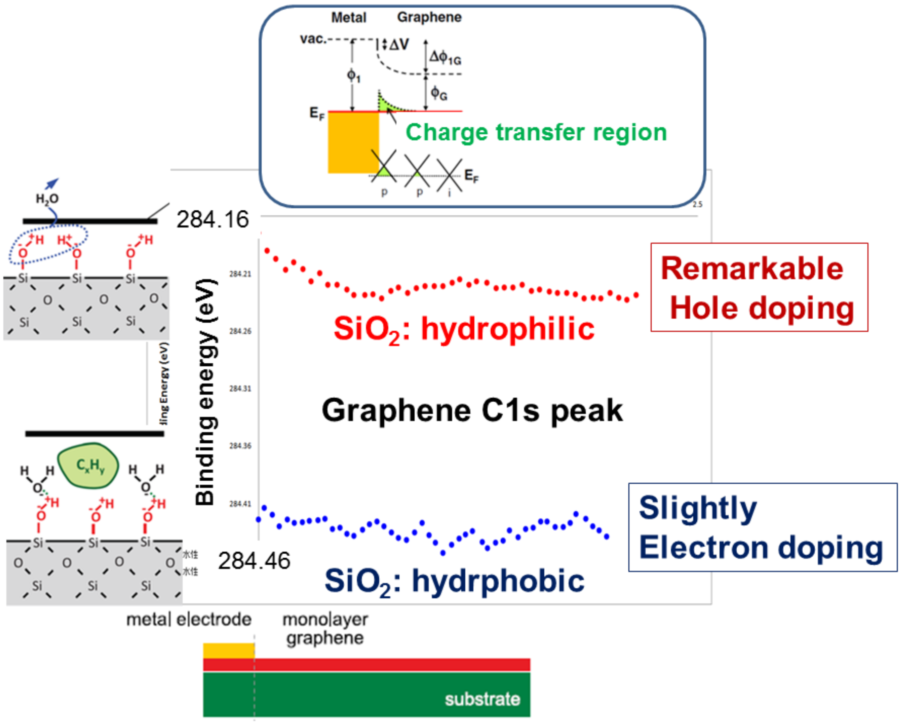

Figure 2 The peak shift of the graphene C1s peak near the graphene metal contact on the hydrophilic and hydrophobic SiO_2/Si.

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