Interface structure between graphene and metal substrates revealed by positron diffraction

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Graphene, a two-dimensional atomic sheet of carbon, is currently of great interest because of many promising features such as extremely high carrier mobility originated from so-called Dirac cone in electronic band structure [1]. Moreover, the graphene has a long spin diffusion length caused by the weak spin-orbit interaction and thus is a good candidate material for spintronics.

The physical properties of graphene adsorbed on substrate change from those of freestanding graphene. Theoretical study shows that the nature of the interaction between graphene and the substrate depends on the actual substrate material and this interaction modulates the shape of the energy dispersion of the Dirac cone [2]. The magnitude of the interaction is closely related to the spacing between the graphene and the substrate. Therefore, the determination of the spacing is important to understand the electronic property of graphene adsorbed on the substrate. In this study, we determined the spacing between the graphene and, the Co and the Cu substrates using total-reflection high-energy positron diffraction (TRHEPD) [3].

TRHEPD is a surface-sensitive tool owing to the positive charge of positron. Fig. 1 shows schematic drawing of experimental setup for TRHEPD. A positron beam incident on a crystal surface at a grazing angle can undergo total reflection at the surface. The penetration depth of the positron beam with an energy of 10 keV is less than approximately 2 Å that corresponds to the thickness of one atomic layer. When the incidence angle is slightly over critical angle for the total reflection, the positron beam reaches the layer just below the topmost layer. Therefore, TRHEPD is suitable for the determination of the atomic configuration of graphene adsorbed onto a substrate. Experiments were carried out at the Slow Positron Facility, KEK, Japan. The readers refer to reference 3 for the details of the experiment.

Figure 2 shows the intensities of the diffracted positrons for the single layer graphene on the Co and the Cu substrates as a function of the incidence angle. The obtained curves for the graphene on the two substrates exhibit different shapes. This suggests that the spacings between the graphene and the two substrates are different. From the analysis of the intensities of the diffracted positrons based on the dynamical diffraction theory, the spacing between the graphene layer and the Co and Cu substrates are estimated as 2.06 Å and 3.35 Å, respectively, as shown in Fig. 3. The spacing for the Co substrate is much smaller than that for the Cu substrate which is close to the interlayer spacing in graphite. This indicates that the graphene on the Co substrate interacts strongly with the substrate as compared with that on the Cu substrate. This study will promote a better understanding of the interface properties of the graphene and substrates.

References
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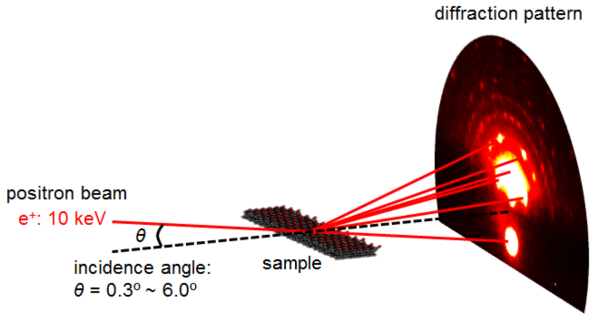

Fig.1 Schematic drawing of experimental setup for TRHEPD.

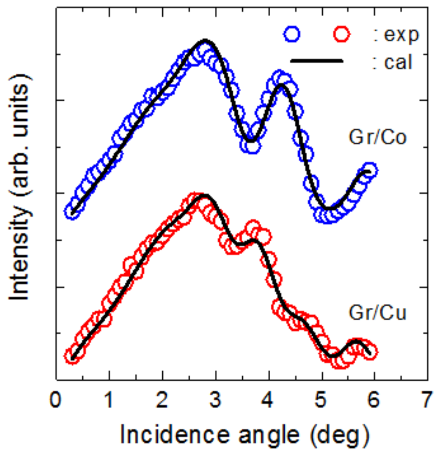

Fig.2 Intensities of diffracted positrons for graphene (Gr) on the Co (upper) and the Cu (lower) substrates. Open circles and solid lines indicate the experimental data and the calculated intensities, respectively.

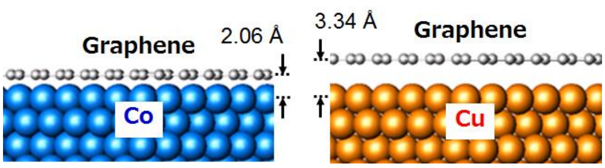

Fig.3 Schematic drawings of graphene on the Co (left) and Cu (right) substrates. Gray circles indicate the carbon atoms. Blue and orange circles do the Co and Cu atoms, respectively.