Atomic Resolved Imaging of Nanostructures on Graphene by TEM

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Graphene has been attracting intensive interest by virtue of its many unique and exceptional structural, optical, and electrical properties based on a perfect two-dimensional (2D) structure and on its sp^2-bonded carbon atoms[1]. The number of layers affects the electronic properties of graphene due to its unique band structure, called a Dirac corn. Raman spectroscopy is a key diagnostic tool for identifying the number of graphene layers and obtaining their physical properties. In this presentation, we report moiré structures in transmission electron microscopy (TEM) observations; these are signature patterns in multilayer, although Raman spectra showed the typical intensity of the 2D/G peak in the monolayer.

Graphene films were grown by a CVD method on a copper substrate (purity 99.8%, thickness 25 μm; Alfa Aesar). After etching the Cu substrate with 100 mM ammonium peroxodisulfate solution, the specimen was rinsed thoroughly with distilled water. Next, it was transferred onto a carbon-supported Cu TEM grid. TEM measurements were made continuously over the monolayer graphene area, using an FEI Titan Cubed 60-300 TEM equipped with image correctors. The TEM was operated at 80 kV with a monochromator for HRTEM imaging to reduce the knock-on damage by electron beam irradiation.

We examined the atomic-resolution TEM images of the graphene membranes characterized as a monolayer graphene by Raman measurement. The HRTEM image revealed the Moiré pattern in the graphene membranes. The TEM image revealed that each graphene membrane was stacked toward the three-dimensional direction [2]. Thus, we observed two layers of graphene groups in the monolayer graphene area. We also performed a multi-slice TEM image simulation using MactempasX software to compare the 3D atomic structures of the two graphene membranes and the experimental HRTEM images. We found that the experimental Moiré image was constructed with a 12 Å interlayer distance between the graphene membranes. Normally, the interval between graphene membranes in graphite is 3.4 Å. Thus, the wide-interval graphene bilayer was treated as two ‘monolayer’ graphene membranes in the Raman measurements. This structure was constructed by CVD-grown graphene films, formed on both sides of the Cu substrate. Some residues were contaminated by the Cu etching process, trapped by each graphene film, and held the interlayer distance [3]. After graphene etching on the reverse side by acid treatment, we barely observed the Moiré pattern in the monolayer graphene area. We demonstrated that two-monolayer graphene was formed by the CVD graphene transfer.

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References

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