3D imaging of monolayer graphene ripple using TEM

Segawa, Y.[1]

[1] Division of Applied Physics, Graduate School of Engineering, Hokkaido University, Japan

Graphene, a 2D crystal with a monolayer of carbon atoms, is reported not to be completely flat, but to have a wavy ripple structure as revealed by TEM-electron-diffraction patterns in reciprocal space [1]. Here we present a new method of imaging 3D ripple structures of monolayer graphene using a single shot of a 2D TEM image in real space. The basic idea is that the 2D TEM image of the ripple structure locally includes depth information in the Z direction. In a 2D crystal such as graphene, since it is unnecessary to consider that the electron beam propagates through the crystal, the contrast is reflected only in the depth information.

Graphene was grown on Cu substrates by chemical vapor deposition (CVD) [2]. After the Cu substrates were removed in ammonium persulfate solution by etching, graphene was transferred to a Quantifoil holey carbon film TEM grid (R1.2/1.3 Cu 400 mesh). Free-standing monolayer graphene was observed using aberration-corrected TEM/STEM (FEI TITAN cubed G2 60-300, 80 kV). The observed TEM image was filtered to reduce noise and extract the structure of a six-membered ring. The height at each point of the 2D-TEM image was obtained by locally comparing the image simulated with a 0.1 nm height step and the filtered TEM image using the normalized cross-correlation value.

Figure 1 shows an example of the result obtained. Figure 1A is a filtered 2D TEM image showing uneven contrast due to height differences. Figure 1B shows the reconstructed 3D ripple structure and contour map in real space using Figure 1A. We revealed an approximately 1 nm structure in a large (5 nm × 5 nm) area. The proposed method can be applied to detect spatiotemporal ripple structures.

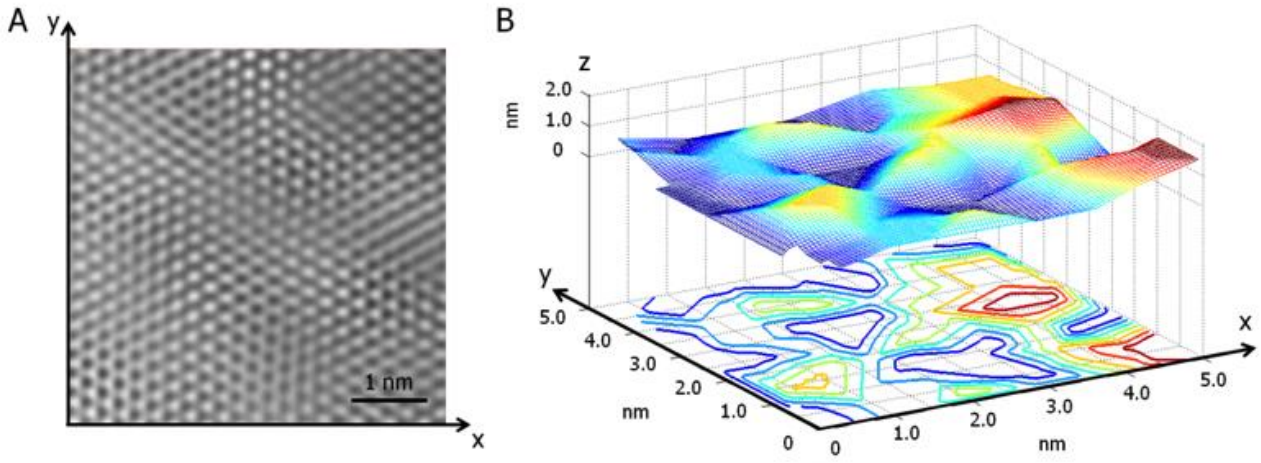

Figure 1. A: Filtered 2D TEM image of free-standing monolayer graphene
B: Reconstructed 3D ripple structure and contour map

[1] Meyer, Jannik C., *et al. Nature* **446**. (2007): 60-63.

[2] K. Yamazaki, *et al. J. Phys. Soc. Jpn.* in press.

This work was supported by JSPS Grant-in-Aid for Science Research on Innovative Areas "3D Active-Site Science": Grant Number 26105009.