Type of presentation: Oral

IT-11-O-1798 Low-voltage electron diffraction microscopy of multi-layer graphene

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The electron microscope is a commonly used to obtain atomic resolution images of materials; however, for light-element materials, radiation damage by an irradiated electron beam is a serious problem. Although transmission electron microscopes (TEMs) and scanning transmission electron microscopes (STEMs) are frequently used to analyse specimens at atomic resolutions, aberration correctors for electron beam at low acceleration voltage (below the threshold voltage of light-element materials) are still under development.

To obtain atomic resolution images without causing serious damage to the specimen, we have investigated a diffractive imaging method [1-6] by using a low-voltage electron beam [7-9], and we have developed a dedicated electron diffraction microscope based on a conventional scanning electron microscope (SEM) [8]. At an acceleration voltage of 30 kV, structure analysis of single-wall carbon nanotube (SWCNT) at atomic resolutions was achieved by diffractive imaging [9], which reconstructs an image of a specimen's structure from experimentally recorded diffraction patterns via iterative phase retrieval (Fig. 1). In this study, we applied the diffractive imaging method to atomic arrangement analysis of multi-layer graphene.

Figure 2 shows a reconstructed pattern of graphene from a diffraction pattern recorded at 20 kV. Atomic arrangement of multi-layer graphene is reconstructed. From the intensity distribution in reconstructed pattern and intensity ratio between (10) and (11) spots in the diffraction pattern, we concluded that this graphene is bi-layer with AB stacking or tri-layer with ABA stacking. For further identification, detailed analysis of intensity profile is required.

[1] D. Sayer, Acta Crystallogr. A5 (1952) 843.

[2] R.W. Gerchberg, and W.O. Saxton, Optik 35 (1972) 237.

[3] J.R. Fienup, Appl. Opt. 23 (1982) 2758.

[4] J. Miao, P. Charalambous, J. Kirz, and D. Sayre, Nature 400 (1999) 342.

[5] U. Weierstall, Q. Chen, J.C.H. Spence, M.R. Howells, M. Isaacson, and R.R. Panepucci, Ultramicroscopy 90 (2002) 171.

[6] J.M. Zuo, I. Vartanyants, M. Gao, R. Zhang, Miao, and L.A. Nagahara, Science 300 (2003) 1419.

[7] O. Kamimura, K. Kawahara, T. Doi, T. Dobashi, T. Abe, and K. Gohara, Appl. Phys. Lett. 92 (2008) 024106.

[8] O. Kamimura, T. Dobashi, K. Kawahara, T. Abe, and K. Gohara, Ultramicroscopy 110 (2010) 130.

[9] O. Kamimura, Y. Maehara, T. Dobashi, and K. Gohara, Appl. Phys. Lett. 98 (2011) 174103.

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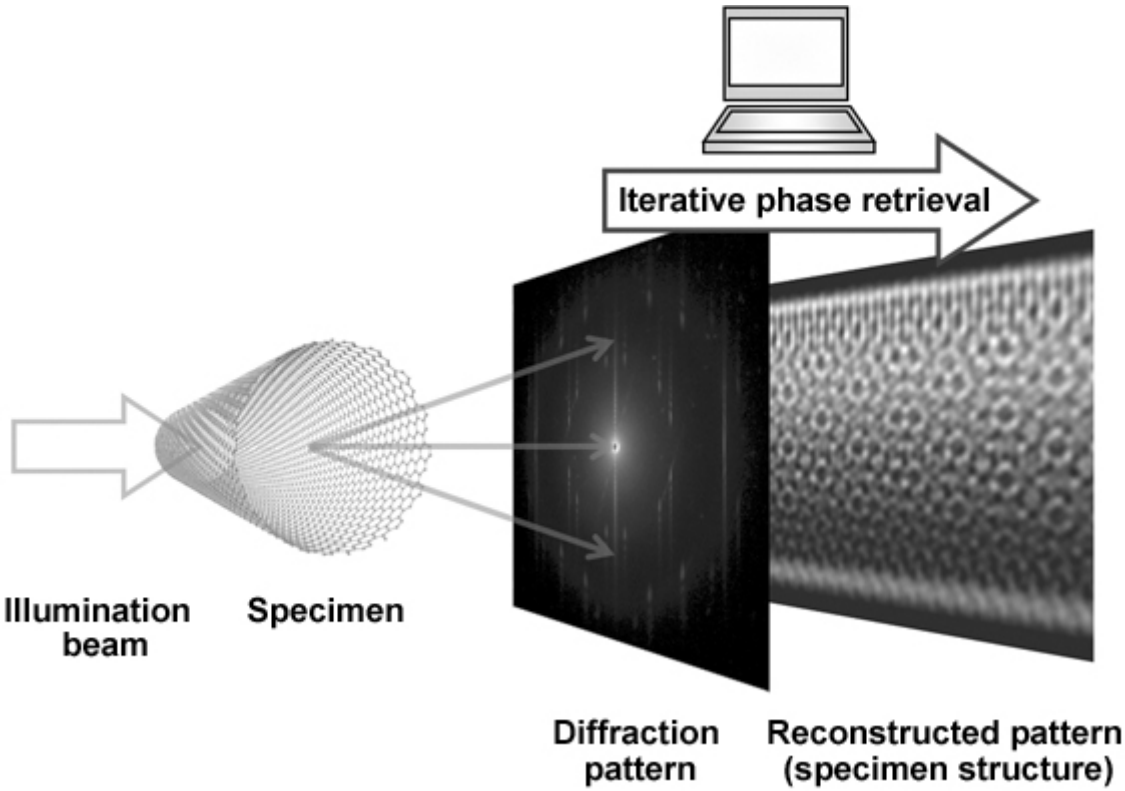

Fig. 1: Schematic diagram of diffractive imaging(specimen: SWCNT). Diffraction pattern is recorded without projecting back-focal plane of objective lens. Specimen structure is reconstructed via iterative phase retrieval (computer processing).

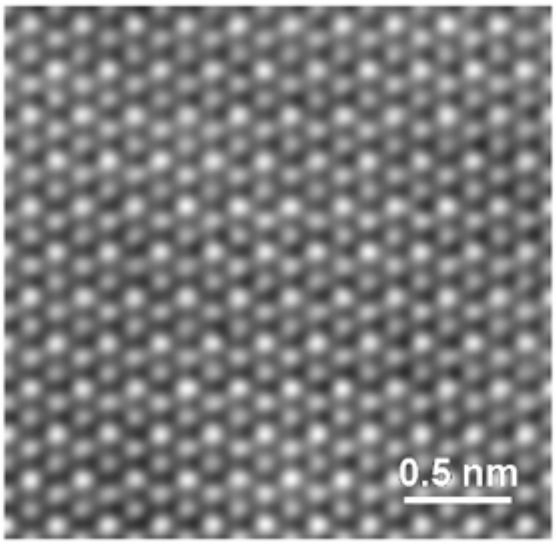

Fig. 2: Reconstructed pattern of multi-layer graphene from 20 kV diffraction pattern.