Growth of boron-doped graphene by thermal decomposition of B_4C

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Graphene, a one-atom-thin carbon material with a honeycomb structure, is attracting extensive researchers after its discovery. It is widely known that wafer-scale graphene can be grown by thermal decomposition of silicon carbide [1]. In this case, annealing the SiC single crystal in a vacuum or in an argon atmosphere leads to the selective sublimation of the silicon atoms, and the remaining carbon atoms form graphene spontaneously on the semi-insulating SiC substrate. This is because the silicon atom is relatively easy to sublimate in a vacuum at high temperatures compared with the carbon atom. This face suggests that graphene can be grown by thermal decomposition of other carbides. In this study, we grew graphene by thermal decomposition of B_4C and investigated its features by high-resolution transmission electron microscope (HRTEM) observations.

We used B_4C particles for graphitization. B_4C particles with their size of about 0.5 μm were annealed at 1600~1900 ºC in a vacuum furnace (~10^{-4} Torr). Transmission electron microscope (TEM) observations and electron energy loss spectroscopy (EELS) measurements were carried out using Topcon EM-002B-, JEM-2010F- and ARM200F-type TEMs at an accelerating voltage of 200 kV.

Figure 1 shows an HRTEM image of graphene grown at 1700 ºC. Graphene layers were observed as dark line contrasts. In the B_4C area in this image, B_{12} clusters can be seen as bright dots. As is seen in the image, graphene layers were grown on the two-dimensional (003) plane consisting of B_{12} clusters. Graphene was also grown on (101) and (-102) surfaces. Figure 2 shows a low-magnification image of graphene on B_4C, together with its carbon and boron mapping images analyzed by EELS measurement. In graphene region, boron atoms were clearly present, suggesting that boron atoms were doped into graphene lattice. Our EELS spectrum obtained from graphene region had a strong boron peak. This is the direct evidence of doped boron in graphene layers.

References:
[1] W. Norimatsu and M. Kusunoki, Phys. Rev. B. **81**, 161410 (2010).
[2] W. Norimatsu, K. Hirata and M. Kusunoki, *J. Phys.: Condens. Matter*, **24**, 314207 (2012).

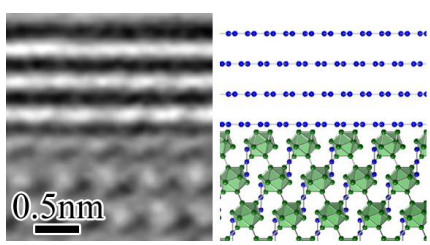

Fig. 1: TEM micrograph and its model of graphene grown on B_4C.

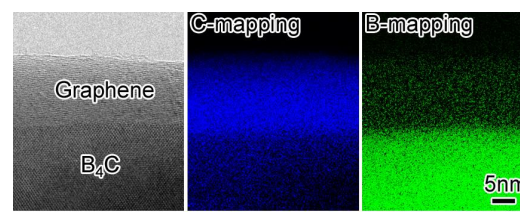

Fig. 2: TEM images and C- and B-mapping images obtained by EELS analysis.