Fabrication of graphene/Mo_2C/SiC heterostructure and its electrical states

Takuya Kamimura[1], Takahiro Ito[2], Akinobu Kanda[3], Hiroki Hibino[4],Wataru Norimatsu[1]

[1] Faculty of Science and Engineering, Waseda University, Japan
[2] Nagoya University Synchrotron Radiation Research Center (NUSR), Nagoya University, Japan
[3] Department of Physics, Faculty of Pure and Applied Sciences, University of Tsukuba, Japan
[4] School of Engineering, Kwansei Gakuin University, Japan

Graphene/superconductor interfaces are expected to host unique quantum phenomena, such as proximity-induced superconductivity in graphene. In this study, we focus on hexagonal Mo_2C, which exhibits a superconducting transition at approximately 3.2 K [1] and has also been proposed as a candidate of a topological superconductor because of its fourfold-degenerate nodal line crossing the Fermi level. Since the lattice constant of hexagonal Mo_2C (a = 3.01 Å) is close to that of 4H-SiC (a = 3.08 Å), epitaxial growth of Mo_2C on SiC is expected. In our previous studies, TiC and B_4C thin films were formed on SiC substrates, and graphene was subsequently synthesized on their surfaces by thermal decomposition of the carbides [2,3]. Based on these backgrounds, we grew a Mo_2C thin film on a 4H-SiC single-crystal substrate, followed by graphene growth by thermal decomposition of Mo_2C. We then investigated the surface electronic structure of the graphene/Mo_2C/SiC heterostructure.

Mo_2C thin film was deposited on the 4H-SiC(000$\bar{1}$) substrate by the pulsed laser deposition technique. The substrate was then heated at 1650°C under vacuum (2×10^{-5} Pa) to fabricate a graphene/Mo_2C/SiC heterostructure. The samples were characterized by atomic force microscopy (AFM), reflection high-energy electron diffraction (RHEED), low-energy electron diffraction (LEED), low-energy electron microscopy (LEEM), and angle-resolved photoemission spectroscopy (ARPES).

Our analysis revealed that the orientation relation between Mo_2C and SiC was $(0001)_{Mo2C}//(000\bar{1})_{SiC}$, $[11\bar{2}0]_{Mo2C}//[11\bar{2}0]_{SiC}$. Graphene was grown with multiple orientations of 0°, 15°, 30°, and 45° with respect to the SiC substrate. Figure 1 is the ARPES image of the graphene/Mo_2C/SiC sample. The E-k image exhibited a clear Dirac cone near the K point of graphene, with the Dirac point located approximately 0.4 eV below the Fermi level, indicating electron doping in graphene. It includes multiple Dirac cones due to different graphene orientations. In addition to the bands due to graphene, some bands convex downward were observed around the Γ point, which can be explained by the band structure of Mo_2C.

References:
[1] T. Shang *et al.*, Phys. Rev. B **110**, 064510 (2024).
[2] K. Kimura *et al.*, Phys. Rev. B **87**, 075431 (2013).
[3] W. Norimatsu *et al.*, Nanotechnol. **31**, 145711 (2020).

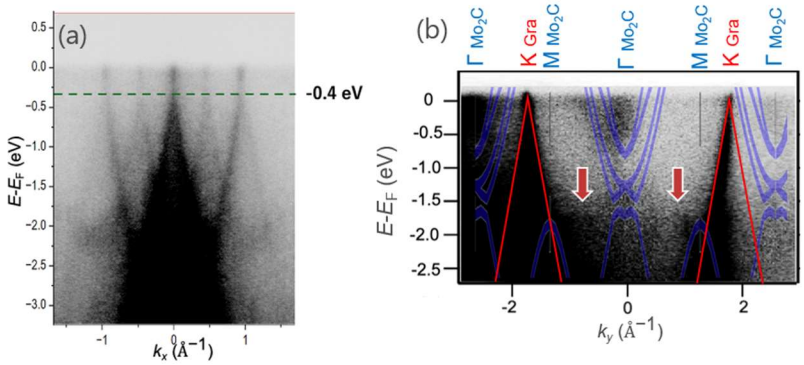

Fig. 1: ARPES images of the graphene/Mo_2C/SiC sample. (a) E-k_x image near the K point of graphene. (b) E-k_y image along the K-Γ-K line of graphene. The band structures of graphene and the Mo_2C(0001) surface, obtained by first-principles calculations, are overlaid by red and blue lines, respectively. The red arrows indicate bands that do not belong to either Mo_2C or graphene.