Scanning tunneling microscopy and angle-resolved photoelectron spectroscopy studies of graphene on SiC (C-face) substrate grown by Si flux-assisted molecular beam epitaxy

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Abstract

Si flux-assisted MBE is a promising technique to grow low thickness graphene on SiC (C-face) with relatively large domain size. By utilizing a high-flux solid Si effusion cell, the sublimation of Si atoms is compensated thereby avoiding graphitization during MBE performed at high growth temperatures (above ~1100°C). The structural and electronic properties of the Si flux-assisted MBE grown monolayer and bilayer graphene samples were characterized by scanning tunneling microscopy (STM) and angle-resolved photoelectron spectroscopy (ARPES). STM overview images, such as in Fig. 1a, depict relatively larger domains (a few hundred nanometers) as compared to samples grown by standard graphitization.[1,2] Moiré patterns of different periodicities were observed confirming the rotational disorder (although with some preferred orientation) present in graphene/SiC (C-face) as also evidenced in the LEED pattern. Figures 1b and 1c are representative STM images of Moiré patterns with the smallest (0.79 nm) and largest (9.6 nm) periodicities which correspond to 17.9° and 1.5° angle of rotation between two adjacent graphene layers, respectively. Atomic resolution STM images reveal the honeycomb structure of the surface graphene layer which implies decoupled graphene layers as exemplified in Fig. 1d.

High energy and k-space resolution ARPES results show linear dispersion in the vicinity of the Fermi energy at the **K** points of the surface Brillouin zone.[3] The SiC substrate induces a strong doping by charge transfer, with a Dirac point located 320 meV below the Fermi level for monolayer graphene as shown in Fig. 2a. The efficient screening by the successive graphene layers results in a reduction of this value to 190 meV for bilayer graphene as depicted in Fig. 2b. The opening of an energy band gap, whose width is inversely dependent on the thickness, is also reported. These measurements emphasize the potentialities of the Si-flux assisted MBE technique, more particularly for homogeneous low thickness graphene growth on the C-face of SiC.

References

[1] F. Varchon, P. Mallet, L. Magaud, and J.-Y. Veuillen, Phys. Rev. B 77, 165415 (2008).
[2] F. Hiebel, P. Mallet, L. Magaud, and J.-Y. Veuillen, Phys. Rev. B 80, 235429 (2009).
[3] E. Moreau, S. Godey, X. Wallart, I. Razado-Colambo, J. Avila, M.-C. Asensio, and D. Vignaud, Phys. Rev. B 88, 075406 (2013).

Figures

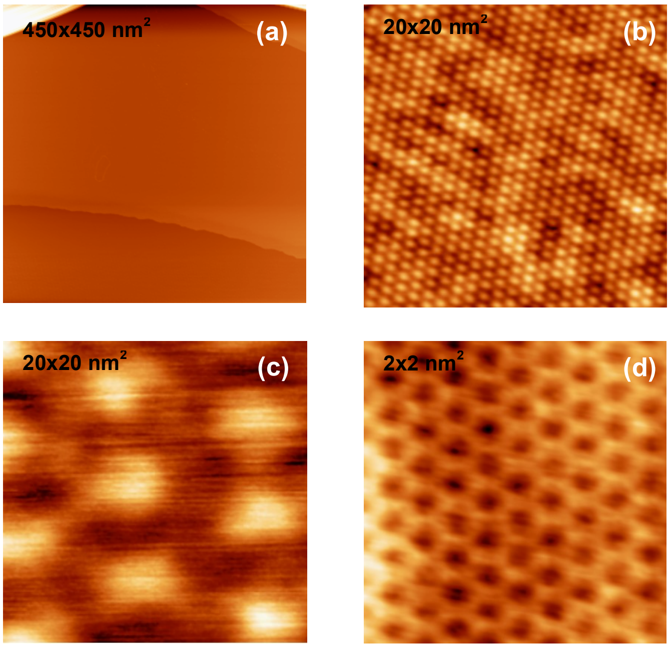

Figure 1. a) STM overview image of a monolayer graphene sample. b)-c) Moiré patterns of periods 0.79 nm and 9.6 nm which correspond to 17.9° and 1.5° relative rotation between two stacked graphene layers, respectively. d) Atomic resolution image showing the honeycomb structure of graphene.

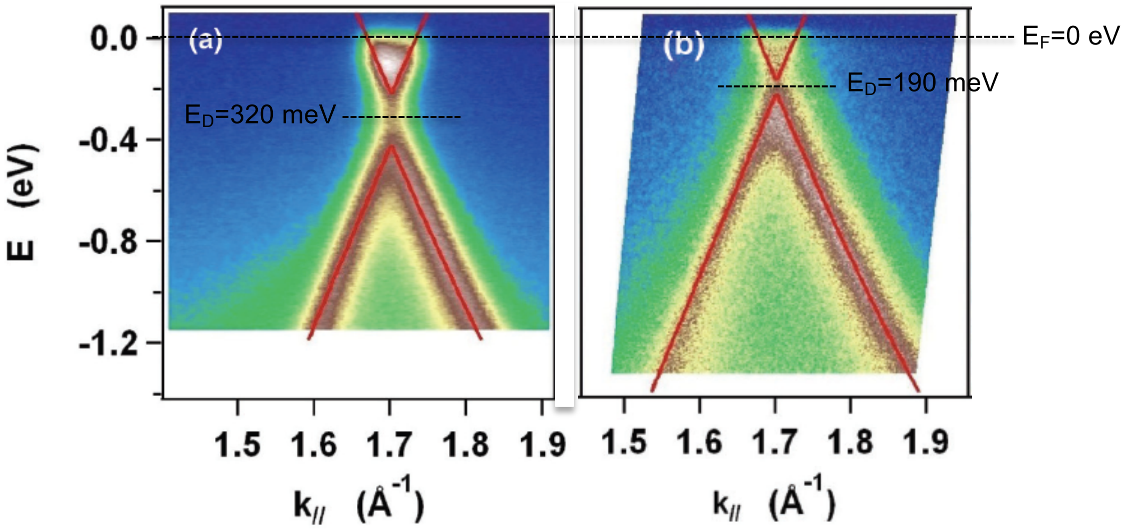

Figure 2. a) The valence band dispersion measured by ARPES parallel to the **Γ-K** direction at a photon energy hv=30 eV using circular polarization of a) monolayer and b) bilayer graphene.