Bilayer graphene grown on 6H-SiC (0001) substrate by sublimation: Size confinement effect

Lebedev A.A.[1,5], Mikoushkin V.M.[1], Shnitov V.V.[1], Lebedev S .P. [1,5], Likhachev E.V [1], Yakimova R [2] , Vilkov O.Yu. [3,4]

[1] Ioffe Institute, 194021, St. Petersburg, Russia
[2] Linkoping University, S-581 83, Linkoping, Sweden
[3] Technische Universität Dresden, D-01062 Dresden, Germany
[4]Institute of Physics, St. Petersburg State University, 199034, St. Petersburg, Russia
[5]Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics, Russia, Saint-Petersburg , 197101 Kronverksky pr., 49
e-mail***:*** E-mail: shura.lebe@mail.ioffe.ru

The epitaxial growth technology based on high temperature annealing of SiC substrates seems to be to posess a real potential for mass production of wafer-scaled and high quality graphene films [1]. Despite the rapidly (quickly) increasing number of publications developing fundamental and applied aspects of this technology, it is still far from being accomplished. In this work we demonstrate that our original technique of substrate pre-growth treatment may promote considerable progress in this field.

Graphene grown on silicon carbide substrate by sublimation method was used in our research. The growth was carried out in inductively heated furnace at temperature of 2000^{o}C and at an ambient argon pressure of 1 atm. Experiments was performed on nominally on-axis, *n*-type 6H-SiC wafers with polished Si (0001) face purchased from Cree Corp. Preliminary high-vacuum annealing of SiC substrate was used before graphene growth for removing distorted surface layer after polishing [2] Properties of the film thus grown were studied “ex situ” by atomic force microscopy (AFM), Raman spectroscopy, low energy electron diffraction (LEED), x-ray photoelectron spectroscopy (XPS), and near edge x-ray absorption fine structure (NEXAFS) spectroscopy. AFM study showed that substrate surface consists of flat and wide (~1 μm) terraces covered with sufficiently large and continuous graphene domains. Numerous LEED patterns (see example in the figure) obtained from different points of the sample demonstrate concurrent presence of a well-ordered graphite (1×1) pattern and (6√3×6√3)R30 pattern inherent to the underlying buffer layer [1] and, thereby, evidence mainly bilayer character of the grown film.

XPS and NEXAFS data obtained on synchrotron BESSY II (Berlin) allowed us to specify a chemical composition and electronic structure of graphene film grown and confirm its high quality and mostly bilayer nature. In particular, the bilayer character of the film was confirmed (also by low energy electron diffraction experiments as well as - *повтор*) by the 0.2 eV film charging due to charge transfer to substrate, which is typical for bilayer films [2-3]. Considering the bilayer as a quantum well with SiC bandgap wall, one can assume appearance of the van Hove singularities in the density of states because of size confinement in normal direction. Indeed, two peaks are seen in the graphene valence band spectrum near the Fermi level. Their energies are E_1= 0.5 - 0.2 = 0.3 eV and E_2= 1.5 - 0.2 = 1.3 eV, taking into account 0.2 eV spectrum shift due to charching the layer. The energy ratio ($E_2/E_1 \sim 4 = n_1/n_2$) and values agree with calculated ones for quantum well mentioned.

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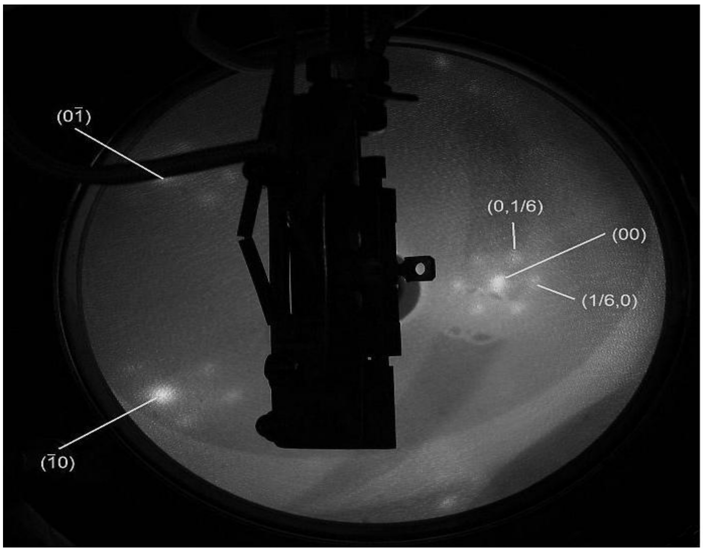

Fig. 1. LEED pattern of graphene film grown on SiC substrate subjected to pre-growth treatment..

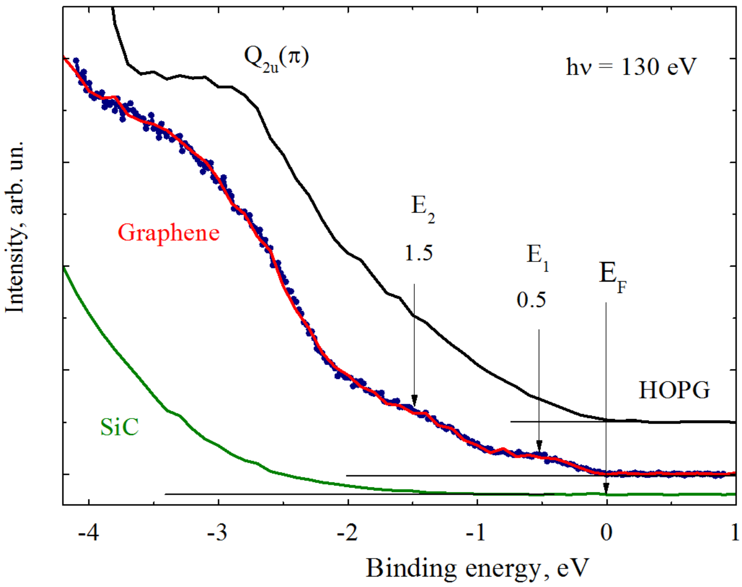

Fig. 2. Valence band density of states spectra of SiC substrate, bilayer graphene film and phyrolytic graphite.