Large-area mono- and decoupled bilayer graphene grown on C-face 4H-SiC(0001) by high temperature sublimation

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Abstract

Graphene grown by sublimation on C-terminated surface of SiC (0001) has attracted significant attention due its high free carrier mobility and the possibility of wafer scale production. However, C-face graphene typically grows in three-dimensional mode resulting in multi-layer graphene (MLG), with small domains and rough surface. Another issue with C-face graphene is that the individual layers of the MLG show a gradual doping profile with different mobility parameters which limit the use of C-face graphene in device application. Therefore, it is critical to achieve growth of monolayer and bilayer graphene with good surface morphology and controlled electronic properties. In this work, we demonstrated the growth of large-area mono- and decoupled bilayer graphene on C-face 4H-SiC (0001). Graphene was grown by high-temperature sublimation at 1950°C in Ar atmosphere. The number of graphene layers was determined using reflectance mapping and low-energy electron microscopy (LEEM). The transport properties were investigated using conductive atomic force microscopy (C-AFM), micro-Raman spectroscopy and mid-infrared optical Hall effect (OHE). The micro-Raman spectroscopy maps were measured simultaneously with reflectance maps, which allowed precise determination of the graphene layers properties such as doping. The LEEM and reflectance mapping showed large-area mono- and decoupled bilayer graphene with size of 600 μm^2 and 200 μm^2 over the total probed area of 900 μm^2, respectively and small domains of thick graphene layers [Fig.1 (a)]. The correlation between the C-AFM, reflectance and micro-Raman spectroscopy showed that the mono- and the decoupled bilayer graphene are *n*-type doped with different electron concentrations: the doping concentration of monolayer graphene was of the order of 10^{13} cm^{-2} and the decoupled bilayers were quasi-neutral. The OHE measurements showed Landau transition energies with a root square dependence on the magnetic field [Fig.1 (b)], which can be attributed to monolayer graphene or stacks of decoupled graphene layers. This result was confirmed by micro- Raman spectroscopy that showed a symmetric 2D Raman peak with a full width at half maximum varying between 26 cm^{-1} and 40 cm^{-1}. Further a splitting of the Landau levels was observed [Fig.1 (b)], indicating different Fermi velocities. By comparing the doping concentration obtained from C-AFM and micro-Raman spectroscopy on one hand, and the inter-Landau-level transition energies obtained from magneto optical hall effect on the other hand, we attributed the observed Landau levels to the decoupled multilayer graphene layers. The splitting of the Landau levels was attributed to the different strain environment of the layers such as uniaxial strain.

Figures

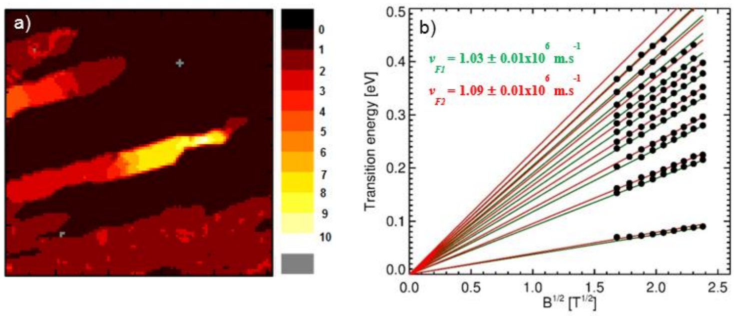

Fig. 1. (a) 30×30 μm^2 color-coded thickness map for the graphene deduced from the reflectance measurement. (b) Inter-Landau level transitions of graphene on C-face 4H-SiC showing √B dependence, which implies a stack of monolayers or decoupled multilayers. The Fermi velocities of different sets of Landau levels are indicated.