Large-area micro-ellipsometry mapping of thickness and electronic properties of epitaxial graphene on bulk 3C-SiC

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Abstract

Epitaxial graphene (EG) grown by sublimation epitaxy on SiC holds great promise for large-scale production of next generation fast electronic devices. Despite significant progress and intense research efforts in the field, state-of-the-art EG shows mobility parameters that are still orders of magnitude lower than those of exfoliated graphene. Understanding the physical origin of the substantially different transport properties of epitaxial and free-standing graphene remains one of the major issues, and prevents further technological advances. The key point is to identify and control how the substrate affects graphene uniformity, thickness and carrier mobility. EG on the hexagonal polytypes of SiC has been extensively studied. On the other hand, cubic 3C-SiC substrates have not been explored, mostly due to the fact that they are not commercially available. However, 3C-SiC can offer advantages over the other poltytypes in terms of isotropic growth surfaces and device performance. Mapping non-uniformities in EG on a large-scale and possible interrelation to its electronic and transport properties will be beneficial for both studying substrate effects and device production. However, the simultaneous mapping of these properties presents a significant challenge due to the domain structure of EG and the fact that characterization techniques with different footprints need to be employed.

In this work, we report large-area micro-ellipsometry mapping of thickness and electronic properties of EG grown on thick bulk-like 3C-SiC(111) layers. We explore both Si and C polarities of the substrate and discuss in detail the determining factors of EG thickness uniformity in relation to its electronic and transport properties. The EG layers were grown by high temperature sublimation in Ar_2 atmosphere [1] under optimized conditions on the Si- and C-face of home-grown 3C-SiC(111). The thick (few hundreds of micrometers) 3C-SiC layers were grown by sublimation epitaxy on 6H-SiC (0001) [2]. Spectroscopic ellipsometry mapping (SE) from 1.25 eV up to 5.45 eV was performed with an M2000 rotating compensator ellipsometer from J. A. Woollam Co. on a circular area of the samples with a diameter of 0.5 cm and with a microspot of $30x30\mu m^2$. Details about the experimental and modeling procedures can be found in Refs. 3-4. SE thickness maps [Figs 1(a) and (c)] demonstrate that 1 monolayer (ML) graphene can be achieved on Si- and C-polarities of the 3C-SiC(111) substrates in good agreement with low-energy electron microscopy and Raman scattering spectroscopy. Large domains with homogeneous ML coverage with size of ~2x2 mm^2 are grown at the Si-face 3C-SiC [Fig. 1(a)]. In this case, few thick graphite-like islands are formed and their nucleation sites can be correlated with an increased interface roughness of the substrate. On the C-polar 3C-SiC the formation of the thick graphite islands is suppressed [Fig. 1(c)]. However, the areas of EG with homogeneous thickness have considerably smaller size and are randomly distributed indicating a different formation mechanism than for EG on the Si-face of 3C-SiC. Our results indicate that the polarity of the 3C-SiC substrates critically affects the formation mechanism and growth kinetics of EG, which will be discussed in relation to substrate defects and surface status. Furthermore, the maps of the free-charge carrier scattering time show that higher mobility can be achieved in the homogeneous areas of 1 ML EG, while the thicker graphite islands show that the carrier mobility drastically decreases [Figs. 1(b) and (d)]. Finally, correlation between the number of MLs and the energy of the critical point (CP) associated with an exciton enhanced Van Hove singularity at ~4.5 eV may be established for both substrate polarities (Fig.2). The CP energy positions and dielectric function shape will be further discussed in view of strain and the interaction of EG with the substrate. The reported results can be used in future works on the application of optical micro-spectroscopy techniques to study electronic properties and monitor graphene thickness homogeneity.

References

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Figures

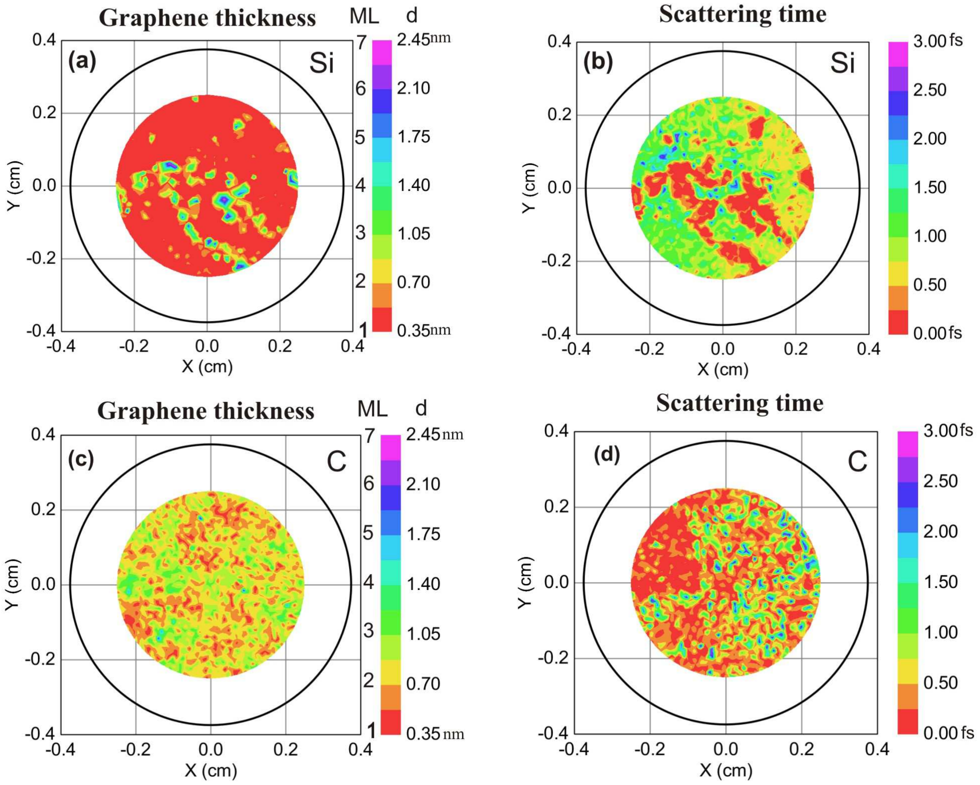

Figure 1 Spectroscopic ellipsometry maps of the thickness of epitaxial graphene grown on the Si-face (a) and C-face (c) of 3C-SiC(111), and the respective free-charge carrier scattering times (b) –Si face, and (d) – C-face.

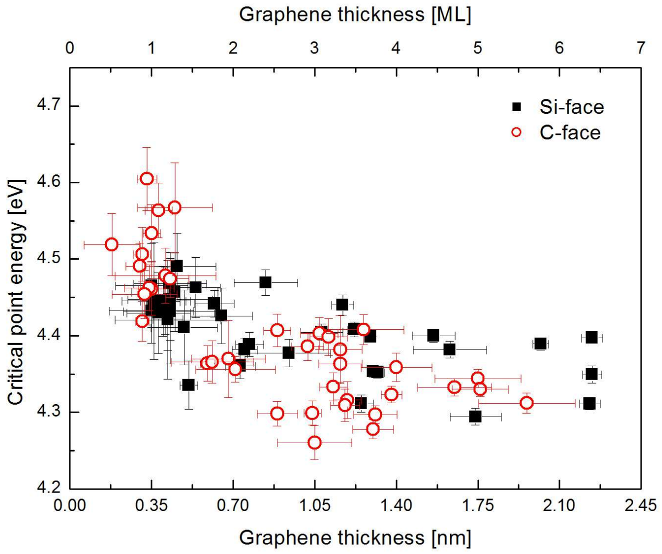

Figure 2 Critical point transition energy as a function of graphene thickness for epitaxial layers on Si-face (squares) and C-face (circles) of 3C-SiC (111).