Atomic scale structural and electronic properties of epitaxial graphene on different SiC orientations

F.Giannazzo* (1), I. Deretzis(1), A. La Magna(1), G. Nicotra(1), C. Spinella(1), F.Roccaforte(1), Q.M.Ramasse(2) R.Yakimova (3)

(1) CNR-IMM, Catania, Italy
(2) SuperSTEM Laboratory, STFC Daresbury Campus, Daresbury WA4 4AD, UK
(3) IFM, Linkoping University, Linkoping, Sweden
filippo.giannazzo@imm.cnr.it

Abstract

Epitaxial graphene (EG) grown by controlled graphitisation of hexagonal SiC is one of the major candidates for novel graphene-based electronics.

The interface with the substrate strongly influences EG electronic properties. As an example, EG grown on a SiC (0001) surface is subjected to a high electron-doping (~ 10^{13} cm^{-2}) originating from the interfacial C buffer layer with a partially covalent bond to the substrate [1]. As a matter of fact, EG grows on a structured substrate, which exhibits steps or facets with different size and orientations depending on the wafer off-cut angle. Recently, many interesting effects related to the local electronic properties of graphene over these substrate features are emerging, like a local conductance degradation [2] and a reduced carrier density [3] of EG at nanosteps-edges. Furthermore, novel metal-semiconductor-metal nanostructures entirely made from graphene, based on the peculiar interaction between EG and patterned SiC steps, have been envisaged [4].

In this work, the electronic transport in EG grown on SiC (0001) substrates with different miscut angles (from on-axis to 8°-off axis) has been investigated both at microscale (on properly designed device structures) and at nanoscale (by scanning probe microscopy) [5,6,7], focusing in particular on the impact of substrate nanosteps or facets on local graphene conductance. In particular, the results of nanoscale electrical measurements, combined with atomic-resolution structural and spectroscopic characterization techniques (i.e. scanning transmission electron microscopy (STEM) and electron energy loss spectroscopy (EELS)) shed light into the properties of EG over the steps of off-axis silicon carbide (0001) substrates. The STEM analysis, obtained at an energy below the knock-on threshold for the C atoms, evidences that the buffer layer present on the planar (0001) face gets detached from the substrate on the (11-2n) facets of the steps, turning into a quasi-freestanding graphene film. Simultaneously, high energy resolution atomic scanned EELS reveals that this layer has the same electronic configuration as a purely sp^2-hybridized graphene layer. This aspect fully explains the observed local increase of EG resistance over SiC facets, due to a significantly lower substrate-induced doping.

References

[1] F. Varchon, et al., *Phys. Rev. Lett*. **99** (2007) 126805
[2] S.-H. Ji, et al., *Nature Mater.* **11** (2011) 114
[3] K. Grodecki, et al., *Appl. Phys. Lett.* **100** (2012) 261604
[4] J. Hicks, et al., *Nature Physics* (2012), DOI: 10.1038/NPHYS2487
[5] S. Sonde, et al., *Phys. Rev. B* **80** (2009) 241406(R)
[6] F. Giannazzo, et al., *Nano Lett.* **11** (2011) 4612
[7] F. Giannazzo, et al., *Phys. Rev. B* **86** (2012) 235422

Figures

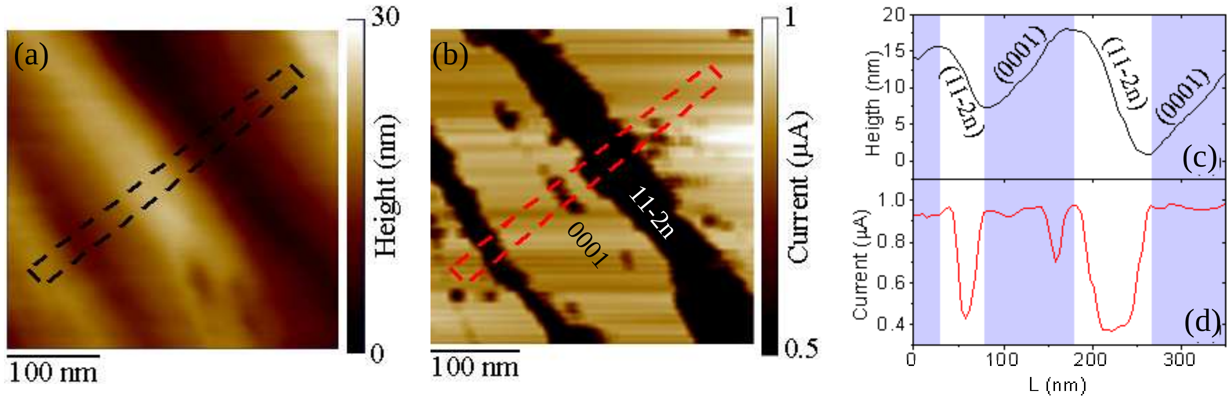

Fig.1 Surface morphology (a) and the corresponding current map (b) measured by conductive atomic force microscopy on the as-grown EG/4H-SiC(0001) sample. Line-profiles of the height (c) and of the current (d) along the indicated directions in the maps. A significant decrease (from 1 to 0.4 μA, *i.e.* more than a factor of two) in the local current measured on the (11-2n) facets with respect to the values measured on the (0001) basal plane terraces can be observed.

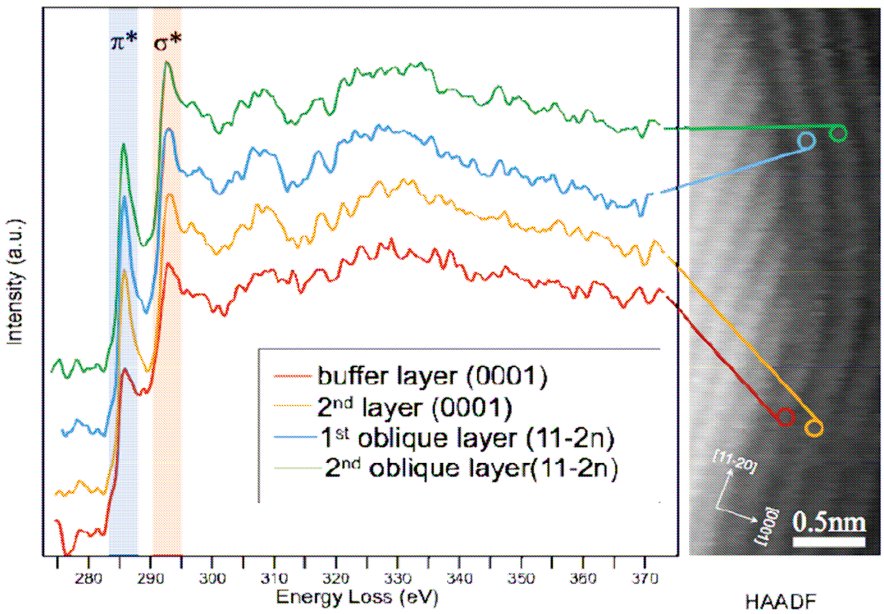

Fig.2 EELS spectra (left) and simultaneously acquired HAADF STEM image (right) on a cross sectioned epitaxial graphene sample grown on a facetted 4H-SiC (0001) surface. The EELS spectrum clearly shows that the buffer layer in the region immediately above the (0001) plane exhibits a stronger σ^*/π^* ratio than the first cabon layer above the (11-2n) surface. This is a direct demonstration that the buffer layer present on the planar (0001) face gets detached from the (11-2n) facets, turning into a quasi-freestanding graphene film.