ELECTRONIC PROPERTIES OF GRAPHENE WITH NANOSCALE LATERAL RESOLUTION

F. Giannazzo[a*], **S. Sonde**[a,b], **C. Vecchio**[a,b],
E. Rimini[a,c] and **V. Ranieri**[a]

[a]CNR-IMM, Strada VIII 5, 95121 Catania, Italy
[b]Scuola Superiore di Catania, Via Valdisavoia 9, 95123 Catania, Italy
[c]Dipartimento di Fisica ed Astronomia, Università di Catania,
Via S. Sofia 64, 95123 Catania, Italy
*Corresponding author: *filippo.giannazzo@imm.cnr.it*

Graphene is currently the object of many research interests especially for its remarkable electronic transport properties. This talk will provide an overview of the research activity on graphene carried out in the last 5 years within the CNR-IMM laboratories.
High crystalline quality graphene is obtained by mechanical exfoliation of HOPG on different substrates or it is grown on large area by high temperature thermal decomposition of hexagonal SiC. In particular, we investigated the mechanisms of epitaxial graphene (EG) growth on the Si face of off-axis 4H-SiC by annealing in inert gas ambient (Ar) at different temperatures ranging from 1600°C to 2000°C. The crystalline quality, the number of graphene layers as well the surface coverage was determined as a function of the growth temperature were evaluated by several techniques (AFM, HRTEM, micro-Raman). The electronic properties of the graphene layers have been investigated on micrometer scale by electrical measurements on test structures (Van der Pauw, transmission line model) and on top gated field effect transistors. Nonconventional applications of scanning probe methods have been also developed to locally probe the electrostatic (quantum capacitance) [1] and transport properties (electron mean free path and mobility) of the graphene layers [2]. The latter approach provides precious informations on the lateral homogeneity of electronic properties, without any need of device fabrication. Electron mean free path (l) and mobility (μ) have been evaluated in graphene mechanically exfoliated on substrates with different relative dielectric permittivities, SiO_2 (k_{SiO2}=3.9), Si_3N_4 (k_{Si3N4}=7.5), 4H-SiC (0001) (k_{SiC}=9.7), Sr_2TiO_3 ($k_{Sr2TiO3} \approx 330$) and in EG grown on 4H-SiC (0001) [3]. The experimentally found dependence of l on the carrier density (n) has been explained by two main scattering mechanisms affecting electronic transport, i.e. (i) Coulomb scattering by charged impurities, either adsorbed on graphene or located at the interface with the substrate, and (ii) scattering by the substrate surface polar phonons (SPP). Scattering by charged impurities is reduced in graphene sheets on substrates with higher permittivity, due to a more efficient dielectric screening of Coulomb potential. As an example, a high l is measured in graphene deposited on SiC compared to graphene on SiO_2, due both to the 3× higher dielectric permittivity of SiC than SiO_2 and to the higher SPP phonon frequency (see Fig.1a,b). In graphene on very-high-k substrates, SPP scattering is the main mechanism limiting l.
Finally, comparing the mean free path locally measured on several surface positions

in exfoliated graphene on 4H-SiC (0001) and in EG grown on the same substrate, it was worth noting, in the latter case, an average value ∼0.4 times than in deposited graphene and a much broader distribution of the locally measured values (see Fig.1c) These differences have been explained in terms of the peculiar interface structure of epitaxial graphene on the Si face of hexagonal SiC, in particular as a consequence of the presence of a large density of dangling bonds between the C buffer layer (the precursor of epitaxial graphene formation) and the substrate (see Fig2a,b) [4].

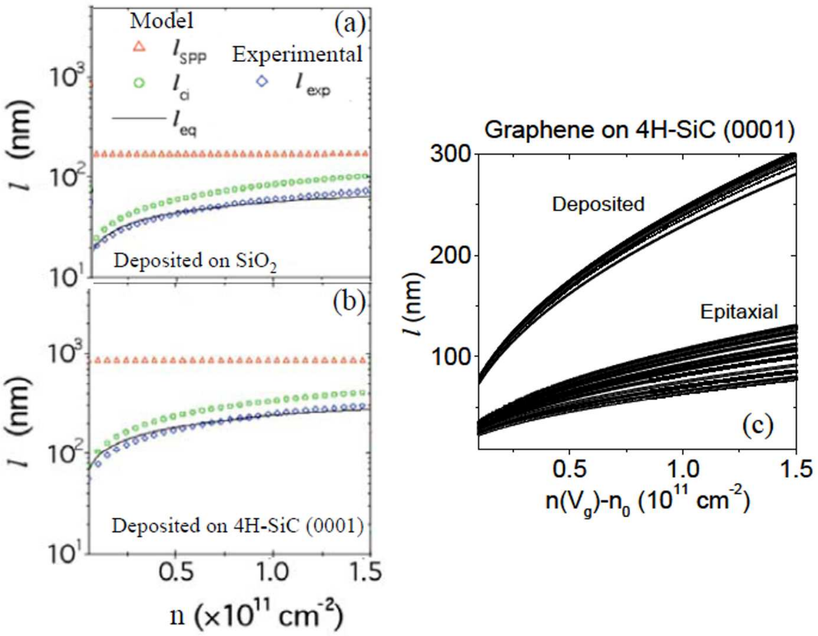

Figure 1: Electron mean free path versus carrier density in graphene exfoliated from HOPG and deposited on SiO_2 (a) and on the Si face of 4H-SiC (b). The fit of the experimental data is reported, as well as the calculated electron mean free path limited by charged impurities and surface polar phonons scattering. (c) Locally measured electron mean free path versus carrier density on several surface positions in graphene exfoliated from HOPG and deposited on 4H-SiC (0001) and in epitaxial graphene grown on the same substrate.

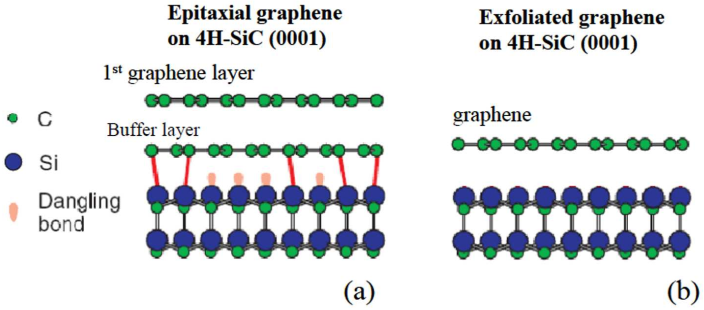

Figure 2: Schematic representation of the interface between epitaxial graphene grown 4H-SiC (0001) and the substrate (a) and of the deposited graphene/4H-SiC (0001) interface (b).

References

[1] F. Giannazzo, S. Sonde, V. Raineri, E. Rimini, Nano Lett., 9 (2009) 23.
[2] F. Giannazzo, S. Sonde, V. Raineri, E. Rimini, Appl. Phy. Lett., 95 (2009) 263109.
[3] F. Giannazzo, S. Sonde, V. Raineri, E. Rimini, Appl. Phy. Lett., 97, (2010) 132101.
[4] S. Sonde, F. Giannazzo, V. Raineri, *et al.*, Phy. Rev. B 80, 241406(R) (2009).
[5] This research was supported by the European Science Foundation (ESF) under the EUROCORE program EuroGRAPHENE, within GRAPHIC-RF coordinated project.