Effect of graphene/substrate interface on the electronic transport properties

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Graphene is currently the object of many research interests especially for its remarkable electronic transport properties, making this material a promising candidate for future "post-Si" electronics. In a free standing graphene sheet without defects and adsorbed impurities, charge carriers can exhibit a giant intrinsic mobility [1] and can travel for micrometers without scattering even at room temperature. So far, very high values of mobility (>2×10^5 $cm^2V^{-1}s^{-1}$) and electron mean free path have been observed in vacuum and at low temperature (5K) in "suspended" graphene after a current-induced cleaning [2]. However, graphene for electronics applications is commonly supported by a dielectric substrate or by semi-insulating SiC, and the values of the electron mean free path (l) and mobility (μ) measured in supported graphene are usually significantly lower than in suspended ones.

In the present work, l and μ have been comparatively evaluated in graphene sheets mechanically exfoliated from highly oriented pyrolytic graphite and deposited 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) and strontium titanate, STO (k_{STO}=330), and in single layer graphene epitaxially grown by thermal decomposition of 4H-SiC (0001). The transport properties have been measured at room temperature both on micrometer size test patterns in graphene, using conventional electrical characterization (sheet resistance and Hall effect measurements on Van der Pauw structures) and, locally, by using a recently demonstrated scanning probe method based on localized capacitance measurements [3,4]. From the experimentally found dependence of l on the carrier density (n), three main scattering mechanisms affecting electronic transport in supported graphene sheets have been identified, i.e. (i) Coulomb scattering by charged impurities, either adsorbed on graphene or located at the interface with the substrate, (ii) scattering by point defects [5], working as resonant scatterers [6] and (iii) scattering by the substrate surface polar phonons (SPP) [7]. Scattering by charged impurities is reduced in graphene sheets on substrates with higher permittivity, due to a more efficient dielectric screening of Coulomb potential. Hence, the role played by SPP and by defects becomes increasingly important in graphene on high-k dielectrics and ultimately limits its transport properties. As an example, both in the case of graphene deposited on SiO_2 and on 4H-SiC(0001), scattering by charged impurities is still the main scattering mechanism. However, a higher electron mean free path is measured in graphene on SiC, due both to the three-times higher dielectric permittivity than SiO_2 and to the higher SPP phonon frequency (see Fig.1). In the case of graphene on the high-*k* substrate STO, a mean free path significantly lower than that expected by charged impurities scattering is measured, indicating that the scattering by SPP and defects become the mechanisms limiting transport properties.

Finally, comparing the mean free path locally measured on several surface positions in deposited graphene on 4H-SiC (0001) and in epitaxial graphene 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. 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 [8,9].

References

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Figures

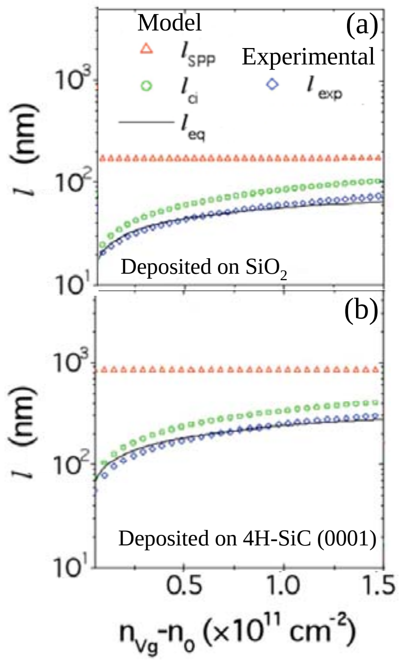

Fig.1 Electron mean free path versus carrier density in graphene exfoliated from HOPG and deposited on SiO_2 (a) and on the Si face of 4H-SiC (b). The fit of the experimental data is reported, as well as the calculated electron mean free path limited by charged impurities and surface polar phonons scattering.

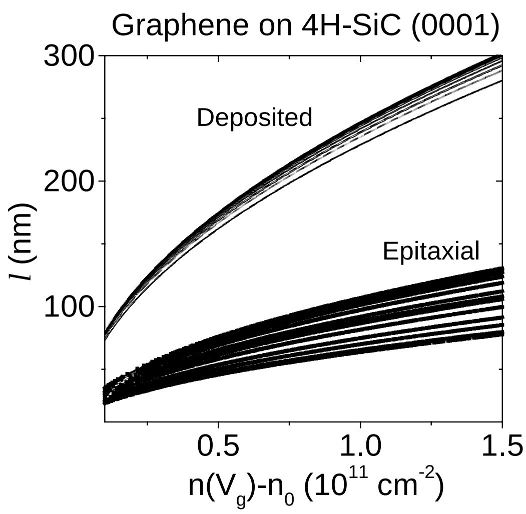

Fig.2 Locally measured electron mean free path versus carrier density on several surface positions in graphene exfoliated from HOPG and deposited on 4H-SiC (0001) and in epitaxial graphene grown on the same substrate.