Two Point-Contact Method for the Electrical Characterization of Graphene-On-Insulator Samples

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Abstract

Graphene is a promising candidate as a material for future electronics [1]. However, a long way has still to be run. For example, new characterization tools to study and monitor its electrical properties has to be developed. These new tools should target its key electronic applications (i.e. Graphene-On-Insulator for device fabrication). In this work, we introduce a new method for the electrical characterization of graphene layers based on a two point-contact configuration, Figure 1.(a). Two tungsten needles acting as source and drain electrodes, are applied on the insulator surface (SiO_2) covered by the graphene layer. For the calibration of the method, the pressure of the needles on the surface should be adjusted. Figure 1.(b) shows the drain current (V_D*=1V,* V_S*=0V,* V_B*=floating*) as a function of the probe pressure. A good saturation is achieved above *50gr* for a tip radius of 25µm. This initial calibration is essential to guarantee reproducible measurements.

Figure 2.(a) shows the current between the two needles, for a given bias point, as a function of the needle inter-distance, *d*. As observed, the resistance remains relatively independent of *d* showing a metallic behavior. Considering a form factor for the current flow of *W/d=0.7* [2] and assuming an electron density of 10^{12} cm^{-2} [3], the extracted value for the surface conductivity is *0.75µS* which turns into a mobility of 4700 cm^2/Vs. This value is lower than expected if only the optical phonon scattering due to the SiO_2 substrate would be considered, and may reflect the impact of the needle to graphene contacts. In Figure 2.(b) the dependence of the driven current with the substrate bias (vertical electric field) is minimal (< 5%) as expected from a zero-band-gap material.

Capacitance measurements were performed with an Agilent 4294A impedance analyzer and a series resistance model. For these measurements, the surface needles were short-circuited acting as low electrodes (L_C, L_P) and the gate was connected to the high (H_C, H_L) electrode [4]. The resulting capacitance curves as a function of the frequency of the AC excitation signal are shown in Figure 3.(a). Different configurations of the surface needles (single needle, two-needle with different inter-distances) have been considered. For a given sample, the maximum value of the capacitance is independent of the needle distribution confirming the reliability of the technique. It is worth noting that, for defective-free graphene layer, the capacitance obtained corresponds to that of an ideal plate capacitor ($C=S_{Graph}\,\varepsilon_{SiO2}/t_{BOX}$=45nF). The different cut-off frequencies must be further investigated and may be attributed to limited carrier spreading effects. Finally, Figure 3.(b) shows the capacitance curves obtained when the high and low potentials are exchanged. The results are identical demonstrating no impact of the silicon substrate.

Acknowledgements

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References

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Figures

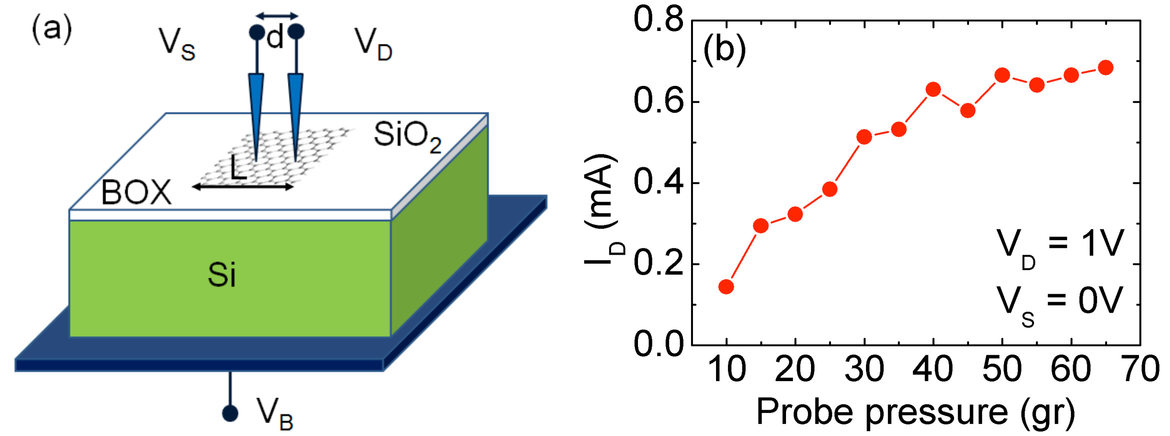

Figure 1: (a) Schematic of the two Point-Contact technique for electrical characterization of Graphene. (b) Drain current as a function of the needle pressure for a given bias point in a square shaped graphene on insulator layer satisfying d << L. The current remains saturated above 50 gr. d=1.59mm.

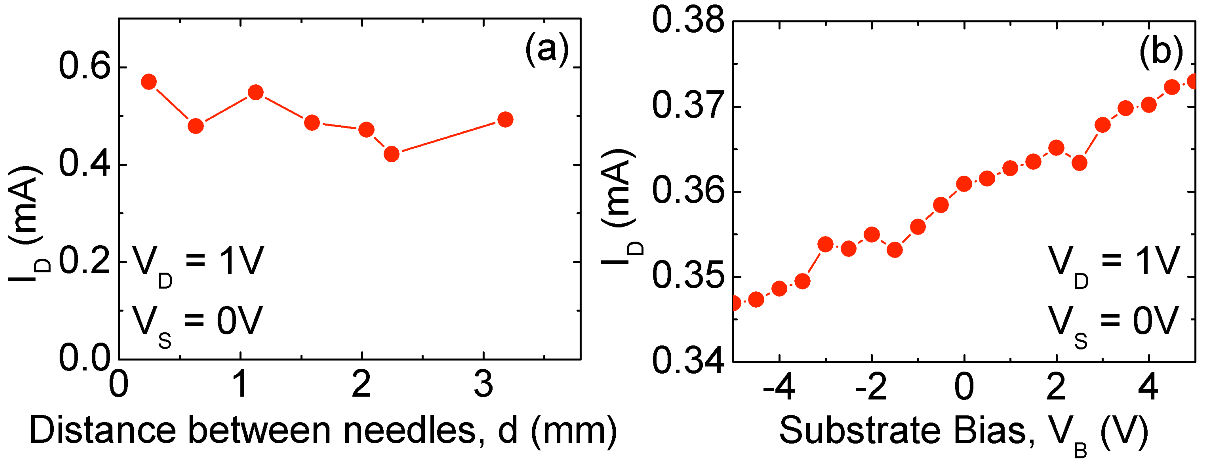

Figure 2: (a) Drain current at a given bias point as a function of the distance between the needles, substrate electrode is floating. (b) Drain current at a given bias point as a function of the substrate bias from -5V to 5V. T_{BOX}=90nm, $N_{D\text{-}substrate}=10^{18}cm^{-3}$.

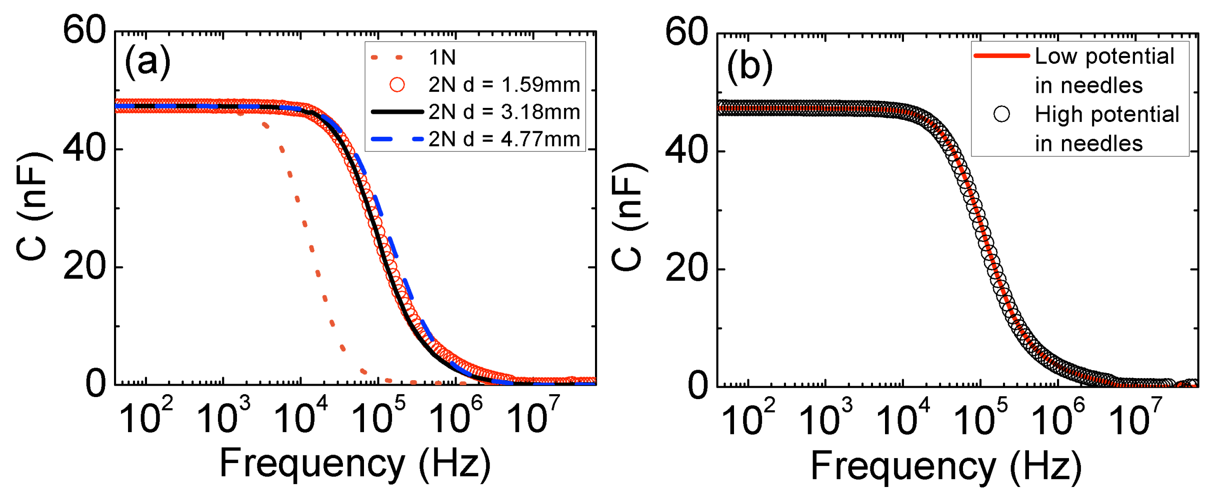

Figure 3: Source-Drain to substrate capacitance as a function of the excitation signal frequency from 40Hz to 60MHz. (a) Capacitance curves measured using one and two needles and considering several distances between them, d. (b) Capacitance curves measured exchanging the high and low potentials in the experimental setup.