Direct Electrical Characterization of Graphene-On-Insulator by Multiple-Point Contact Configuration

Luis Segura, Noel Rodriguez, Cristina Fernandez, Akiko Ohata, Carlos Marquez, Francisco Gamiz

Nanoelectectronics Laboratory, CITIC-UGR, Dept. of Electronics, University of Granada, Spain
noel@ugr.es; fgamiz@ugr.es

Abstract

The experimental characterization of the physical properties of graphene has been the subject of a large number of manuscripts devoted to research results of this promising material [1]. When the characterization targets electrical parameters, microsized graphene sheets with ad hoc fabricated contacts (electrodes) have been extensively used [2]. From an industrial monitoring perspective, this task requires complex post-processing of the samples, which takes time and cost. We propose an alternative method for the electrical characterization of as-fabricated large CVD graphene-On-Insulator samples.

The experimental setup is based on a four/two-probe measurement system with conductive chuck as schematized in Figure 1. The validity of this contact-based technique for testing large graphene samples is successfully demonstrated in the conductivity curves shown in Figure 2. The voltage between needles 2 and 3 in Figure 1.a is measured as a function of the substrate voltage, V_{Sub}, when a constant current is forced between probes 1 and 4 (four-probe configuration, current form factor $\pi/\ln 2$ [3]). The thickness of the SiO_2 layer is 90nm and the size of the monolayer of graphene is 1cm×1cm. Substrate silicon is highly P-type doped.

This method has been further simplified by employing a two-point contact configuration. Special caution must be paid in this case to the contact resistance (R_c) consequence of the simultaneous measurement of the voltage while the current is flowing. In the case of our experiment, Tungsten-Carbide tips were used leading, potentially, to a large R_c value due to the similar graphene work-function [4]. In a first stage, we studied the impact of the probe pressure on the sample (Figure 3). At a given bias point, the current level saturates at a pressure of 50g on 25µm-radius tips (250MPa). Once the minimum measurement pressure is set, the total resistance curve as a function of the probe separation allows the extraction of the contact resistance ($R_{tot}=\rho_{s\text{-}Gr}\ d/W+\ R_c$) when $d=0$. $\rho_{s\text{-}Gr}$ is the sheet resistance of graphene obtained previously by four-probe measurements; W, the equivalent width of the current flow and d the separation between probes (on first approach we have assumed a linear relation between resistance and probe separation). Further exploitation of the two-needle configuration requires the determination of the form factor for the current flow between the needles (f_g~d/W). f_g can be evaluated by combining the resistivity extracted from four-probe measurements and the slope of the total resistance versus the distance between the probes of Figure 4 (under linear approach). The result is shown in Figure 5.

One useful application of the technique is the fast monitoring of graphene quality by extracting parameters such as the carrier mobility. The results obtained for two graphene samples (clean and contaminated) are presented in Figure 6. As the number of defects increases, graphene mobility values reduce dramatically more than 60%. This method can be used for vendors and research laboratories for the fast characterization of samples.

Acknowledgements

This work has been partially funded by the Spanish Government through project TEC-2011-28660. Thanks are given to AMO-GmbH and Graphenea for sample supplying and Prof. A. Toriumi from University of Tokyo and Prof. S. Cristoloveanu from INP-Grenoble for useful discussions.

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Figures

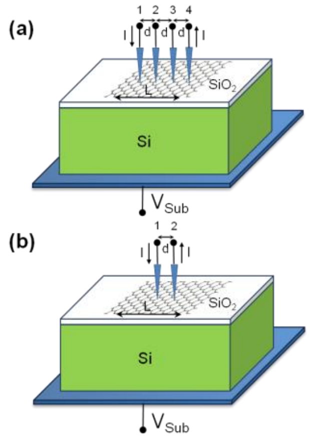

Figure 1. Schematic experimental setup. **(a)** Four-probe Kelvin measurement, probes 1 and 4 are used to source and drain the current; 2 and 3 for voltage measurement. **(b)** Two-point contact measurement, only two probes on the graphene are used to drive the current while the voltage is simultaneously measured or applied.

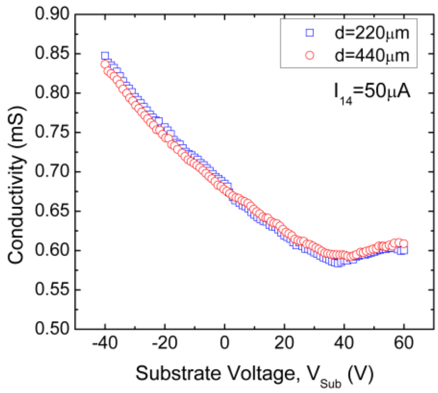

Figure 2. Conductivity as a function of the substrate voltage obtained from four-probe contact measurements with two probe separations. The probes are located far away from the graphene borders [3] (current form factor $\pi/\ln 2$). The conductivity values are independent of the probe separation and decrease until the Dirac point is achieved.

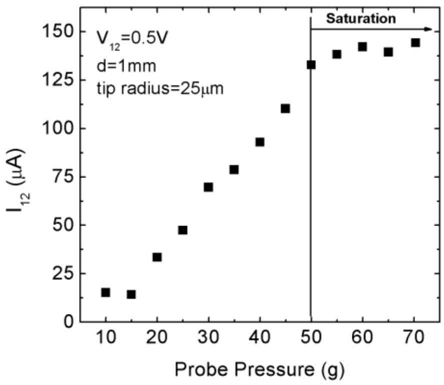

Figure 3. Current flow between probes (two-point contact configuration, Figure 1.b, *d=1mm*) as a function of the needle pressure. The current remains saturated above 50 grams. Further pressure increase only contributes to damage the underneath SiO_2 layer until physical breakdown. Substrate voltage is 0V.

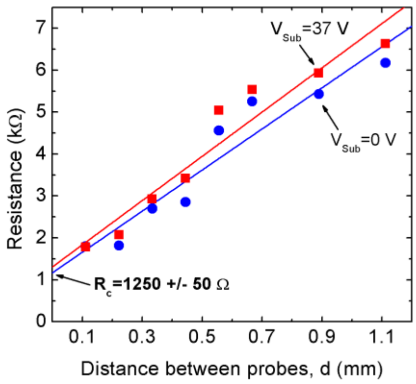

Figure 4. Total resistance between probes (two-point contact configuration) as a function of the probe separation. Linear regression for *d=0* allows the extraction of the contact resistance. Tungsten Carbide needles, tip radius 25µm. Two substrate voltages are presented.

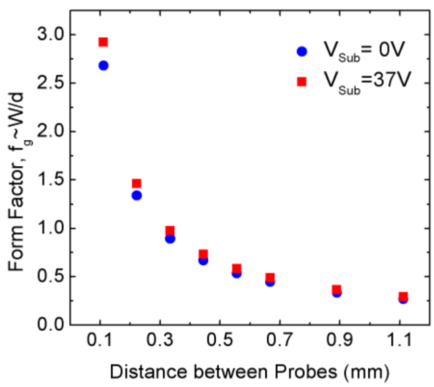

Figure 5. Form factor of the current flow for two-point contact configuration extracted combining four-probe and two-probe measurements. For large probe separation (d>1mm), the form factor, f_g, can be approximated by 0.25.

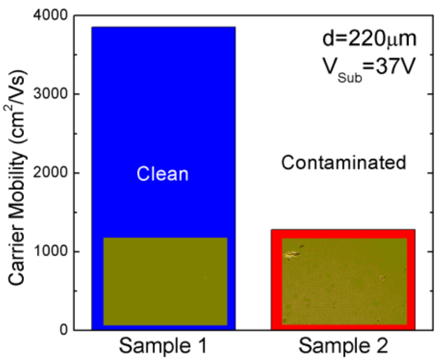

Figure 6. Carrier mobility extracted by the proposed two-point contact configuration for clean and contaminated samples of graphene. As observed, the mobility extracted for the contaminated sample dramatically decreases. The actual microscope images of the graphene surface are shown inside the bars.