Graphene based heterojunction solar cells

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Thanks to properties like excellent optical transmittance, low resistance and high mechanical and chemical stabilities [1], graphene has a great potentiality in the field of solar energy [2].
Tongay et al. [3] were the first to anticipate applications where single layer graphene is directly contacted to a semiconductor substrate; later, the formation of graphene/semiconductor Schottky barriers was experimentally verified, opening the interesting scenery of graphene based solar cells [4, 5]. Application of graphene in this field is a very open question and requires investigation on different aspects of the material and the devices.
In this frame, we have fabricated and characterized devices based on graphene/silicon heterojunction, with simple planar thin-film geometry (Fig. 1), in order to inspect the properties of the material and its interaction with the semiconductor.
The graphene sheets used in this work have been grown by chemical vapor deposition (CVD) on copper foils [6]. Raman spectroscopy performed on our samples (Fig.2) has shown a few layers graphene (FLG) structure. The rectifying properties of the devices have been verified through dark current-voltage (I-V) measurements (Fig.3). An estimation of the Schottky barrier height (SBH) has been given using the thermionic-emission based diode equation and extrapolating, to zero bias, the dark saturation current density. The obtained value of SBH is 0.69 eV consistent with a FLG [7], in agreement with Raman results.
As shown in Fig. 3, we have also used capacitance-voltage (C-V) measurements plotted in the form $1/C^2$ vs. V, where V is the reverse bias voltage, to characterize our junctions at room temperature. Linear extrapolation (dotted line) to the intercept with the abscissa identifies the built-in potential, V_{bi}, which is related to SBH. The SBH values extracted from the C−V measurements is 0.75eV. We note that this value is slightly higher than the value extracted from I-V analysis. This trend might be attributed to the fact that I−V and C−V provide complementary techniques for determining the SBH. While I−V measurements manifest current transport processes across the graphene/Si and give informations about the lowest SBH, capacitance measurements probe the space charge region of the Schottky junction and provide an average SBH at the interface.
External quantum efficiencies (EQE) have also been measured (Fig.4) to evaluate the charge separation and collection, as a result of the Schottky barrier formed at the interface graphene/silicon. Our devices show an EQE values over 50% for wavelengths in the range 400 nm<λ<950 nm with 60% peaks, indicating significant electron-hole pair generation and the subsequent charge collection by the corresponding electrodes. These values, are in line with the best results presented in literature[8]. Short circuit current (J_{sc}) extracted from EQE reaches values of 23mA/cm^2.

References

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Figures

(a) (b)

Fig.1: Schematic illustration of graphene/Si heterojunction (a) and photograph of the frontal part of the device (b): the yellow window is the gold contact, the shadow visible on gold is graphene film, the central grey zone is the active area of the device where graphene contacts silicon and the dark zone is SiO_2/Si.

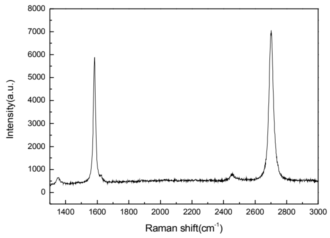

Fig.2: Raman spectrum of a CVD grown FLG.

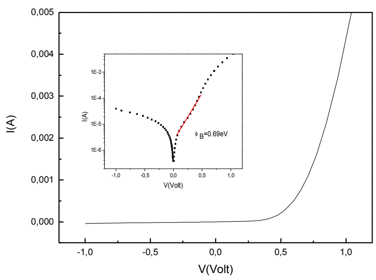

Fig.3: Dark I-V characteristic

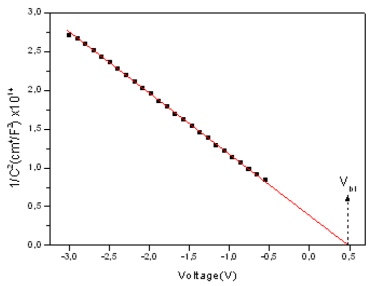

Fig.4: Inverse square of the capacitance ($1/C^2$) versus bias plot of graphene/n-type c-Si heterojunction. The continuous line is linear extrapolation of data for the built-in voltage evaluation.

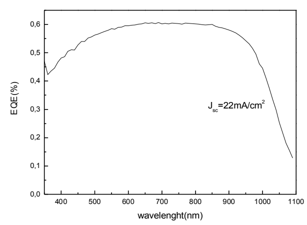

Fig.5: External quantum efficiency (EQE) vs. wavelength