Spectral Sensitivity of pn-junction Photodetectors based on 2D materials

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Broad spectral range detection is interesting for several technological applications such as imaging, sensing, communication and spectroscopy. Two-dimensional (2D) materials are very promising for such applications. Graphene is a suitable material for broadband detection due to its absorbance covering the entire spectrum from ultraviolet to terahertz, which is a consequence of its linear dispersion and zero bandgap characteristic [1], [2]. In contrast to graphene, molybdenum disulfide (MoS_2) is an n-type semiconducting 2D material. MoS_2 shows a more limited spectral response due to its band structure. Monolayer MoS_2 has a direct band gap of ~1.8 eV, whereas bulk MoS_2 has an additional indirect band gap of ~1.3 eV [3].

In this work, we investigate graphene – silicon Schottky barrier diodes composed of chemical vapor deposited (CVD) graphene on n-type Si substrates. A device schematic along with its cross-section is shown in Fig. 1a and 1b, respectively. The effects of incident light intensity and wavelength are investigated. Fig. 1c shows the band diagram of the device in reverse bias under illumination. The diodes exhibit good rectifying behavior and high sensitivity to changes of incident light, as shown in Fig. 1d. A broad spectral response (SR) of 60 - 407 mAW^{-1} at reverse dc bias of 2V is measured from ultraviolet (UV) to near infrared (NIR) light (Fig. 2a). In our previous work on MoS_2/Si diodes, we reported a maximum SR of 8.6 mA/W (Fig. 2b, [4]). This is 47 times less than the Si-graphene diode value presented in this work, even though multilayer MoS_2 should have higher absorbance than graphene. We attribute the greatly enhanced SR to an optimized design, with larger contact electrodes that were also placed closer to the active device area. This results in an increased external electrical field. Therefore, more photo-generated electron-hole pairs can be captured before recombination and consequently, the overall photodetection efficiency is improved.

References

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Figures

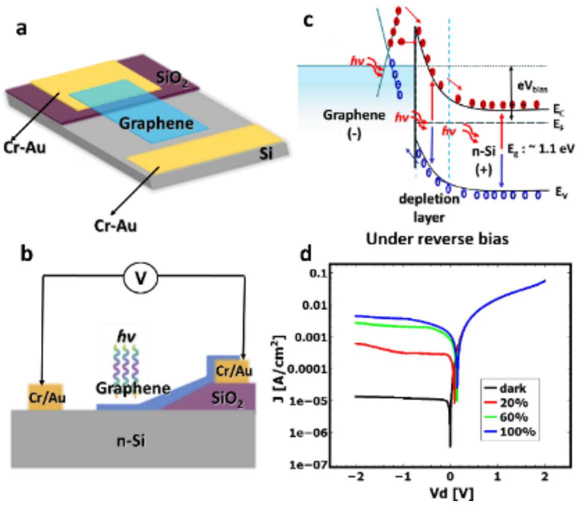

Figure 1: a) Schematic, (b) Cross-section of the graphene/n-Si heterojunction diode and (c) its band diagram in reverse bias under illumination. (d) J-V plot of the diode on a semi-logarithmic scale under various light intensities of 20%, 60% and 100% compared to the dark-state.

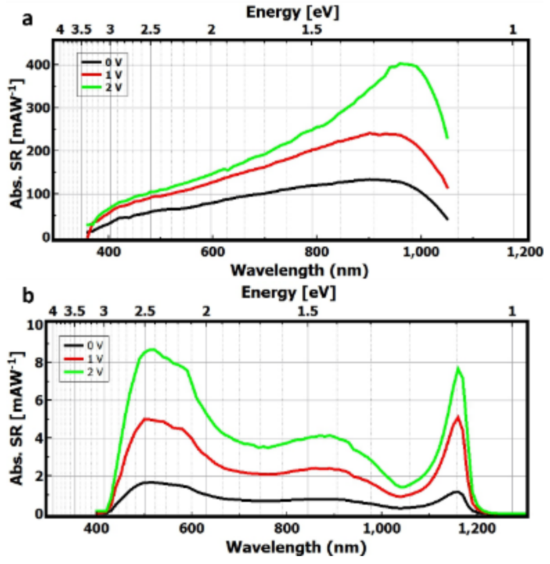

Figure 2: Absolute spectral response (Abs. SR) vs. wavelength (lower x-axis) and energy (upper x-axis) of the (a) graphene/ n-Si photodiode and for comparison (b) MoS_2 /p-Si photodiode at zero bias and reverse bias of 1 and 2 V taken from [our previous paper].