Photoresponsivity characterization of all-graphene p-n vertical-junction photodetectors at various doping concentrations

Dong Hee Shin, Sung Kim, Chang Oh Kim, Jong Min Kim, Ju Hwan Kim, Kyeong Won Lee, Suk-Ho Choi

Department of Applied Physics, Kyung Hee University, Yongin 446-701, Korea
sukho@khu.ac.kr

Abstract

Previous studies of photocurrent (PC) in graphene have demonstrated photoresponse near metallic contacts [1], at the interface between single-layer and bilayer regions [2], at lateral-type p-n junctions [3], or in the heterostructures with two-dimensional semiconductors [4]. Here, we firstly fabricate and characterize vertical-type graphene p-n junctions for photodetection. Single-layer graphene was synthesized by using chemical vapor deposition, and transferred on SiO_2/Si substrates. For the formation of graphene p-n junction, a solution of benzyl viologen (BV) was first dropped and spin-coated on the 10 x 10 mm^2 graphene/SiO_2/p-type Si wafer, and then annealed at 100 ^oC for 10 min to make graphene uniformly n-type. Subsequently, a 5 x 5 mm^2 bare graphene was transferred on ~1/4 area of the n-graphene/SiO_2/p-type Si wafer, a solution of $AuCl_3$ was dropped and spin-coated on the surface of graphene, and similarly annealed. As a result, the graphene p-n vertical junction was formed on the ~1/4 area of the SiO_2/p-type Si wafer. 1-mm-diameter Ag electrodes were deposited on the top of both n- and p-graphene layers to complete the graphene p-n device. The p-n junctions were fabricated for various n doping concentrations at a fixed highest p-doping concentration. The devices were named as D1 ~ D5 when doping time (t_D) in the BV exposure was 0.5, 1, 2, 3, and 4 min, respectively. The dark current (DC)-voltage (I-V) curves are symmetric and linear in the forward/reverse directions with respect to zero voltage for D1 to D3 devices, indicating no rectifying behaviors at the p-n junctions, consistent with Klein-tunneling effect [5]. The I-V characteristics of these devices are almost not varied even under illumination at various photon wavelengths from 300 to 1000 nm. For t_D > 2 min, the DC is greatly reduced over the full range of bias voltage, with the current reduction being stronger under forward bias than under reverse bias. The dark I-V curves show non-linear properties with varying bias voltage, indicating rectifying behaviors. The graphene p-n junction-based photodetectors (GPDs) shows strong PC responsivity in the UV-visible-near IR ranges, as shown in Fig. 1. High detectivity is achieved in the broad spectral range from ultraviolet to near-infrared and the photoresponse is almost invariant even after 6 months since the GPDs were fabricated, as shown in Fig. 2. The GPD structures permit a large PC flow by the tunneling of charge carriers through the interlayer formed between the p and n graphene layers at higher n doping concentrations. These results are discussed based on possible physical mechanisms.

References

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Figures

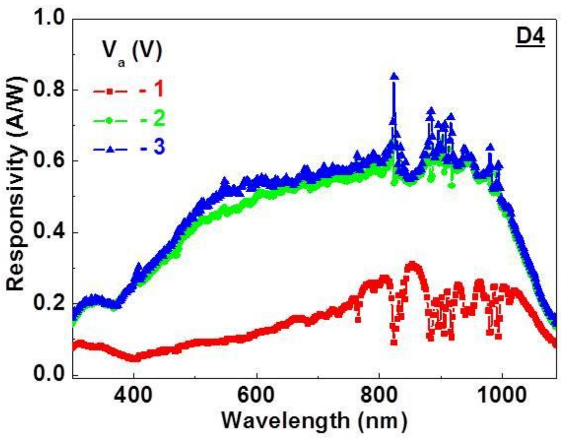

Fig. 1. Spectral responsivities of D4 device under forward-bias voltages from 1 to 3 V.

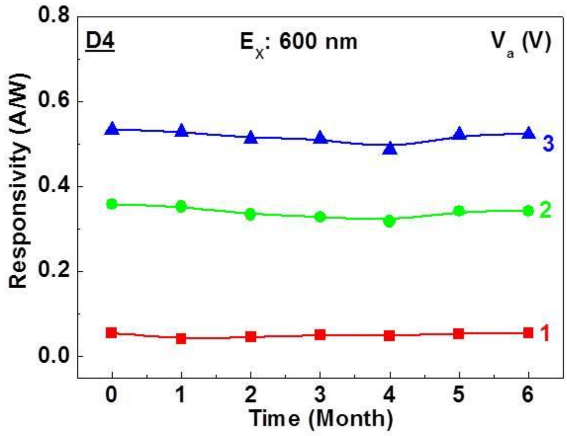

Fig. 2.Time-dependent responsivities of D4 device under different bias voltages for photon wavelengths of 600 nm.