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Using Novel Properties of Graphene for Designing Efficient Infrared Photodetectors

Graphene has unique electronic and optical properties that makes it suitable for use in optoelectronic devices such as photodetectors. A high carrier mobility exhibited by graphene allows it to be used for building efficient high-speed charge carrier collector. Graphene also shows highly controllable charge transport properties that can be leveraged for dynamic control of electrical characteristics in a device. Ultrafast carrier multiplication has also been observed in monolayer and bilayer graphene recently [1]. Using these novel features of graphene, we propose two designs of photodetectors where graphene is coupled with standard photosensitive materials, which can form the starting points for a new generation of high performance photodetectors. We propose a graphene-PbSe infrared photodetector, structure shown in Fig. 1(a), that can be operated in three different modes (schematic shown in Fig. 1(b)): a) high mobility collector, b) controllable Schottky barrier based photo-rectifier, and c) Graphene PhotoFET [2]. These different operating modes depend on the insulator material thickness that is inserted between the graphene-PbSe interface during device fabrication. We also propose a novel bilayer graphene|CdTe|HgCdTe photodetector whose schematic is shown in Fig. 1(c). This design uses photon-trapping micro-holes [3] and the carrier multiplication in graphene (schematic illustration shown in Fig. 1(d)) to increase the efficiency of photon absorption for higher performance. Using first-principles based calculations and semi-analytical models we demonstrate the feasibility and superiority of these detector designs. Using these designs the dark current can be decreased by an order of magnitude while the photo current can be increased by a few orders in comparison to standard photodetectors.

References

[1] P. George *et al.*, Nano Letters, 8.12(2008), pg. 4248-4251.
[2] S. Ganguly *et al.*, IEEE Photonics Conference, 2019.
[3] H. Rabiee-Golgir *et al.*, SPIE DCS, 2019.

Figures

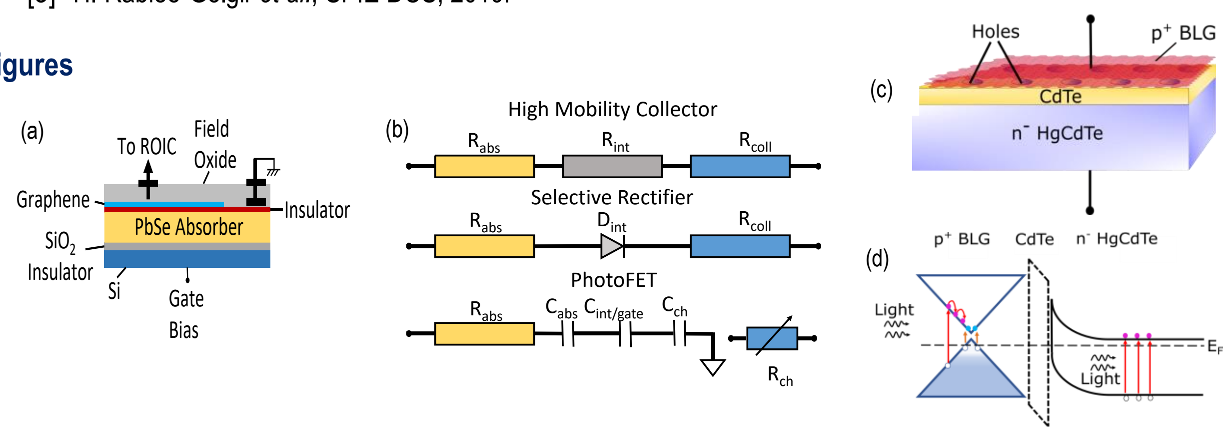

Figure 1: **(a)** schematic of graphene-PbSe photodetector, **(b)** circuit schematic of different operation modes of graphene-PbSe photodetector, **(c)** bilayer graphene|CdTe|HgCdTe photodetector with micro-holes, and **(d)** band diagram of the bilayer graphene|CdTe|HgCdTe photodetector demonstrating carrier multiplication process and light absorption regions.