Graphene-PbS Quantum Dot Based Highly Sensitive Infrared Photodetector

Anindita Sahoo[1]
Peter Reiss[2], Etienne Quesnel[1], Bérangère Hyot[1]
[1]*Univ. Grenoble Alpes, CEA, LETI, MINATEC Campus, 38000 Grenoble, France*
[2]*Univ. Grenoble Alpes, CEA, CNRS, IRIG, SyMMES, STEP, 38000 Grenoble, France*
anindita.sahoo@cea.fr

Infrared (IR) photodetectors have a wide range of applications in various fields such as telecommunication, thermal imaging, remote sensing, night assistance car driving etc. Combining highly efficient light absorbing nanomaterials with high mobility 2D materials, a new kind of hybrid photodetector has been introduced which dramatically increases the responsivity and gain of the photodetector. Such low dimensional IR phototransistor based on graphene/PbS QD hybrid was first proposed in literature [1, 2] in 2012. Later in 2017, a high-resolution broadband image sensor based on such hybrid materials was demonstrated [3], which is sensitive to ultraviolet, visible and infrared light (300–2000 nm).

We have systematically studied the evolution of photo-sensing qualities in graphene/PbS QD hybrid phototransistors as compared to bare graphene phototransistor in the visible-NIR-SWIR region of optical spectra. Our initial study on CVD-grown single layer graphene phototransistor showed a responsivity of about 5×10^4 A/W in the visible-NIR region. Such responsivity of 10^7 orders of magnitude higher [4] than conventional graphene phototransistor [5] is associated with the low–doped Si substrate. However, Si being the light absorbing material, limits the photo-sensing wavelength range of such device up to 1100 nm. In order to expand the wavelength range up to SWIR region, we have explored the potential of graphene/PbS QD hybrid phototransistors. We synthesized the colloidal PbS QDs absorbing in the NIR-SWIR region and developed a layer-by-layer controlled dip coating procedure with simultaneous ligand exchange and surface passivation at each dipping layer to deposit homogeneous PbS QD layers on graphene sheet. The hybrid phototransistor, fabricated in this process, achieved a significantly high responsivity of ~10^8 A/W at 940 nm wavelength with irradiation power density of 10^{-4} W/m^2. In the NIR range, the peak responsivity appears to be ~ 10^7-10^8 A/W, whereas in the SWIR range, the observed peak responsivity is ~ 10^6 A/W. Interestingly, graphene/PbS QD hybrid is highly sensitive at low irradiation power upto 0.06 pW in the NIR region (upto 0.6 pW in the SWIR region), whereas bare graphene photodetector is unable to sense such low intensity light of less than 50 pW in the visible-NIR region.

References

[1] Konstantatos, Gerasimos, et al. Nature nanotechnology 7, 363 (2012).
[2] Sun, Zhenhua, et al. Advanced materials 24, 5878 (2012).
[3] S. Goossens et al. Nature Photonics, 11, 366 (2017).
[4] Guo, Xitao, et al. Optica 3, 1066 (2016).
[5] Y. Zhang, et al. Nature communications 4, 1811 (2013).