Interband multi-graphene-layer versus intersubband quantum well infrared photodetectors

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We compare the characteristics of the intersubband quantum-well infrared photodetectors (QWIPs) based on the traditional semiconductor materials and the interband graphene layer (GL) infrared photodetectors (GLIPs) based on van der Waals (vdW) heterostructures.

Depending on the materials used for the QWs and inter-QW barrier layers, as well as on the QW width, QWIPs can operate from the near-IR to the THz frequencies. The main advantages of QWIPs are the maturity of the material and processing technology and the possibility of integration with other devices on the same chip. Drawbacks of QWIPs include cooling the detector to about 80 K due to high thermal dark current at higher temperatures and their response being limited to the polarization perpendicular to the QW layer, *i.e.* these detectors need an additional radiation coupling structure.

We have recently proposed and evaluated [1] IR photodetectors based on heterostructures in which GLs replace QWs and the barrier layers are made of vdW materials like hBN, WS_2, InSe, or GaSe. The structure and operating mechanism of GLIPs resemble those of vertical QWIPs. However, in contrast to the QWIPs, GLIPs use interband electron photoexcitation arising from the zero bandgap of graphene. As a result, GLIPs are polarization-independent and do not require special radiation coupling structures. GLIPs can operate over a wide spectral range from far IR to UV frequencies. In addition, GL absorption is at least an order of magnitude higher than that of a typical QW. The probability of capture of photoexcited and contact-injected electrons propagating over the barriers into the GLs is smaller than into the QWs in a QWIP. Finally, the GL/vdW heterostructures do not require lattice matching, making it possible to use a wide family of vdW materials with diverse electronic properties. As seen from Fig. 1, the responsivity and dark current-limited detectivity of GLIPs exceed those of QWIPs.

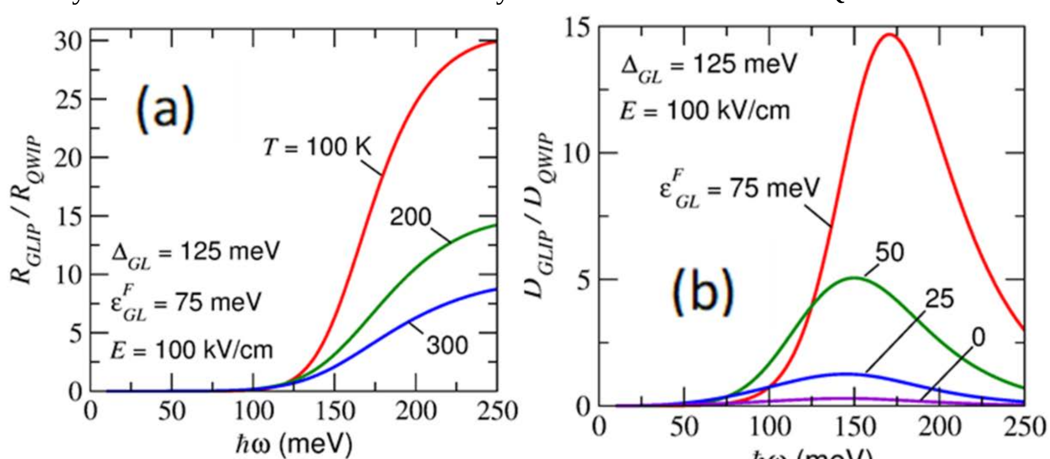

Fig. 1. (a) Ratio of the GLIP and QWIP responsivities *vs.* photon energy for different temperatures in GLIPs with potential barriers Δ_{GL} = 125 meV and hole Fermi energy $\varepsilon_{GL}{}^F$ = 75 meV (both measured from the Dirac point of the GLs) at an electric field E = 100 kV/cm. (b) Ratio of the GLIP and QWIP detectivities *vs.* energy for different $\varepsilon_{GL}{}^F$ and Δ_{GL} = 125 meV.

1. V. Ryzhii *et. al.*, submitted to *IEEE J. Quantum Electron.* (2017); *Infrared Phys. Technol.* **84**, 72 (2017); *Optics Express* **25**, 5536 (2017); and *J. Appl. Phys.* **122**, 054505 (2017).