A self-consistent modelling framework for graphene-based photodetectors, sensors, and modulators in mid-infrared to THz

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The interactions between light and graphene carriers are in the heart of graphene-based optoelectronic applications [1]. They manifest graphene's optical, electrical, and thermal properties as well as the interplay between them, including hot carrier heating and electron-phonon cooling [2]. Here, we present a self-consistent multi-physics framework for the simulation and design of graphene-based photodetectors, sensors, and modulators, targeting the mid-IR to THz spectral regime. In the mid-IR, we present a graphene/Si Schottky photodetector [2,3] operating in the thermionic regime. We show that a proper device optimization can push the external responsivity to 1 A/W and detectivity to 10^7 Jones in this ultrafast photodetection platform [2]. In the far-IR, we exploit graphene plasmonic resonances in nanoribbons forming a graphene/Si Schottky junction [3], to electrically detect the graphene plasmons with an external responsivity of 110 mA/W and noise equivalent power of 190 pW/HZ$^{0.5}$. We further demonstrate this platform as a chemical sensor, utilizing the surface-enhanced absorption technique [4], to detect and identify analyte molecules. Finally, in the THz regime we present the self-induced ultrafast absorption modulation of a Salisbury screen type of device based on graphene [5]. Our calculations show a 40 dB absorption modulation upon strong (up to 654 kV/cm) THz excitation, in excellent agreement with the experimental findings. The presented framework can be used to design different optoelectronic devices reliably and realistically, across a broadband spectral regime, using a plethora of materials alongside graphene, including vdW heterostructures.

References

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