Exploring Quantum Dots/Graphene van der Waals Heterostructures for Uncooled SWIR-MWIR Detection

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Semiconductor quantum dots/graphene (QD/Gr) heterostructures provide a quantum sensor scheme for photodetection and have witnessed remarkable progress in broadband photodetection. The QD/Gr photodetectors take advantages of the quantum confinement in QDs for spectral tunability and that in graphene for superior charge mobility to enable a high photoconductive gains or high photoresponsivity. A key question on whether high detectivity (D*) may be achieved in uncooled QD/Gr photodetectors in infrared (IR) spectrum is whether thermal noise in narrow bandgap semiconductor QDs in the QD/Gr photodetectors would degrade the detector performance in a similar way to conventional IR detectors based on semiconductor films and therefore demand cryogenic cooling to reduce the thermal noise. In order to answer this question, this talk presents our recent investigation on the noise origin of the QD/Gr heterostructures in the short-wave to middle-wave (SWIR-MWIR) spectra. Interestingly, it is found to be dominated by the noise in graphene either in dark or illuminated by SWIR-MWIR illumination. Furthermore, it has been found that the narrow-bandgap semiconductor QDs may be designed to reduce the noise towards the intrinsic limit in graphene by shifting its Fermi energy towards the Dirac point. Through development of atomic-scale surface and interface engineering approaches for optimize QD/Gr interface, uncooled $D^* > 10^{11}$ Jones at wavelengths of 2.25-3.25 μm has been achieved. This result reveals a different noise origin in the QD/Gr heterostructures, which is not directly affected by the thermal noise in narrow-bandgap semiconductor QDs. Therefore, QD/Gr heterostructures may provide a promising low-cost, scalable scheme for uncooled SWIR-MWIR detection.