Highly sensitive hexagonal boron nitride encapsulated graphene hot electron bolometers with a Johnson noise readout

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Graphene has remarkable opto-electronic and thermo-electric properties that make it an exciting functional material for various photo-detection applications. Its ultra broadband light absorption from the UV to the THz and a strong and ultra-fast photo-thermal-response allow to realize highly responsive photo-detectors with competitive sensitivities to state of the art detectors in the mid-IR and THz wave-lengths. In particular, owed to graphenes unique combination of an exceedingly low electronic heat capacity Ce and a strongly suppressed electron-phonon thermal conductivity Gth, the electronic and phononic temperatures are highly decoupled. These properties enable the use of graphene devices as ultra-sensitive hot electron bolometers (HEB) with predicted photo-detection sensitivities down to single terahertz photons.

Here we demonstrate highly sensitive HEBs made of high quality hexagonal boron nitride/graphene stacks (hBN/G/hBN) and employing a direct electronic temperature read out scheme via Johnson noise thermometry (JNT). The almost two orders of magnitude lower impurity concentrations of σi ~ 109 cm-2 in the hBN/G/hBN stacks, as compared to typical graphene devices on SiO2, translate into extremely low potential fluctuation of the Fermi energy ef ~ 5meV around the charge neutrality point. We perform combined mid-IR pump-probe and JNT measurements to demonstrate the strongly damped Ce and Gth in this regime, which results in unprecedented photo-detection sensitivity and noise equivalent power for graphene HEBs. We can increase the sensitivity further, we demonstrate that we can integrate the hBN/G/hBN HEBs into photonic crystal cavities and silicon wave-guides, which enable an almost 20-fold enhancement of the light absorption. The ease and CMOS compatibility of the integration process of the HEBs onto silicon photonic circuits paves the way towards high-speed graphene-based photonic integrated circuitry.