Cavity integrated silicon-graphene Schottky photodetectors

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The development of CMOS compatible Si photodetectors (PDs) operating at the near-infrared (NIR) wavelength of 1550nm is attractive for on-chip optoelectronic integration, power monitoring, imaging and reflectography[1-4]. While Si PDs are widely employed in the visible spectral range (0.4-0.7μm)[2], they are not suitable for detecting NIR radiation above 1.1μm, because the energy of NIR photons at 1550nm 0.8eV) is not sufficient to overcome the Si indirect bandgap (1.12eV) and induce photogeneration of electron-hole pairs. Schottky diode PDs based on internal photoemission (IPE), whereby photoexcited carriers from a metal are emitted to Si over a potential barrier Φ_B at the Si-metal interface, offer a solution for detecting sub-bandgap optical signals. The advantages of Schottky PDs are the simple material structure, easy fabrication process and straightforward integration with CMOS technology. The main disadvantage is the limited (<1%)[5] quantum efficiency, which results in limited responsivity of few mA/W for plasmonic-enhanced free-space illuminated devices[6] and 10 mA/W for waveguide integrated Schottky PD operating at 1550nm[7]. Graphene is a promising material for photonics and optoelectronics due to its light absorption over a broad spectral range, ultrafast carrier dynamics, high mobility and tunable optical properties via electrostatic doping[8]. Single layer graphene (SLG) placed at the Schottky interface increases the IPE quantum efficiency up to 7%[9,10] and therefore it is attractive to integrate SLG in Schottky PDs. However, SLG absorbs only 2.3%[11] of the incident light in the NIR, limiting the responsivity to ~10mA/W in free-space illuminated Si-graphene Schottky PDs operating at 1550nm[9]. The optical absorption in SLG can be enhanced by using a guided mode approach obtained by integrating graphene PDs with an optical waveguide[10], or using an optical cavity for the free-space illuminated devices[12]. Here, we report the integration of a Fabry-Perot optical cavity in Si-graphene Schottky PDs operating at 1550nm under free-space illumination. This is realized by using a 200μm Si wafer, and it enables responsivity enhancement at resonant wavelengths (Fig. 1a). We get an external responsivity R_{ext}~0.3mA/W at 1V reverse bias. R_{ext} can be increased by applying higher (1-10V) biases to lower Φ_B, and/or integrating a gold mirror to improve reflectivity compared to the air/Si interface. The PD with a gold mirror at V_R=10V reaches R_{ext}~20mA/W, which corresponds to an internal responsivity of ~0.25 A/W (Fig. 1b) and a quantum efficiency of 20%. This is at least an order of magnitude higher compared to previously reported free-space illuminated Si-graphene PDs for NIR wavelengths[9].

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(a) **(b)**

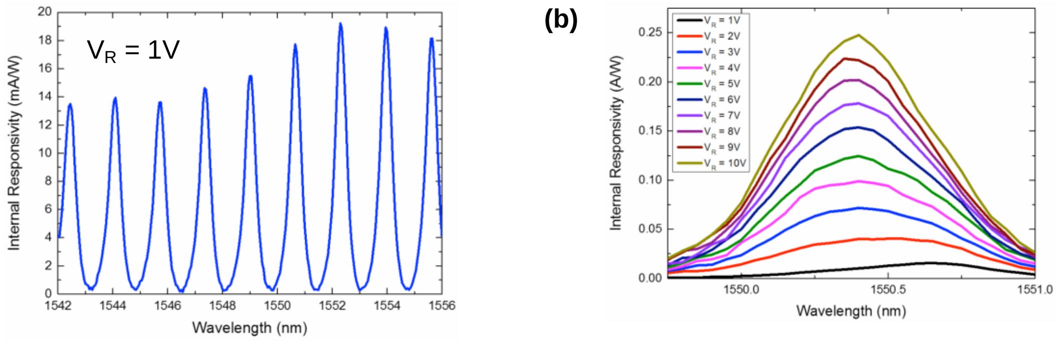

Fig 1. (a) Spectral response of Si-graphene Schottky photodetector at 1V reverse bias. (b) Internal responsivity as a function of bias.