Responsivity of Gated Photodiode in SOS Technology

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Summary

We report on the responsivity of Silicon-on-Sapphire (SOS) gated photodiode. A test chip, consisting of 1024 photodetectors, connected in parallel, was fabricated in a Peregrine's 0.5µm SOS technology and successfully tested by direct photocurrent measurements. We include measurements from a test chip, showing photocurrent dependence on reverse applied voltage, incident illumination intensities and light wavelengths. Dark current measurements are also reported. The measurement results are compared with recently presented PIN photodiodes showing that the gated photodiode can be appropriate candidate for further implementation in image sensor arrays.

Motivation

SOI has the potential of becoming an alternative to CMOS for low-power integrated image sensors implementations. However, it is not trivial to design high performance image sensors in SOI technology. Because of the thin top silicon film (usually bellow 2000Å), most of the photons pass through the sensitive regions without generating electron-hole pairs. Several papers have demonstrated SOI devices capable of imaging, but only a few groups have assembled such devices in working systems[1]. Unfortunately, most of the devices reported suffer from large dark current levels and low SNR.

In this paper we propose for the first time to employ gated photodiode, available for implementation in Silicon on Sapphire (SOS) process, as an efficient photodetector. SOS is one flavor of SOI technology, where the sapphire-aluminum oxide (Al_2O_3) is used as the substrate. SOS also features all the typical advantages of a standard SOI process, and it is thus an excellent alternative for future design of ultra low-power image sensors. Fig. 1 shows the structure and layout of the implemented gated photodiode. The device is the $p^+p^-n^+$ junction with floating polysilicon gate above the p^-. It has been previously observed that the presence of the gate significantly reduced dark current, compared to PIN device[2]. Our measurements have proven this claim.

Results

The implemented devices featured 6.1 x 6.1µm size. Fig. 2 shows measured photo and dark currents of the fabricated device. The measurements were performed for incoherent light at low illumination levels typical of indoor environments. As can be seen, very low dark current of under 0.1pA at reverse bias voltages under 1.5V was achieved. The dark current significantly increases when higher reverse voltages are applied, resulting in reduced SNR. Calculations show that operating in integration mode (with integration time of 30msec) at room light conditions (~1mW/cm^2) and ignoring readout noise, the photodiode achieves SNR of up to 56dB at 1.5V operating voltage supply. Previously reported PIN photodiodes showed much larger dark current levels of more than 1pA for the similar sized devices.

Device responsivity vs. wavelengths (at 0.8mW/cm^2 illumination condition) for different applied reverse voltages (Vb) is shown in Fig. 3. The measurements were performed from 435nm to 620nm wavelengths. It can be seen that the peak responsivity is approximately in the green region, while there is degradation in photocurrent in the blue and red regions. The same tendency can be observed in measured Quantum Efficiency (QE), shown in Fig. 4. The sensitivity and QE degradation in the blue region is due to photogeneration in the polysilicon gate, while their reduction in the red region is due to thin top silicon film. In comparison with the recently implemented PIN photodiodes, where no polysilicon gate was used, the measured devices show similar spectral response behavior.

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[1]A. Apsel, E. Culurciello, A. Andreou, and K. Aliberti, "Thin film PIN photodiodes for optoelectronic silicon on sapphire CMOS", Proc. of the Iscas'03, pp. 908 – 911, Bangkok, May, 2003.

[2]M. Stewart and M. K. Hatalis, "High performance gated lateral polysilicon PIN diodes", Solid-State Electronics vol 44, pp. 1613-1619, 2000

Figures

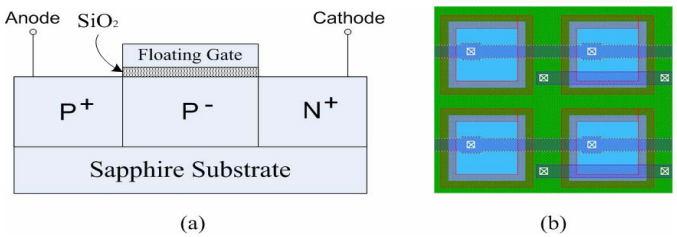

Fig. 1: *Gated photodiode with floating gate (a) device cross section, (b) layout of four devices connected in parallel*

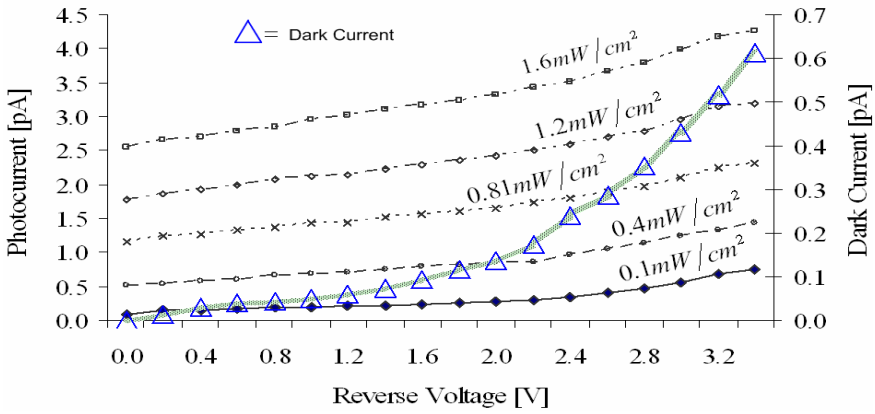

Fig. 2: *Measured photo and dark currents of gated photodiode with floating gate*

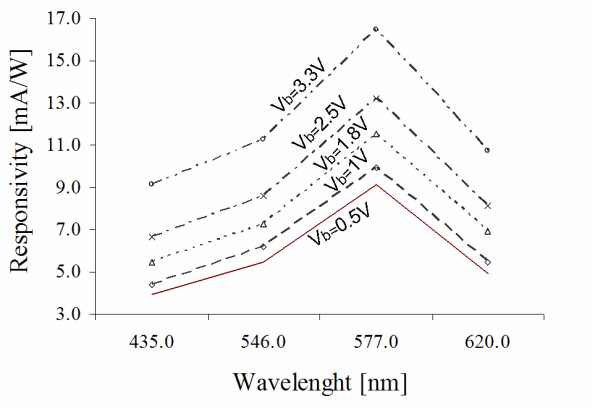

Fig. 3: *Responsivity vs. wavelength for different applied reverse voltages (Vb) under 0.8mW/cm² illumination condition*

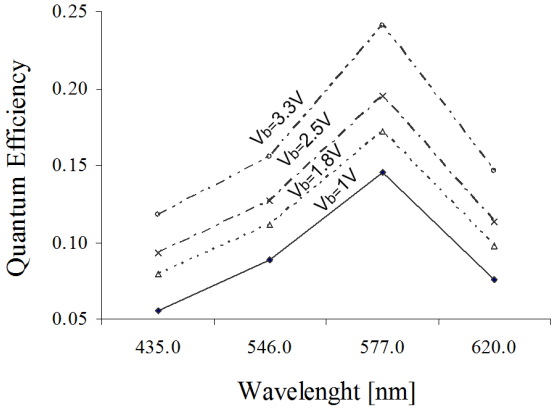

Fig. 4: *Measured Quantum Efficiency vs. wavelength for different applied reverse voltages (Vb)*