An FPGA-Based Real-Time Signal Processing for SOI MOSFET Single-Photon Detector

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Conventional single-photon detectors such as avalanche photodiodes (APDs) has the main advantage of an internal gain mechanism when a high reverse bias voltage is applied. However, the drawbacks are large dark counts, necessity of high-voltage power supply, operation speed limited by the long recovery time, etc. Since these issues are overcome by detecting photo-generated carriers one by one without multiplication. Due to the remarkable progress in silicon integrated circuit (IC) technology, a short- and narrow- channel silicon-on-insulator (SOI) metal-oxide-semiconductor field-effect transistor (MOSFET) could detect single electrons at room temperature [1]. In this work, the signal processing method for the SOI MOSFET single-photon detector is studied. Hardware implementation of single-photon counting in real-time based on field-programmable gate array (FPGA) is considered. It is further advantageous to realize the output signal from the detector in real-time rather than to route the signal in software to get the output.

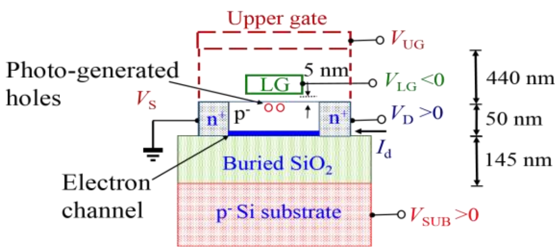

Fig. 1 Cross-sectional view of the device [2].

Fig. 1 represents the cross-sectional view of the device. The photo-generated holes can be stored by the potential well formed by the $n^+p^-n^+$ junction and upper gate (UG), lower gate (LG) and substrate voltages, and the photo-generation of holes is detected as the increase in electron current through the backside channel when the positive substrate voltage is applied [2]. The detector output is forwarded to an analog-to-digital converter (ADC) of the Zynq ZC702 FPGA board, the output of the ADC signal is processed to detect the events of hole generation by photon incidence. By the signal processing algorithm, incidence of single photons is properly counted even if multiple photons enter at the same time.

Fig. 2 shows the real-time signal processing output for the device with 65nm gate length and 105nm channel width under the illumination at the wavelength of 550 nm and the intensity of 4.5 x 10^{-6} W/cm^2. The output of the single-photon detector is differentiated primarily to detect the photo-generation of holes, and then peak area of the differentiated signal is integrated to obtain the number of generated holes associated with the photon incidence event. This differentiation-integration steps make the processing insensitive to the baseline shift. The value (3) in Fig. 2 indicates the number of holes generated in an event. The total number of incident photons for the observation time of 0.52 s is 22. Thus the number of incident photons is counted exactly by the real-time signal processing algorithm. From the results, it is confirmed that the proposed signal processing algorithm can properly extract the photon incidence information from the SOI MOSFET output.

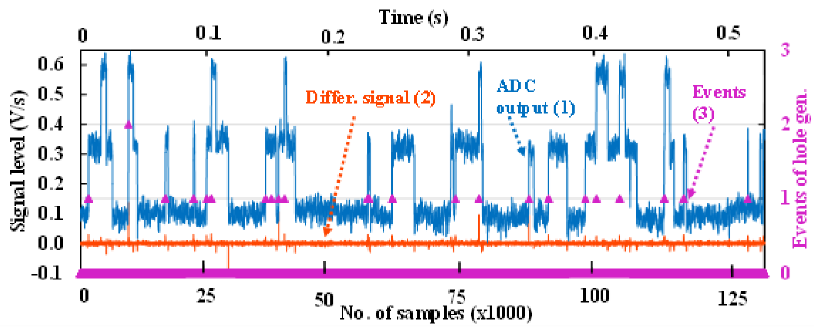

Fig. 2 Output of ADC (1), differentiated signal (2), and the number of photo-generated holes in each event (3).

References:
[1] K. Nishiguchi, et al., *Appl. Phys. Lett.,* Vol. 88, No. 18, pp. 183101_1-3, 2006.
[2] W. Du, et al., *Optics Lett.,* Vol. 36, No. 15, pp. 2800-2802, 2011.