Development of SOI pixel sensor for environmental radiation monitor†

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We have developed a prototype SOI pixel sensor, called RADPIX, for a radiation monitor. This is based on the silion-on-insulator (SOI) pixel CMOS technology and developed by Y. Arai et al.[1)] The RADPIX is a monolithic pixel detector that consists of a thin CMOS readout array (40 nm, 10 Ω), a buried oxide layer (200 nm), and a thick high-registivity Si-sensor (260 μm, 700 Ω) vertically on a single chip. Figure 1 shows the schematic view of the Nested-Well structure SOI detector (p-in-n type sensor). The buried N-well suppresses the back gate effect from the electric field in the sensor and reduces the cross-talk by isolating the sensor from the circuit.

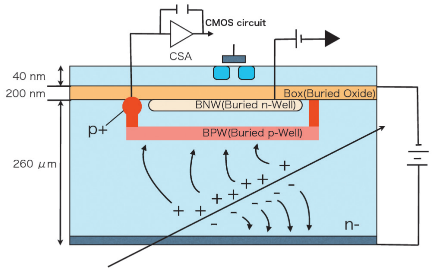

Fig. 1. Schematic diagram of the nested-well SOI structure

RADPIX aims to count the rate of the radiation and to visualize the hit pattern in real time for environmental radiation. From the hit pattern, one can estimate the radiative source such as beta-ray, γ-ray, or α-ray. The sensor is a DC-coupled device and the sensor's capacitance is in a few tens of femtofarads. The typical leakage current for a 40 μm × 40μm pixel is of the order of picoamperes at room temperature, which saturates the baseline within about 10 ms. Therefore, this device needs to reduce the leakage current or compensate the current to be able to measure the environmental radiation, which is of the order of 10^{-2} Hz/cm^2 in 1 μSv/h from ^{137}Cs. The Krummenacher feedback scheme[2)] is used for long exposure, which has an individual leakage current compensation circuit. Figure 2 shows the schematic of RADPIX. We implemented charge-sensitive preamplifers with different gains (1fF and 5fF as feedback capacitors). Two inverter chopper comparators are implemented to generate a trigger signal, and the latched output can be read from each pixel. The analog signal is sampled by the 230 fF store capacitance and is readout from each pixel. This analog information can be used for the pattern recognition and identification of the radiative source.

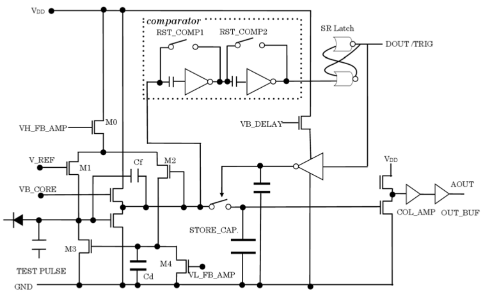

Fig. 2. Schematics of RADPIX

Figure 3 shows the pixel-by-pixel gain variation for two different charge-sensitive preamplifiers. This was studied by using test pulses. The average of the gain is 23 μV/electron (RMS∼1.4) and 94 μV/electron (RMS∼5.1) for the low gain type and high gain type, respectively. Position dependence is not found. We also evaluated the performance of the comparator. Figure 4 shows the counts of comparator output as a function of comparator threshold. We observe a 5%-10% fake hit rate even at high threshold. This is due to the large noise, which shows up when the digital signal is readout. The reason of the large noise and the strategies for further improvement are under investigation.

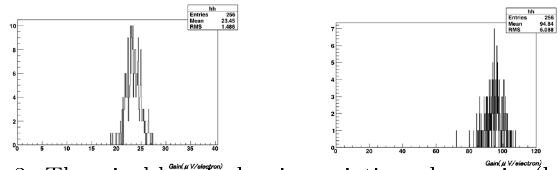

Fig. 3. The pixel-by-pixel gain variation: low gain (left) and high gain (right)

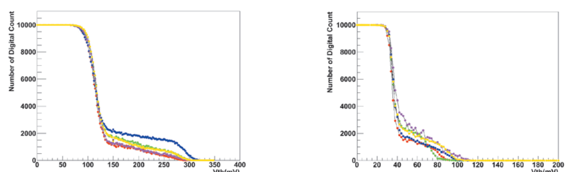

Fig. 4. Counts of comparator output as a function of comparator threshold for four typical pixels : low gain (left) and high gain (right)

References
1) Y. Arai, et al.; Nucl. Instr. and Meth. A636, 31 (2011).
2) F. Krummenacher; Nucl. Instrum. Methods A 305, 527-532 (1991).

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