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Improvement and Evaluation of Event-driven Performance with Double-SOI Pixel Detectors for X-ray Astronomy

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We have been developing a monolithic active pixel sensor with the silicon-on-insulator (SOI) CMOS technology for use in future X-ray astronomical satellite missions. Our objective is to replace the X-ray Charge Coupled Device (CCD), which is the standard detector in the field, by offering high coincidence time resolution (~ 50 ns), superior hit-position readout time (~ 10 μs), and wide bandpass (0.5 −40 keV) in addition to having comparable performances in imaging spectroscopy. We have been developing prototype detectors, called "XRPIX"series. XRPIX contains comparator circuit in each pixel to detect an X-ray photon injection; it offers intra-pixel hit trigger (timing) and two-dimensional hit-pattern (position) outputs. Therefore, XRPIX is capable of direct access to selected pixels to read out the signal amplitude. In our previous study, we evaluated its basic imaging spectroscopic performance and obtained the X-ray spectra by this system. Recently, we designed a prototype device named XRPIX6D, to which we introduced a Double-SOI structure, to improve an X-ray responsivity. The difference from the conventional SOI wafer is that the Si layer, called middle-silicon is added to the buried oxide layer. The Double-SOI structure reduces the parasitic capacitance between the sense-node and the CMOS circuit by fixing the potential of middle-Si layer, and suppresses crosstalk between them. This structure is also expected to increase in conversion gain due to reduction in the sense-node parasitic capacitance and increase in closed-loop gain due to reduction in the feedback parasitic capacitance. XRPIX6D has the chip output gain of 40.5 μV/e−, and the readout noise of 16 e−(rms), the energy resolution of 290 eV in full width at half maximum for 6.4 keV X-rays in all pixel readout mode. We successfully improved the spectroscopic performance also in the event-driven readout mode. Furthermore, we improved the event determine rate by introducing a hit-pattern processing circuit in XRPIX.

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