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# Monolithic Deep Depletion CMOS Pixel Sensor for Detection of Minimum Ionizing Particles and X Rays

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High energy radiation like X rays and Minimum Ionizing Particles (MIPs) have a radiation length of several tens of microns in silicon. When using standard CMOS processes with low-resistivity silicon substrates or thin high-resistivity EPI layers, the achievable signal amplitude is too small to provide competitive performance for applications in particle tracking or low energy X-ray detection. For those applications a deep depletion silicon detector is necessary which cannot be built using standard CMOS processes.

We modified a standard 180nm CMOS process using high resistivity silicon substrate to create a thick depletion layer in which a strong drift field is created when a high voltage is applied to the backside. High charge collection efficiency is expected to be maintained up to neutron irradiation of to 1016 neq/cm2 by increasing the depletion voltage on the backside, without constraints by the CMOS circuitry on the front side. We have demonstrated complete and accurate charge collection for detector thicknesses from 50 to 400 microns. In the past two years we have designed and fabricated the following devices that have applicability to X-ray and MIP detection in high energy physics:

(1) 640 x 512, 15μm pitch, low-noise imaging sensor

(2) 1K x 1K, 20μm pitch, digital-output OrthoPix sensor that detects and reports locations of MIP events at high brilliance (>100M hits/cm2/sec)

(3) 36 x 36, 50μm pitch demonstration device for X-ray tracking

We present measurement results from the latest developments of our deep depletion sensors for these applications. In particular, we successfully demonstrated imaging with high MTF on our 640 x 512 sensor with 400μm thickness, which is the thickest fully depleted silicon sensor reported in the literature, to our knowledge. Our recently developed megapixel OrthoPix detector supporting a frame rate of 50 MHz at 200 mW/cm2 power dissipation is suited for large-area particle trackers at low sensor cost.

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