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Performances of depleted Monolithic Active Pixel Sensor in a high-resistivity CMOS process for X-ray detection

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We discuss the performances measured in laboratory of a MAPS prototype we developed with a pixel architecture allowing substrate depletion from the front side. The sensor was fabricated in a 180 nm CMOS Image Sensor Technology and features 4 matrices of 16 x 128 pixels with 22 x 22 μm² pitch. For all matrices, the charge sensing diode is AC-coupled to a source follower or amplifier and is biased through a forward diode connected to the high voltage. Analogue pixel values are read out with a rolling-shutter steering.

The chips were produced over two types of high-resistivity substrates: 18 μm epitaxial layer (> 1 $k\Omega \cdot cm$), and 200 μm Czochralski (>600 $\Omega \cdot cm$). Front-side measurements using a monochromatic X-ray ^{55}Fe source and ß-ray ^{90}Sr source have been conducted on chilled sensors to evaluate the noise, gain, energy resolution and charge collection for applied bias up to 40 V. Energy resolution (FWHM) of 300 eV for the epitaxial layer and 490 eV for the Czocharlski substrate were obtained for 5.9 keV X-rays.

For the epitaxial layer version, our tests indicate that full depletion is achieved for bias below 20 V, in line with predictions from TCAD simulations. Sensors were irradiated with various neutron fluences up to $5 \cdot 10^{14}$ neq/cm2. We will report on the mild performance degradation observed under these conditions.

The TCAD simulation of the 200 μm thick Czochralski substrate predicts a depleted depth of a few tens of micrometers, largely depending on the actual value of the resistivity assumed. However sensors thinned to 50 μm (the CMOS process occupying the top 10 μm) were also characterized in backside illumination condition, targeting the efficient detection of soft X-rays. We will present our conclusion considering a model for the charge collection within the depleted substrate.

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