DEPMOSFET sensor matrix prototypes for the XEUS Wide Field Imager

Active Pixel Sensors based on the DEPMOSFET (DEpleted P channel MOSFET) are a promising candidate for the APS section for the XEUS Wide Field Imager. They combine excellent energy resolution, high readout speed in combination with random accessible pixels and low power consumption with a 100% fill factor and high quantum efficiency. DEPMOSFET matrix design variants from the first prototype production are currently under study at the MPI HLL and show very good performance.

The DEPMOSFET is a P-channel MOSFET integrated onto a fully depleted, high-resistivity n-type silicon bulk (fig. 1). Using the principle of sideward depletion, a potential minimum is generated underneath the surface of the silicon, which can be enhanced and localized by the help of an additional deep-n implantation directly below the transistor channel. Electrons released in the silicon bulk will drift to this so-called “internal gate” and stay there, modulating the transistor current by inducing additional charge carriers in the channel. Thus, the transistor current is a function of the charge stored in the internal gate. The charge can be removed by applying a positive voltage pulse to an adjacent n+-doped “clear”-contact. The charge information can be retrieved by comparing the transistor current values before and after the clear pulse.

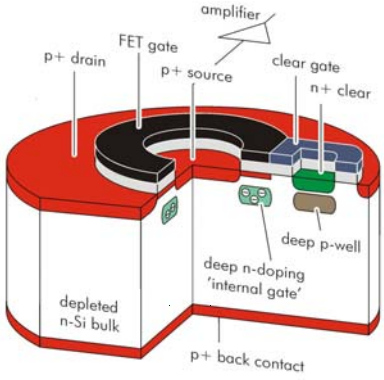

Fig. 1: *Cross section of a circular DEPMOSFET pixel cell. Charges collected in the ‘internal gate’ modulate the transistor current.*

Within the matrix, the pixels’ gate and clear contact are connected row wise, while the sources are connected column wise and the drain contact is global. The pixels are biased using a column-individual current source and are thus operated in source follower mode. By applying appropriate voltages to the external gate contacts, all except for one pixel rows can be turned off. As the internal gate persists, independent from the state of the external gate, the pixels are sensitive all the time. Thus, the matrix can be read out row by row in a 64 column parallel mode. The devices require additional control circuitry, which provides the clear and gate pulses, and an analog read out IC. A variant of the CAMEX IC providing 64 channels with an 8-fold CDS filtering stage each is used for that purpose.

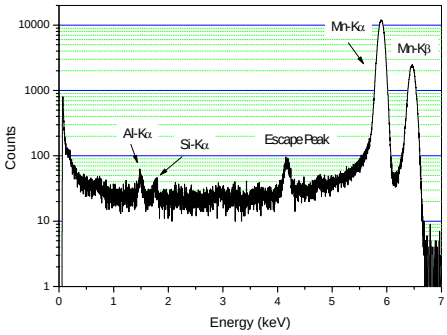

Fig. 3 *Example for ^{55}Fe spectrum measured with DEPMOSFET pixel sensor hybrid at -40 °C. The FWHM of the Mn-Kα is 131 eV, corresponding to 6.1 electrons ENC.*

The test of the different designs included in the recent production is in progress. The devices have 64 x 64 pixels of 75 x 75 μm^2 size, the total sensor area is 4.8 x 4.8 mm^2. Several readout hybrids have been built (fig. 2) and tested (fig. 3, fig. 4). The devices show excellent homogeneity and energy resolution values as good as 6.1 electrons have been measured for the first prototypes for a temperature of -40° C. The next prototyping production, including larger sensor prototypes, will start in 2005.

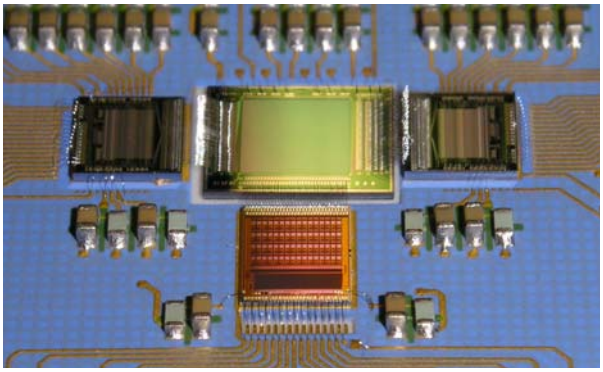

Fig. 2: *Photo of a fully assembled DEPMOSFET pixel hybrid. The sensor IC sits in the middle. The ICs on the left and the right control the external gates and the clear. The IC below is the analog front end CAMEX 64G.*

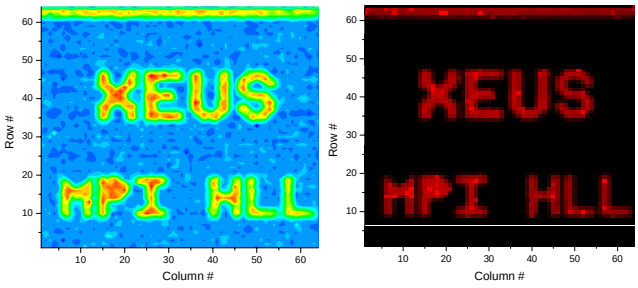

Fig. 4: *Imaging measurement with DEPMOSFET pixel sensor with an 300 μm thick silicon baffle, illumination with an ^{55}Fe source. Minimum structure size was 150 μm. Shown: sum of X-ray energy per pixel (left), number of photons per pixel (right).*

References:

- *J. Treis et al*. First results of DEPFET based Active Pixel Sensor prototypes for the XEUS Wide Field Imager, *submitted to Proceedings of SPIE Astronomical Telescopes and Instrumentation, 2004*
- *L.Strueder et al.* Xeus wide field imager: first experimental results with the x-ray active pixel sensor DEPFET, *SPIE Proceedings 5165, 2003.*

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