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Detection Performance of MIMOSIS-1, a CMOS Sensor Prototype Developed for the CBM-MVD

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The Micro-Vertex Detector of the CBM experiment at FAIR/GSI requires very light detector stations equipped with highly granular and thin pixel sensors adapted to hostile running conditions. A specific CMOS pixel sensor, called MIMOSIS, is being developed for this purpose. Inspired by the ALPIDE sensor equipping the ALICE ITS, its design is adapted to higher hit rate and radiation tolerance. The first full scale prototype was fabricated in 2020 with several epitaxial layer variants. The chips were assembled in a beam telescope which was operated at DESY. First results of the signal-to-noise and detection performance evaluations will be presented.

Summary (500 words)

MIMOSIS-1, the first full size pixel sensor prototype developed for the CBM-MVD (FAIR/GSI) was fabricated in 2020 in a 180 nm CMOS imager technology with a 25 µm thick epitaxial layer featuring a resistivity exceeding 1 kΩ·cm. The layer was declined in 6 different doping profiles to enhance its depletion depth and, consequently, the sensor radiation tolerance and charge collection speed.

MIMOSIS-1 features 1024 columns of 504 pixels (27 x 30 µm² wide). Its dimensions (31 x 17 mm²) are those of the final sensor, to be produced in 2023. Fig.1 displays a photograph of a diced sensor. Each pixel includes a pre-amplifier connected to the sensing node and to a shaping and discrimination circuit with tuneable threshold. The depletion of the epitaxial layer is obtained either from usual back bias or from the sensing node, possibly connected to a voltage source. The signal of each hit pixel comes down to its logical address, combined with a time stamp expressing a 5 µs frame read-out time. The pixel read-out proceeds through a data driven architecture similar to the one of the ALPIDE sensor equipping the ALICE-ITS. It is connected to a data processing micro-circuit integrated on the sensor edge, which prefigures the sparse data scan circuitry and elastic buffer to be integrated on the final sensor, suited to deliver up to 2.4 Gbits/s of data. More details may be found in [1, 2].

MIMOSIS-1 incorporates 4 different variants of in-pixel circuitry, each populating a different sub-array. Two sub-arrays host pixels where the sensing node is DC-coupled to the pre-amplifier. The two others feature pixels where the node is connected through a capacitor to the pre-amplification and shaping circuitry. In the latter case, called AC-coupled, the voltage source connected to the sensing diode is decoupled from the in-pixel signal processing circuitry, which allows to raise the diode input voltage to several tens of volts, and thereby extend the depleted volume [2].

For each sub-array, the pixel temporal noise (TN) and the dispersion of the discriminator thresholds (FPN) were estimated on several tens of sensors in the laboratory. The study was performed for 3, out of the 6, different epitaxial layers. The TN and FPN values were derived from a "threshold scan", where the charge injection of all pixels composing a sub-array was repeated while increasing step by step the discriminator thresholds. Most TN and FPN values were found in the ranges 3-5 and 8-15 e- ENC, respectively (see Fig.2).

A two-arm beam telescope was constructed with 4 sensors thinned to 60 µm, complemented with 2 sensors placed in between both arms for a first detection performance evaluation. The talk will present the detection performance observed with particle beams for the 4 different pixel designs and 3 different substrates, as a function of discrimination threshold and depletion voltage.

References:

[1] M. Deveaux et al., "Observations on MIMOSIS-0, the first ⋯", arXiv : 1909.05614v1

[2] F. Morel, "The MIMOSIS-1 sensor ⋯", talk pres. at the TIPP workshop (24-28 May 2021)

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