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Design and characterization of pixelated needle probe for molecular neuroimaging on awake and freely moving rats

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IMIC is a Monolithic Active Pixels Sensor prototype designed for the MAPSSIC project, which aims at developing wireless intracerebral probes dedicated to the local counting of low energy positrons in situ in the brain of awake and freely moving rats. Former experiments using a passive PIXSIC circuit validated the proof of concept, but have also clearly demonstrated the need to improve signal-to-noise ratio and robustness. The IMIC circuit features a matrix of 16 x 128 pixels of 30 x 50 µm2 size. The sensor has a needle-like aspect ratio of 610 µm x 12 000 µm. The sensitive layer consists in a thin 18 µm thick high-resistivity epitaxial layer preceded by a 10 µm thick integrated electronic layer.

The foreseen application requires high sensitivity to ß+ rays while being immune to gamma-ray background. Another important constraint is the limited power dissipation to avoid thermal-induced damages in the brain of the rat, hence requiring low electrical power consumption. The sensor is a fully-programmable digital output sensor. The pixel design is based on the front-end architecture of the ALPIDE chip developed at CERN. However, modifications have been made to mark fired pixels between two readouts.

Laboratory tests confirm the designed low power consumption, which reaches 161 µW for the whole sensor. Characterizations using a ^{55}Fe X-ray source, and a ^{90}Sr ß− source with various metallic shielding thicknesses show a constant measured activity for short, and long integration times if the activity is sufficiently low not to saturate the sensor. Various measurements with a ^{18}F source indicate an excellent response to ß+ rays with a low sensitivity to the background 511 keV annihilation gamma rays.

In this paper, we will present the probe design in detail together with the principal features of the needle shaped sensor. We will also discuss complete characterization results.

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