ID de Contribution: **91** Type: **12mOral**

Design and characterization of Low-Gain Avalanche MAPS in 110nm CMOS

jeudi 21 novembre 2024 10:50 (17 minutes)

Charged Particle detection in High-Energy Physics (HEP) applications increasingly asks for sensors with improved timing resolution and low power. A trade-off between these two requirements is typically necessary and strongly linked to the design and technology of front-end readout electronics. Low-Gain Avalanche Detectors (LGADs), which have become an established technology in HEP experiments, offer significant improvements in this respect. However, advanced packaging techniques are required to fully exploit the potential of large-area pixelated detectors based on LGADs, thus substantially increasing system costs and reducing the yield.
To address these limitations, several research groups are beginning to explore the feasibility and performance of CMOS-integrated LGADs. This work presents the ongoing activities towards customizing the fully depleted monolithic sensor technology developed at INFN project ARCADIA by adding a gain layer to the readout electrodes. In this way, the electrons generated in the active volume of the sensors by the absorbed radiation and drifting towards the collection electrodes need to cross a high-field region, resulting in a net signal improvement. The sensors' active region is a high-resistivity n-type epitaxial layer grown on a standard p+-doped silicon substrate, and its thickness can thus be easily modified by changing the thickness of the epitaxial layer. The gain layer is depleted by applying a sufficiently high voltage at the top electrode, which requires a bias resistor and needs to be AC-coupled to the readout electronics. The substrate has to be biased at a negative voltage to deplete the full active substrate and generate the required drift field in all the device's active regions.
Several test pixel layouts have been included in the first design, exploring large pixels for improved timing resolution and smaller pixel test structures suitable for simultaneous tracking and timing (4D detection). Large test pixels, designed for the requirements of ALICE 3 Time of Flight layers, have an active area of 250µm x 70µm and 250µm x 250µm, while smaller square pixels feature a pitch of 25 and 50µm. A sensor array with integrated readout electronics was also designed for the 250µm x 70µm pixels.
Different sensor terminations have been explored in the design. For large pixels, a termination similar to the one used in standard LGADs, where the edges of the sensor provide charge collection with unit gain is acceptable, since a small amount of generated charges is collected at the periphery. However, in small pixels, the fraction of electrons collected by the gain-less termination region would be unacceptably large and spoil the pixel performance. To this end, another termination type exploiting deep p-well implantations, capable of conveying all the collected charges to the gain region, was also included in the design.
A preliminary characterization campaign, exploring electrical device characteristics, and functional measurements with optical sources and charged particles is underway. A summary of updated simulation results and experimental data obtained on the different pixel configurations will be presented.

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Classification de Session: Timing with pixels

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