

Eleventh International Workshop on Semiconductor Pixel Detectors for Particles and Imaging



ID de Contribution: 60

Type: Poster

Topmetal-M3: a position and time sensitive MAPS with delay line readout

jeudi 21 novembre 2024 13:54 (3 minutes)

Monolithic active pixel sensors (MAPS) integrating sensitive element and readout circuits into one silicon chip have proven their good performance as high spatial resolution particle trackers in the past years. The MAPS provides high granularity with low material budget and has been applied in high energy physical experiments, such as MIMOSA sensors for the STAR HFT at RHIC, ALPIDE sensors for the ALICE ITS upgrade at LHC and so on. MIMOSA sensors use a rolling shutter technology to read out the data. While a priority readout technology is adopted in ALPIDE to read out the data. Compared to the rolling shutter readout scheme, the priority readout scheme can significantly reduce the integration time, power consumption and data volume. But both MIMOSA and ALPIDE are position-sensitive MAPS but the time of arrival cannot be measured.

Topmetal-M3 is a position- and time-sensitive MAPS which is developing at Central China Normal University in China. A delay-line readout scheme with column-level Time-to-Digital Converter (TDC) is adopted in Topmetal-M3. The Topmetal-M3 is composed of a pixel array arranged in 256 (row) x 96 (column), column-level TDCs, a digital readout module and a configuration module. A bidirectional inverted "U"-shaped delay line which is composed of inverters is inserted in each double column and shared by all pixels in the double column. When a pixel is hit, the signal is amplified and converted into a digital signal. And then the leading edge is converted into a narrow digital pulse with a pulse width of less than 1 ns. The narrow digital pulse is fed into the bidirectional inverted "U"-shaped delay line and transmits in opposite directions. The arrival time of the leading edge in the end of each column is measured by the column-level TDC. By calculating the time difference of the arrival time on each double column, the hit position can be located. The TDC architecture mainly consists of a coarse counter and a delay-line-based analog-digital hybrid interpolator. The outputs of the TDCs are fed into the digital readout module. The data are framed in the digital readout module and transmitted off-chip in parallel.

The Topmetal-M3 sensor has been designed and taped out in a 180 nm standard process. The pixel size is $32 \mu\text{m} \times 26 \mu\text{m}$. The detailed simulations have been done. The delay time of the delay unit of the inverted "U"-shaped delay line is about 90 ps. The time resolution of the TDC is better than 10 ps. Each hit pixel can be located by the time information. The chip has come back to the lab and the test work is ongoing. We will present the test results in the conference.

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Classification de Session: Posters

Classification de thématique: Monolithic sensors