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Characterization of the Column-Based Priority Logic Readout of Topmetal-II- CMOS Pixel Direct Charge Sensor

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We present the detailed study of the digital readout of Topmetal-II- CMOS pixel direct charge sensor integrated 72x72 pixels each capable of directly collecting charge through exposed metal electrodes in the topmost metal layer. In addition to the time-shared multiplexing readout of the analog output from Charge Sensitive Amplifiers in each pixel, hits are also generated through comparators with individually DAC settable threshold. Hits are read out via a column-based priority logic, pertaining both hit location and time information. We study the detailed working behavior and performance of this readout and demonstrated its potential in imaging applications.

Summary

We have successfully implemented a CMOS IC, Topmetal-II-, for direct charge collection and imaging. It is a highly pixelated sensor with 83 μm pitch between 72x72 pixels fabricated in a standard 350 nm CMOS technology. The sensor utilizes exposed metal patches on top of each pixel to directly collect the charge. Each pixel contains a low-noise charge sensitive preamplifier (CSA) to establish the analogue signal and a discriminator with a tunable threshold to generate hits. Hits are read out digitally through a column-based priority logic scheme. A Priority Logic Module in each pixel responds to the output of the comparator, which compares the CSA output to a set threshold. A Column Read Module reads the hit and resets the pixels. A digital multiplexer (MUX) polls the status of each Column Read Module and assembles the hit pixel's address and time information, then ships them off the sensor. The threshold is set by a 4-bit DAC in each pixel, aiming to reduce the spread of the Baseline and Transition in the whole pixel array.

Firstly, we disable all the 4-bit DACs and set the proper level for the baseline of the discriminator. Then, we apply the external trigger to excite each pixel and scan the reference voltage of the discriminator by a few steps. Through this scanning, both the number of hits and injected pulses will be recorded via the Data Acquisition (DAQ). Based on the DAQ analysis, we're able to draw the S-Curve for each pixel. Moreover, we plot the distributions and histograms of both Baseline and the Transition. According to these preliminary results, we developed a software module to generate the configuration data for 4-bit DAC for every pixel. Afterwards, we retest and redraw all the plots. The results show that the sensor achieves a threshold distribution of the whole matrix with Mean = 13 mV, RMS = 3.4 mV, and the RMS value of both Baseline and Transition reduce by a factor of 5 with proper 4-bit DAC settings. Additionally, the step size of 4-bit DAC has also been proved to have good uniformity with Mean = 9 mV, RMS = 0.4 mV.

We operated the Topmetal-II- sensor at an identical setting as in the digital readout tests. A purple LED was driven by a narrow pulse to emit a beam of light with wavelength = 390 nm, filtered by a "T" shaped photo-mask. Since the sensor was quite sensitive to the light, the irradiated pixels reacted to generate hits.We successfully reconstructed the image of a perfect "T" on the sensor. In this experiment, we also measured and analysed the 10-bit time information of pixel hits, which

verified the correctness of the readout implementation.
To improve the performances of Topmetal-II-, besides decreasing the Mean value of the threshold for each pixel, we can further reduce the distribution of both Baseline and Transition values. Most of these optimizations are ongoing in future series of Topmetal sensors.

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