Design and characterization of active pixel sensors in 0.25 CMOS

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Abstract

We are developing CMOS monolithic active pixel sensors. We have produced two test structures designed in 0.25 CMOS. They feature four different types of pixels: standard 3MOS, 4MOS allowing correlated double sampling, charge amplifier pixels and a Flexible APS. The FAPS has a 10 deep pipeline on each pixel. This is specifically designed for the linear collider.
A program to test our devices is well underway. We will report results of a radiation test including measurements and simulations. Also results of a source test will be presented and the first results using the FAPS will be shown.

Active pixel sensors

The first test structure, RALHEPAPS 1, contains eight 8×8 pixel arrays. It was designed in the IBM 0.25 CMOS process. The pixels are 15×15 μm. The sensitive layer, the epi-layer, is 2 μm thick. The four pixel types that were studied are the standard 3MOS pixels, one containing 4 small diodes in stead of one, a 4MOS structure allowing Correlated Double Sampling and a standard 3MOS with a calibration utility.
The second test structure, the RALHEPAPS 2, contains 4 pixel types and each type comes in various flavors. It is designed in the 0.25 μm TSMC process. Its epi-layer is 8 μm thick, this yields, as shown later, a MIP signal of about 600 e^- while the noise is measured to be around 20-50 e^-. The first and second type are the standard 3MOS and 4MOS. Both come in 6 flavors with varying diode and p-well sizes. Also some gate-all-around pixels are produced. The 6 arrays each consist of 64×64 pixels. The fourth type is the Flexible Active Pixel Sensor, which will be discussed later.

Charge collection

The RALHEPAPS 1 was characterized using a laser system. Position and timing scans were made to measure the charge collection time and charge sharing. A simulation of the collected signal was also performed. The agreement for both position and time dependence of the signal is reasonably good. However, the simulation does not contain the metal layers that are present on the chip.
Results of the measurements and the simulations will be presented.

Radiation tests

The RALHEPAPS 1 was irradiated to 10^{11} p/cm^2 and 10^{12} p/cm^2. The RALHEPAPS 1 showed no degradation in performance up to these doses. Our simulation shows that these devices will still operate well after a dose of 10^{14} p/cm^2. Unfortunately, due to the small size of the device and the very thin epi-layer, it was not possible to measure the signal and signal to noise ratio as a function of dose using MIPs. But this is possible with the RALHEPAPS 2, see the next section. The RALHEPAPS 2 will be irradiated up to a dose of 10^{15} p/cm^2. The irradiation will take place starting the 21^{st} of May, so results will be ready and presented on the radiation hardness of the RALHEPAPS 2.

Source tests

The second test structure, the RALHEPAPS 2, was characterized using a β-source. The results are shown in figure 1. Not all of the 12 3MOS and 4MOS arrays had enough gain to detect particles. The gain in the gate-all-around devices is

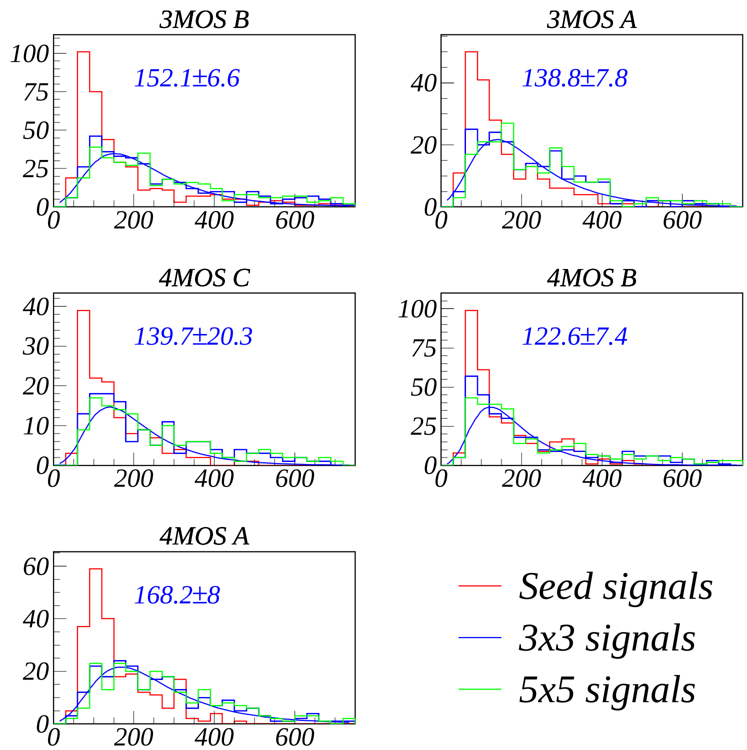

Figure 1: *Cluster signal distributions.*

too low. But the other showed S/N-values of about 12. A fault in the motherboard, increasing the noise by ≈40 %, was identified and fixed. The measurements will be repeated and S/N values of ≈20 are to be expected.

FAPS

The FAPS are the fourth type of active pixel on RALHEPAPS 2. The FAPS are standard 3MOS pixels, but have a 10 deep pipeline on each individual pixel. This is designed with the cold linear collider vertex detector in mind. The signal is stored in the pipeline using a fast write clock and read out later using a slower read clock. It also proves that we are capable of building storage on each pixel.

Conclusions

We have successfully designed, fabricated, characterized and simulated two active pixel sensor test structures. We will present results on charge collection, MIP signals, simulations and radiation tests. Also results of the first pixel sensor having a 10 deep pipeline on each pixel will be shown.