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Passive CMOS Strip Detectors Response with Alpha Particles

M. Baselga,[a,*] J.-H. Arling,[b] N. Davis,[b] L. Diehl,[c,d] J. Dingfelder,[e] I.-M. Gregor,[b,e] T. Hemperek,[e] F. Hügging,[e] K. Jakobs,[c] M. Karagounis,[f] R. Koppenhöfer,[c] K. Kröninger,[a] F. Lex,[c] U. Parzefall,[c] A. Rodriguez Rodriguez,[c,g] B. Sari,[a] N. Sorgenfrei,[c,d] S. Spannagel,[b] D. Sperlich,[c] T. Wang,[e] J. Weingarten[a] and I. Zatocilova[c]

[a] *AG Kröninger, TU Dortmund University, Otto-Hahn-Str. 4a, 44227 Dortmund, Germany*
[b] *Deutsches Elektronen Synchrotron (DESY) Notkestrasse 85, 22607 Hamburg, Germany*
[c] *Physikalisches Institut, Albert-Ludwigs-Universität Freiburg Hermann-Herder-Straße 3, 79104 Freiburg, Germany*
[d] *now at CERN Esplanade des Particules 1, Meyrin, Switzerland*
[e] *Physikalisches Institut, University of Bonn Nussallee 12, 53115 Bonn, Germany*
[f] *Fachhochschule Dortmund Sonnenstraße 96, 44139 Dortmund, Germany*
[g] *now at Littelfuse Edisonstraße 15, 68623 Lampertheim, Germany*

E-mail: marta.baselga@cern.ch

Current high energy particle trackers use mostly silicon detectors as they give very good spatial resolution, they are radiation hard, easy to integrate in electronic circuits and can take advantage of silicon technology development for their fabrication. When covering large areas of sensitive materials, strip detectors are very convenient since they can be produced in the full area of the wafer, have reduced readout channels compared to pixel detectors, and when stacked smartly, they give very precise 3D spatial resolution.

Fabricating strip detectors with a CMOS foundry promotes different foundry markets for strip detectors vendors and allows to introduce electronic circuitry embedded in it. Large area CMOS strip production can be cost effective when producing a great number of sensors.

In this project we fabricated silicon strip detectors with a CMOS foundry stitching reticles. In this proceedings we show passive CMOS strip detectors' response with alpha particles.

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*Speaker

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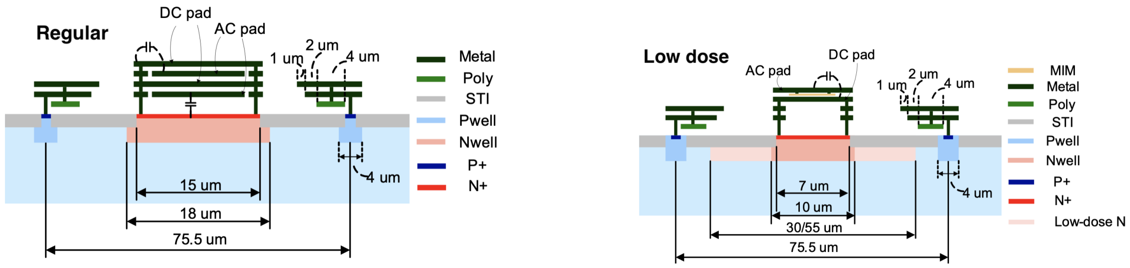
1. Introduction

Strip sensors are excellent particle detectors that can cover a large area of detection with few readout channels. The ATLAS and CMS experiment upgrades in the High Luminosity Large Hadron Collider fill the outer tracker systems with strip detectors. Typically, strip detectors are not fabricated in CMOS foundries since the CMOS foundries use stitched reticles to cover all the wafer area. For this project we fabricated passive strip detectors in a CMOS foundry using two different reticles, one reticle designed with the two ends of the strips and the second reticle with the body length of the strips. Fabricating strips in a CMOS foundry opens the market for the fabrication of strip detectors and takes advantage of the CMOS technology. Stitching various reticles together, strip detectors were fabricated with two different sizes, 2.1 cm and 4.1 cm.

Passive CMOS strip detectors were fabricated at LFoundry[1] with a 150 nm process and a reticle size of 1 cm^2. The wafer used was a p-type FZ with 150 µm thickness and a resistivity of 3-5 kΩ.

The strips have two different flavours, one called *Regular design*, which is similar to the ATLAS Phase II upgrade strip detector (shown in Figure 1a). The second flavour is called *Low Dose design* (shown in Figure 1b), and this one has a lower dose implant (compared to the main implant) underneath the STI (Shallow Trench Isolation) layer and it incorporates a MIM (Metal Insulator Metal) capacitor. The Low Dose implant has two different widths, 20 strips with 30 µm implant width and 20 strips with 55 µm implant width. Low Dose design was envisaged for mitigating the effects of radiation upon the detector, and to improve the uniformity of the electric field. Figure 2 shows a picture of a 4.1 cm long passive strip detector glued on a testing board with the different flavours depicted in the image. The image shows the stitching positions, the locations where two reticles are connected.



(a) Cross section sketch of a Regular design. **(b)** Cross section sketch of a Low Dose design.

Figure 1: Cross section sketches for the Regular and Low Dose design.

Passive CMOS strip detectors show very good performance after irradiation, in test-beams and beta sources testing setups[2–6]. Here we show how passive CMOS strip detectors respond to Americium 241 alpha sources from different distances. Testing the detector with an alpha source gives information on the uppermost surface and backplane response since alpha particles only penetrate a few micrometers inside the silicon.

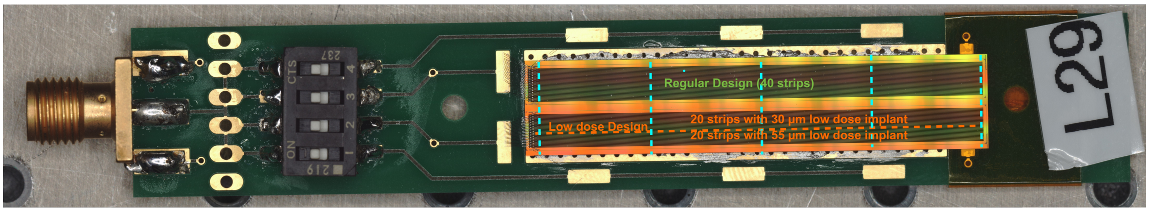


Figure 2: Picture of a 4.1 cm long passive CMOS strip detector glued to the testing board. The dashed cyan vertical lines show the stitching positions.

2. Experimental setup

The measurements were taken with an Americium 241 radioactive source, which decays via an alpha decay with a Q-value of 5.486 MeV with a probability of 85%. Am241 also emits 59.5409 keV gamma photons, but they do not reach the detection threshold of the setup therefore no gamma photons were observed with the measurements. The detector strips are wire-bonded to the same pad, as shown in Figure 2, and therefore the detector in this study has no spatial sensitivity.

The detector is connected to a CIVIDEC Diamond Shaping Amplifier[7]. The amplifier is spectroscopic; therefore it gives information about the deposited energy. The amplifier is connected to a high voltage power supply which distributes the high voltage to the sensor. A low voltage power supply delivers 12 V to the amplifier. The output signal is read out with an oscilloscope.

3. Results

The measurements were acquired at two bias voltages: 50 V (with the sensor fully depleted) and 0 V. The radioactive source was located on a movable stage and data was taken for different distances from the detector. The detector was located with the strips facing the source (alpha measurements from the top) or the backplane facing the source (alpha from the backplane).

Readout of the oscilloscope is triggered at a signal threshold of 80 mV. The threshold value was chosen as a compromise between minimizing the noise occupancy and maximizing the sensitivity of the system.

Figure 3 shows the maximum peak heights of 2000 waveforms for different distances at 50 V bias voltage with the alphas impinging on the strip side of the sensor. Capacitance-Voltage measurements indicate that the detector is fully depleted at 35 V therefore maximum collected charge is expected. Some of the energy of the alpha particle is lost within the air between the source and the detector, the uppermost inactive layers of the detector or inside the detector. Since the alpha particles' path is not expected to cross all the detector bulk (the Bragg peak is expected after some µm), the expected energy deposited curve is an inverted Landau.

We repeated the measurement for 0 V with the alpha particle from the top and 50 V with the alpha from the backplane. At 0 V the detector is not depleted therefore the alpha particles are not detected when impinging from the backplane because the electrons and holes generated are recombined.

The data was fit with an inverted Landau as shown as an exemplary plot in Figure 4a. Figure 4b shows the most probable value of the Landau fits for the detector biased at 0 V with the alpha

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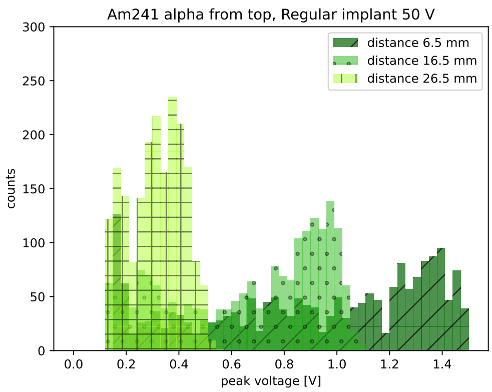
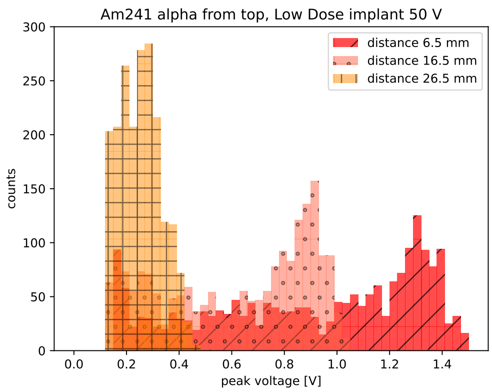


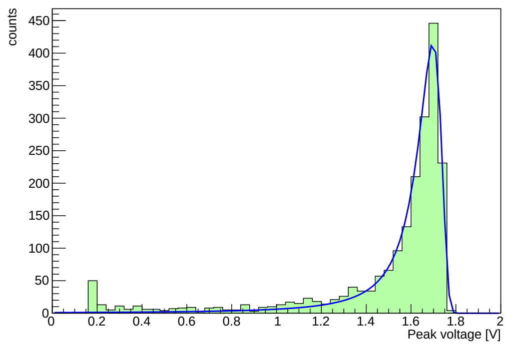
(a) Regular design biased at 50 V, alpha particles impinging from the strip side.



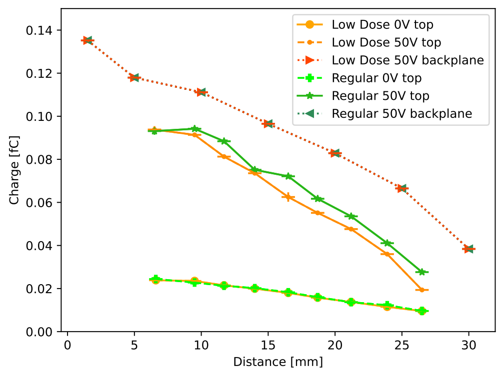
(b) Low dose design biased at 50 V, alpha particles impinging from the strip side.

Figure 3: Maximum peak of 2000 wavelengths.

from the top, and the detector biased at 50 V with the alphas impinging from the top and the backplane of the detector. The calibration of the voltage peak value to charge is done according to the specifications of the amplifier, with a gain of 12.5 mV fC^{-1}. Error bars for the distance position are shown as well as error bars for the most probable value of the Landau fit.



(a) Exemplary plot of the inverted Landau fit (blue line).



(b) Calibration of the Am241 deposited charge at the passive CMOS strip detector at different distances.

Figure 4: Fit and calibration of the charge deposited by the alpha radioactive source to the passive CMOS strip detector.

The charge deposited by the alpha particles at 0 V is lower than the charge deposited by the alpha particles at 50 V since more electron hole pairs created will recombine in the undepleted region of the sensor at 0 V. Nevertheless still some charge is measured at 0 V bias voltage. The results for the alpha particles from the backplane of the detector show larger charge probably due to thinner inactive areas of the detector at the backplane compared to the strip side. Figure 4b shows a discrepancy in charge between the Regular and Low Dose designs when the alpha particles impinge from the top of the detector with a bias voltage of 50 V. That is because the uppermost inactive layers of the strip detector have more volume for the Low Dose than the Regular design. That explains the slight difference for the charge generated by the alpha particles from the top than from the backplane, because the backplane processing is homogeneous for both designs. At 0 V, there is a slight difference between designs but it is not noticeable because the active detection volume is too small to show.

4. Conclusions

Passive CMOS strip detectors show excellent results and stitching reticles do not have any negative impact upon the performance of the detector. This work shows the measurements of charge with alpha particles, which gives a view of the detector in the implant and uppermost layers. Here we show some differences between Low Dose and Regular design due to differences in processing the uppermost layers.

Future production of CMOS strips aims to have active strips including an amplifier and discriminator embedded, as well as to have a full CMOS strip wafer detector, covering a larger area.

5. Acknowledgements

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