Fine-Calibration of Pixel Detector

Tomas Steponavičius
Supervisors: dr. Enrico Junior Schioppa, dr. Susanne Kühn.

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Abstract

The aim of this project was to calibrate the new CMOS pixel sensor by using X-Ray fluorescence experimental setup. Since the setup produces well-defined monochromatic energy spectra of X-Rays, the number of electron-hole (e-h) pairs in the silicon detector can be calculated. Changing threshold voltage (V_{th}) of the detector enables us to vary the amount of detectable e-h pairs. However, the noise of electrical origin increases considerably with lower V_{th}. Different noise-removal techniques have been implemented to obtain X-Ray fluorescence signal.

1 Introduction

Over the course of two months, it was inteded to work on the threshold calibration of MALTA pixel detector. In this report, the experimental setup and the results of the project will be discussed.

2 X-Ray Fluorescence

When polychromatic x-ray beams hit a certain target material, secondary x-rays are emitted (x-ray fluorescence). X-ray fluorescence beams are known to be monochromatic and so to have well defined energy. The energy of x-ray fluoresescence rays may be varied by changing the target material. Principle scheme of the experiment is given in figure 2.

X-ray fluorescence occurs when an electron from the inner shell is ionized by incident x-rays and electron from the higher orbital falls to fill the hole. Consequently, photon is emitted with energy corresponding to difference between the two orbitals. Therefore, it's possible to vary the energy of x-ray fluorescence photons by changing the material.

3 The Setup

The experimental setup is shown at figure 1. The essential parts are *Amptek* x-ray generator, target material (which emits fluorescence), DUT (device under test), FPGA board and two computers. For safety reasons, separate computers are being used for to read out the data and to control of x-rays. Interlocked eccentric clips are used to prevent exposition to x-rays if the copper box is open.

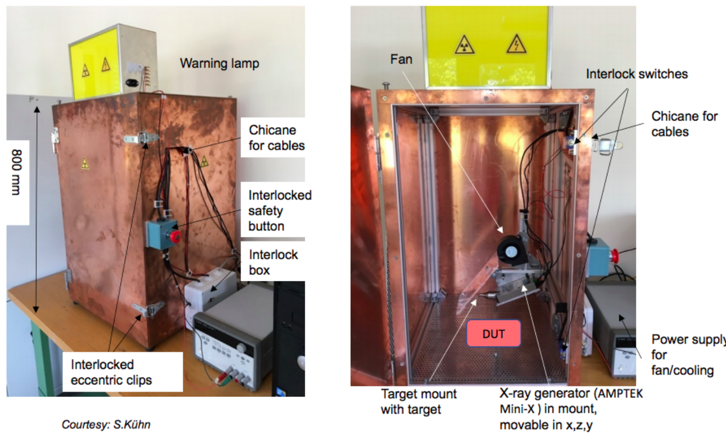

Figure 1: The experimental setup. *Courtesy: S.Kühn*

For the vast majority of our experiments the voltage of *Amptek's* x-ray source has been set 40 kV and the current to 70 mA. The collimation was adjusted by implementing a cylinder tube with cavity of either 1 or 2 mm.

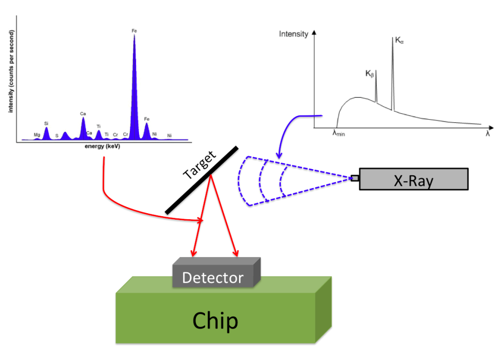

Figure 2: X-ray fluorescence. Conversion of polychromatic x-rays to monochromatic.

Different target materials for the generation of x-ray fluorescence have been used. The table of K_α for some of our target materials is given in table 1.

Table 1: K_α of our target materials.

Material	$K_\alpha (keV)$
Na:	1.041
Cl:	2.622
Ti:	4.510
Zn:	8.638
Ge:	9.886
Sn:	25.270

4 The Results

During the experiments the amount of photon hits on the detector were being counted. The hit is only counted as such, if it has sufficient energy to create enough e-h pairs to produce charge for the discriminator. The discriminator has two main inputs: charge comming in from a certain pixel and a threshold voltage. If threshold voltage is low enough (the higher the voltage, the lower amount of e-h pairs may be detected), the hit is counted.

Two main output parameters were of the particular interest: the hit map (the display of the number of hits per pixel) and the total amount of hits on the detector. Examples of hit map can be seen in figures 4(a) and 4(b). For both of the hit maps *Pixel mask* script has been used. Even though 4(a) and 4(b) are known to have different threshold voltages, the figures appear to be almost identical. This is due to the fact that the energy of X-ray is always higher than the adjusted threshold.

However, the total amount of hits may not always be evaluated directly. The reason for that is sharp increase of noise at lower thresholds as seen in figure 3. It's evident that even though Sn creates considerably higher amount of e-h pairs than Ti (about 1200 for Ti and 25 000 for Sn), the trasition point is the same (around 1.35 V).

Due to the high noise levels, our fluorescence signal was not visible. Because of that, two different noise-removal ROOT scripts were introduced:

- *Noise removal*. This script has two inputs ("/directory of hit map/file.root", cut-off frequency). The first input is the hit map file itself and the second one is *cut-off frequency*. The script sets all the pixels to zero that have the same or higher values of hits per pixel than *cut-off frequency*.

- *Pixel mask*. This script has two inputs as well ("/directory of noise hit map/noise file.root", "/directory of hit map/file.root"). The first argument takes noise file at certain voltage as an input and second argument takes hit map with fluorescence signal as an input. This code sets every pixel of hit map to zero that flashes up in noise file.

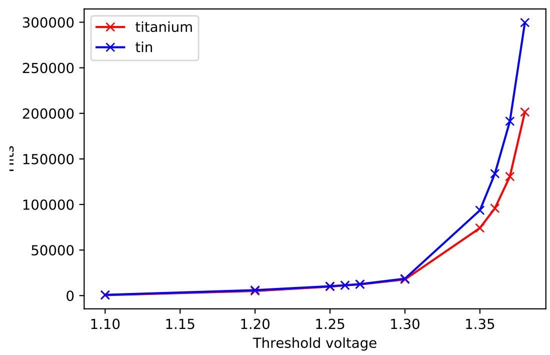

Figure 3: The total amount of hits versus treshold voltage.

Both codes were executed in order to extract the fluorescence signal. In case of *Noise removal* script, different cut-off frequencies were used. However, even with cut-off frequency values as low as 2 hits, we kept observing the same shape plots as seen in figure 3. This suggests that noise level of electrical origin was increasing cosiderably stronger than X-ray fluorescence originating from target material.

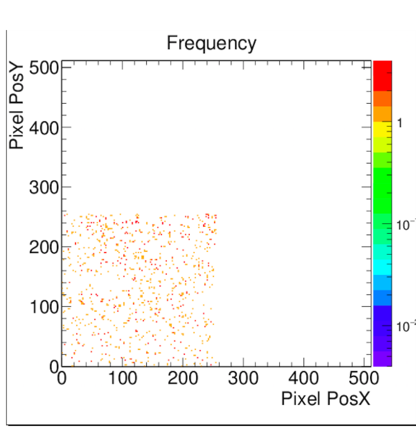

Figure 4(a) Hit map at V_{th}=1.3 V.

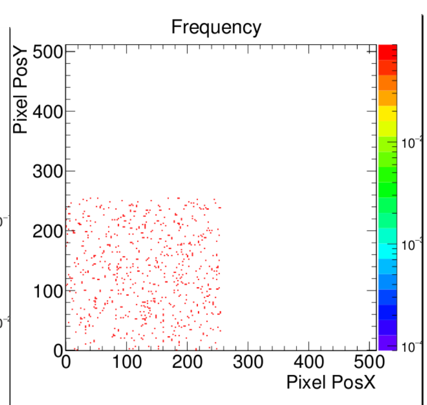

Figure 4(b) Hit map at V_{th}=1.0 V.

5 Conclusions

The first steps of characterising the new CMOS silicon sensor have been made. The sensor currently exhibits higher level of noise than signal. Further investigation is needed for better understanding of the chip.