Investigation of the Small Pixel Effect in CdZnTe Detectors

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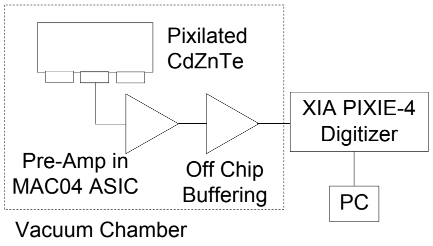
Introduction

CdZnTe is used as a high energy X-ray detector conversion material to achieve both fine spatial imaging and good spectral resolution. In this investigation the small pixel effect is used to negate the poor hole transport properties in CdZnTe. The signal shapes for pad and pixilated CdZnTe detectors from X-ray and α-particle radiation are examined. The TCAD simulator from Synopsys is used to model the CdZnTe detectors.

Experimental Technique

The detector had a16x16 array of 300μm pitch pixels. The detector was bump bonded to a MAC04 ASIC that amplifies the signal from each pixel. The signals from a pixel were buffered off-chip and digitized using an XIA PIXIE-4. A schematic of the experimental equipment is shown in Fig 1. The pixilated detector was compared to a 3mm pad detector made from 2mm thick eV Products CdZnTe. The signal shapes from the pad detector were amplified by an AmpTek A250 and digitized.



Pixilated CdZnTe

Pre-Amp in MAC04 ASIC

Off Chip Buffering

XIA PIXIE-4 Digitizer

PC

Vacuum Chamber

Fig 1. Schematic of the experimental equipment

Pixilated and Pad Detector Measurements

The pad and pixilated detectors were exposed to Am-241 α-radiation and biased to -100V, signal shapes are shown in Fig 2. The 10-90% signal rise-times were 227ns and 590ns for the pixilated and pad detectors respectively. The faster signal rise-time from the pixilated detector is due to the small pixel effect. The pad detector signal shape has a linearly rising signal due to the weighting field in the detector. The curved top of the signal is due to the lower density tail in the charge carrier cloud. The signal shape from the pixilated detector has a slow rising edge due to a combination of the small pixel weighting field and the charge carrier cloud having a lower density at the front. The curved top to the signal is due to the low density tail in the charge carrier cloud.

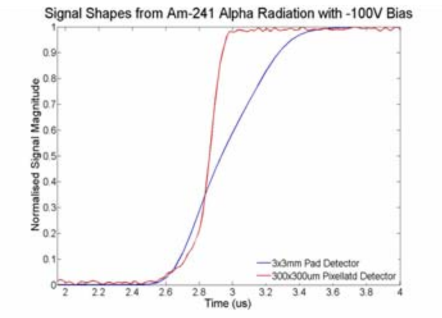


Fig 2. Am-241 α signal shapes for the pixilated (red) and pad (blue) detector.

X-ray, α and TCAD simulations

The pixilated detector signal shapes were examined for Am-241 α particles and Tb fluorescence X-rays, shown in Fig 3.

(a) (b)

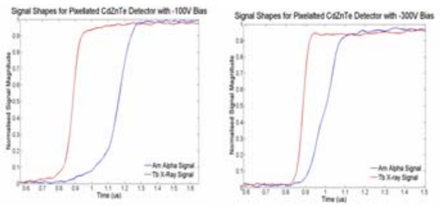


Fig 3. The signal shapes for Tb fluorescence X-rays (red) and Am-241 α particles (blue) for a bias of (a) -100V and (b) -300V.

At lower bias the signal shapes from the α exposure are considerably longer than those from X-rays. As the bias increases the signal shape rise-time from the α exposure gets closer to that of the X-rays, as plotted in Fig 4.

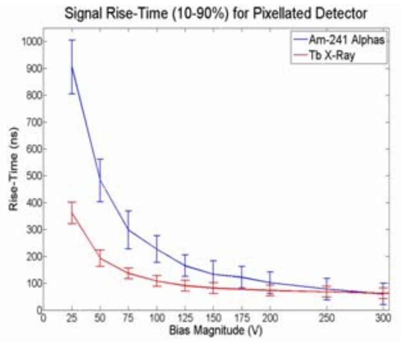


Fig 4. The signal rise-times (10%-90%) against bias magnitude for the pixilated detector from Tb fluorescence X-rays (red) and Am-241 α particles (blue).

The reason for the slower signal shapes from the α exposure is the higher density of charge carriers created by the α particles. The positive and negative charge carrier clouds interact strongly when they are in close proximity. As the bias is increased the effect becomes less pronounced as the charge carrier clouds separate more rapidly.

This is confirmed with TCAD, where the negative charge carrier clouds have an elongated shaped tail, as shown in Fig 5. The significant width of the charge carrier cloud is responsible for charge sharing. The length of the charge carrier cloud contributes to the signal rise-time.

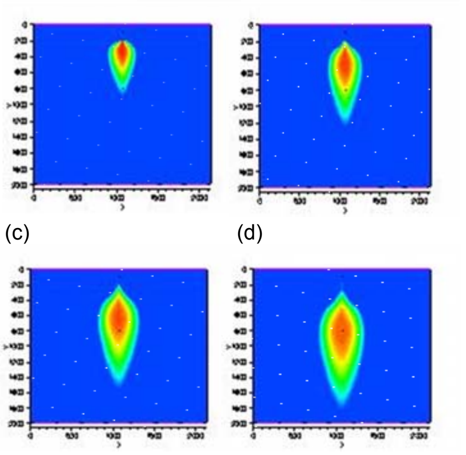

(a) (b) (c) (d)

Fig 5. TCAD simulation of a 2D, 2mm thick CdZnTe detector with 250μm pixels separated by 50μm. The detector was biased to -300V. The figures show the electron density at (a) 10ns, (b) 20ns, (c) 30ns, (d) 40ns after the charge was generated.

TCAD simulates the signals induced on the pixels. The signal shapes are compared in Fig 6. The main difference in the simulated signal shapes is the linear rising edge to the signals. The effect is present in all simulations but is less visible in the faster signals at higher bias.

(a) (b)

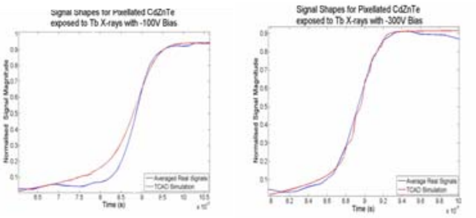


Fig 6. The signal shapes for Tb fluorescence X-ray exposure for experimental (blue) and simulated (red) data at (a) -100V and (b) -300V.

This disagreement between the experimental and simulated data is believed to originate from an inaccurate doping and trap profile in the simulator.

Conclusion

The small pixel effect has been studied by observation of signal shapes. Different types of radiation and detector geometry significantly effect the signal shapes. TCAD simulations have the potential to accurately model CdZnTe detectors. The visualisation of the charge carrier cloud drift and diffusion has aided the understanding of the current detector and will be used to model future detectors.

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