Simulation of Charge Sharing Effects in 70 μm Pixelated CdTe Sensor

Jakub Jirsa[1,2], Miroslav Havránek[1], Jiří Jakovenko[2]

[1]Faculty of Nuclear Sciences and Physical Engineering Czech Technical University in Prague, Czech Republic
[2]Faculty of Electrical Engineering Czech Technical University in Prague, Czech Republic

Introduction

- Pixel detectors becoming an integral part of medical imaging.
- Current research tends to use CdTe/CdZnTe as gamma-ray sensors due to its high absorption coefficient in the gamma spectrum.
- To increase spatial resolution of the detector, the pixel pitch has to be reduced.
- Decreasing size of pixels leads to charge sharing between neighboring pixels.
- It is important to develop a precise sensor model for characterization of analog front-end amplifiers.

TCAD simulation

- 3D model of CdTe sensor with Pt cathode and Al/Au pixelated anode was created in TCAD.
- Sensor was modeled using CdTe material from standard TCAD material library with following parameters:

	Electrons	Holes
Mobility ($cm^2V^{-1}s$)	1100	100
Lifetime (s)	3×10^{-6}	2×10^{-6}

Table 1: Parameters of electrons and holes in CdTe.

- The pixel pitch was set to 70 μm which corsponds to 55 μm electrode and 15 μm street.
- The sensor was biased at -1000 V.
- The HeavyIon model was used to generate e-h pairs in the sensor to investigate the sensor response to X-ray photons.
- The photon interactions were placed at the center of the middle pixel.
- The interaction depth of each photon was set based on the mean free path, which was calculated by the NIST XCOM software [1].

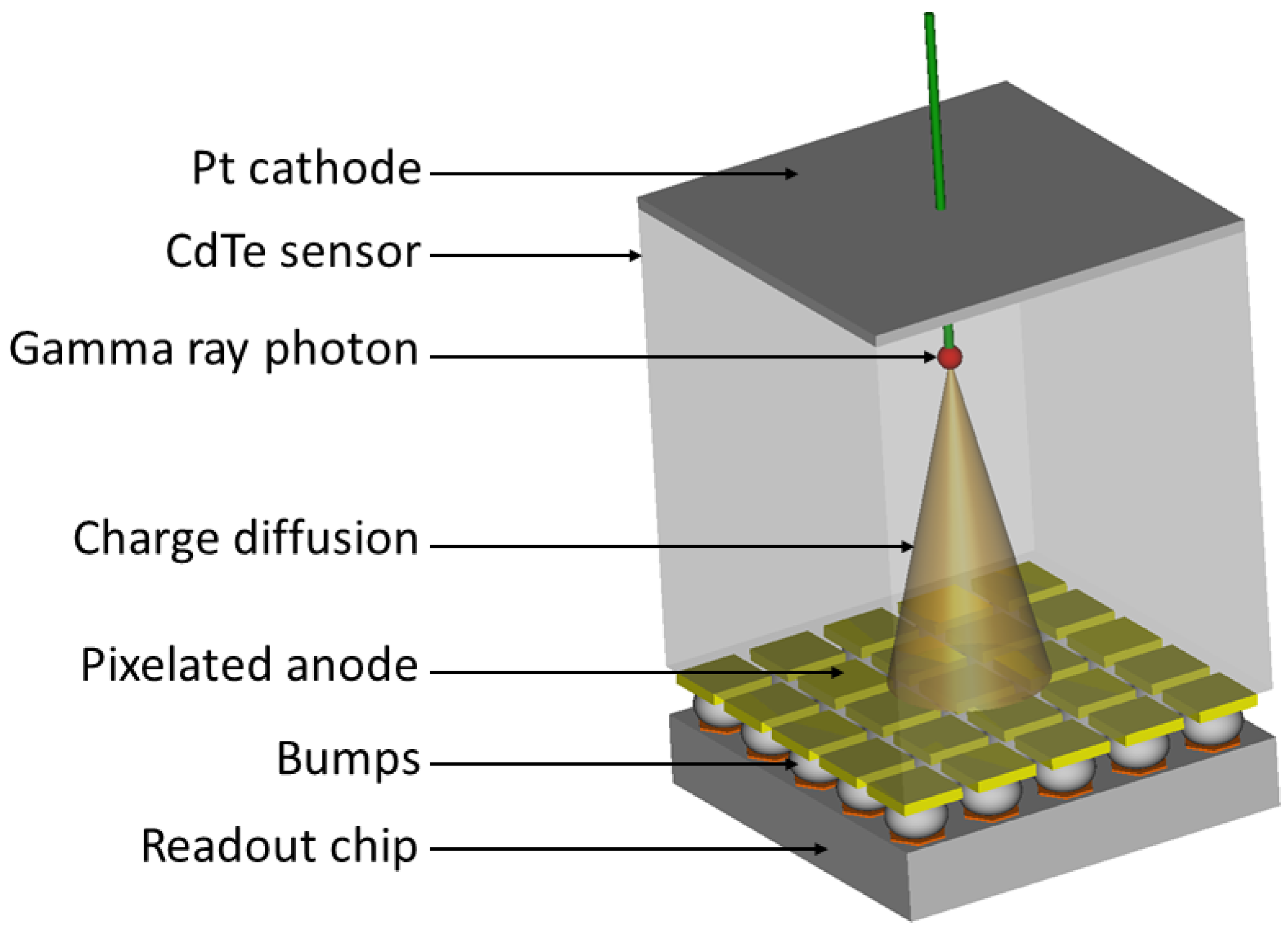

Figure 1: Illustration of a CdTe sensor bump-bonded to a readout chip.

- The induced signal on the central electrode by drifting e-h can be computed based on the Shockley-Ramo theorem [2].
- Figure 2. shows the simulation outcome of weighted potential which shows the small pixel effect in pixelated sensor.

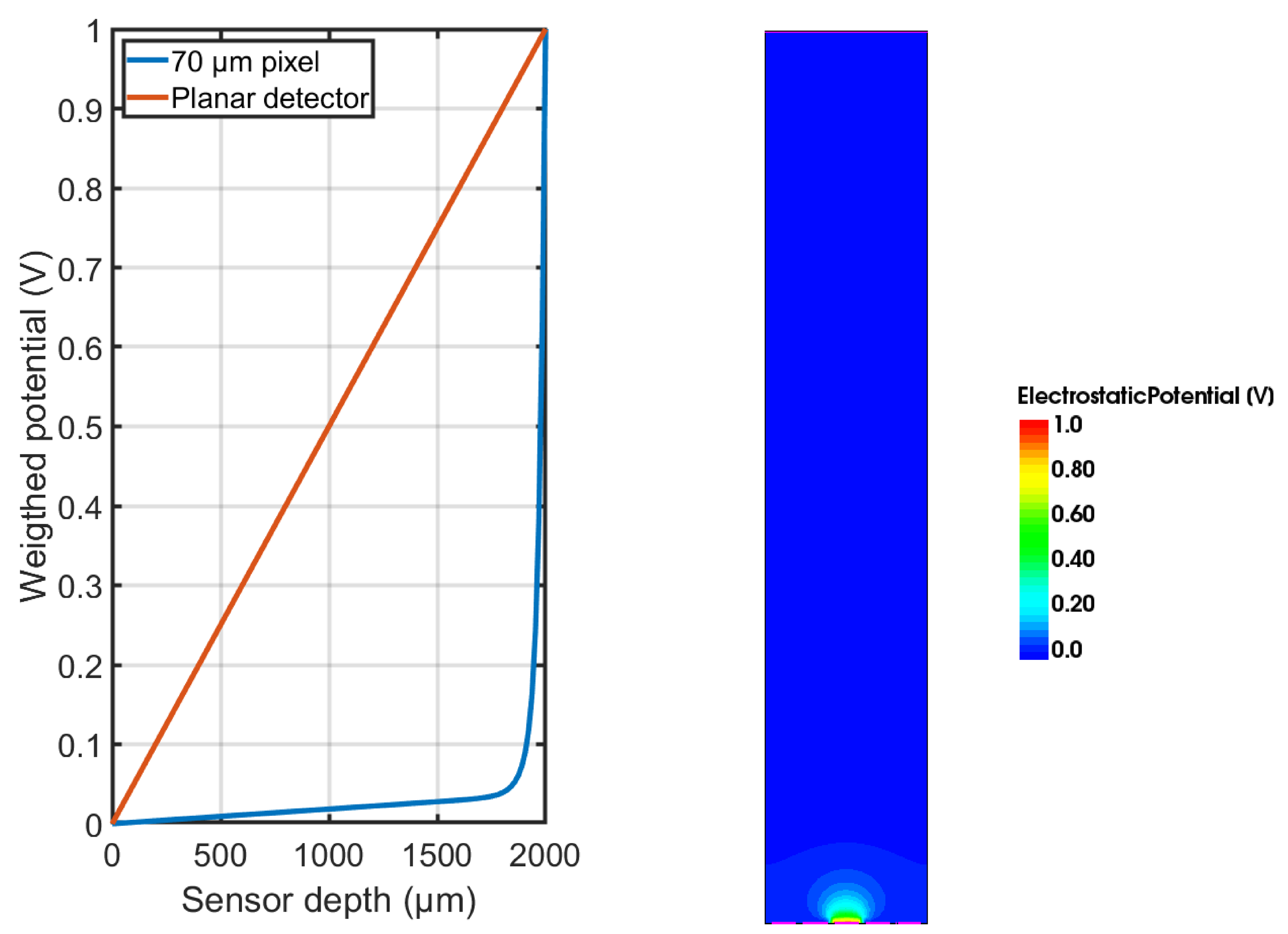

Figure 2: Comparison of weighted potential in planar and pixel detector.

Results

- Several important parameters of CdTe sensors were studied to create a circuit model of the sensor. The most important are collection time and inter-pixel capacitance.
- The collection time-t_c and diffusion time-t_d of a 2 mm CdTe sensor for different interaction depths were obtained.

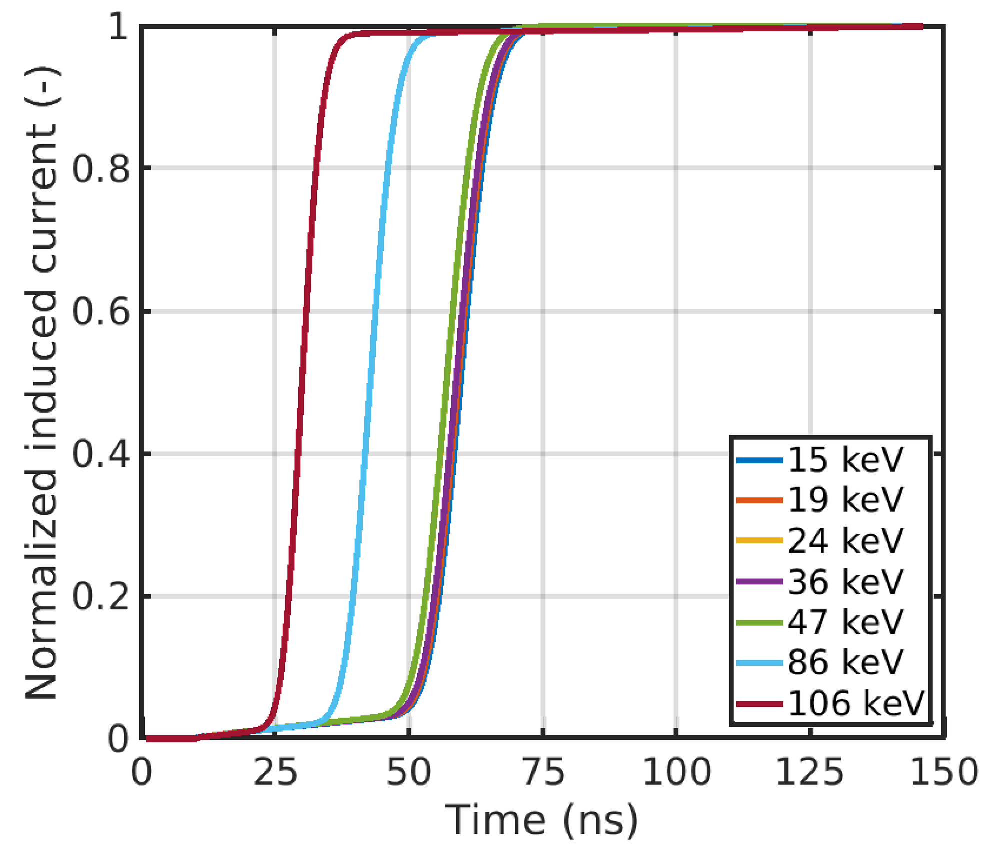

Figure 3: Normalized induced current in central pixel.

Photon E (keV)	t_d (ns)	t_c (ns)
15	49.7	16.9
19	49.2	16.8
24	47.1	16.4
36	48.8	16.8
47	47.0	16.4
86	32.8	13.5
106	20.1	10.4

Table 2: Diffusion and collection time for various photon energies.

- Based on the t_d a spread of charge between neighboring pixels can be modeled.
- The charge distribution at collection electrodes can be modeled with Gaussian pulse.
- Its standard deviation can be found based on Einstein diffusion coefficient and diffusion time:

$$\sigma = \sqrt{2Dt_d}$$

- The simulation of inter-pixel capacitance was done using AC simulation.
- Table 2 show the inter pixel capacitance values. C_{1-5} are capacitance between neighboring pixels. C_6 is the capacitance between cathode and central pixel.
- Based on the simulation outcome the total capacitance is 24.887 fF.

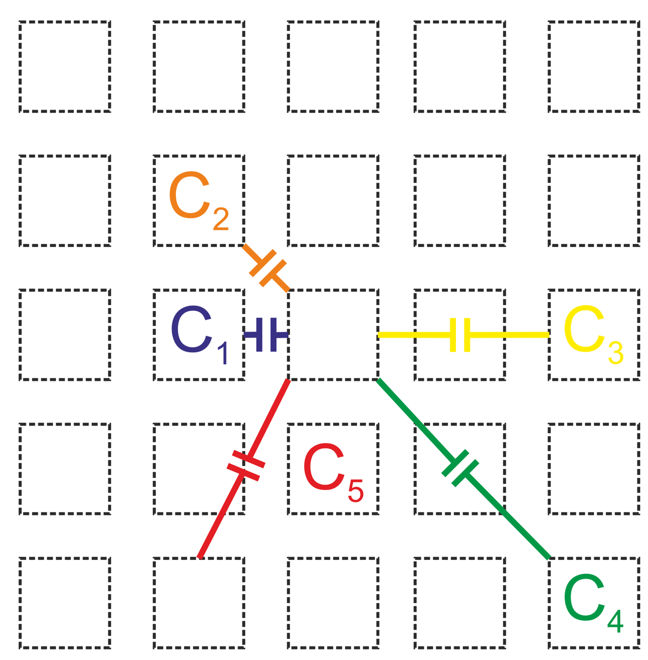

Figure 4: Inter-pixel capacitance schematic diagram.

Capacitance	Occurrence	Value (fF)
C_1	4	4.611
C_2	4	0.778
C_3	4	0.255
C_4	4	0.159
C_5	8	0.203
C_6	1	0.231

Table 3: Interpixel capacitance.

- The simulation outcome have been used to create a sensor model in verilog-AMS. pixel front-end electronics.

Conclusion

This work has introduced a 3D simulation of pixelated CdTe sensor. The key parameters such as collection time, drift time and pixel capacitance have been obtained. Using the simulation outcome we have created a circuit model which is to be used for development of pixel front-end electronics.

References

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 jakub.jirsa@fjfi.cvut.cz