Energy selective NanoCT with direct converting CdTe semiconductor detector

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Research Objective

An innovative computer tomograph (CT) is being developed and set up in order to significantly expand the existing analytical methods and to enable cross-scale material characterization. This consists of a spectroscopic detector unit, a high-resolution X-ray source, a probe holder which performs stress and strain on the specimen and a computer system for storing very large amounts of data within short periods of time. This complex CT setup will allow the characterization of different material systems and will be used for thein-situ investigation of dynamic processes.

Spectroscopic Imaging with Pixel Detector

With directly converting detectors, the ionizing radiation generates charge carriers directly in the sensor material, see *Figure 1 (left)*. The resulting pulse has a height and a duration correlating to the deposited energy. In time-over-threshold mode (TOT), the length of the pulse is measured above the pixel-specific, defined threshold value.

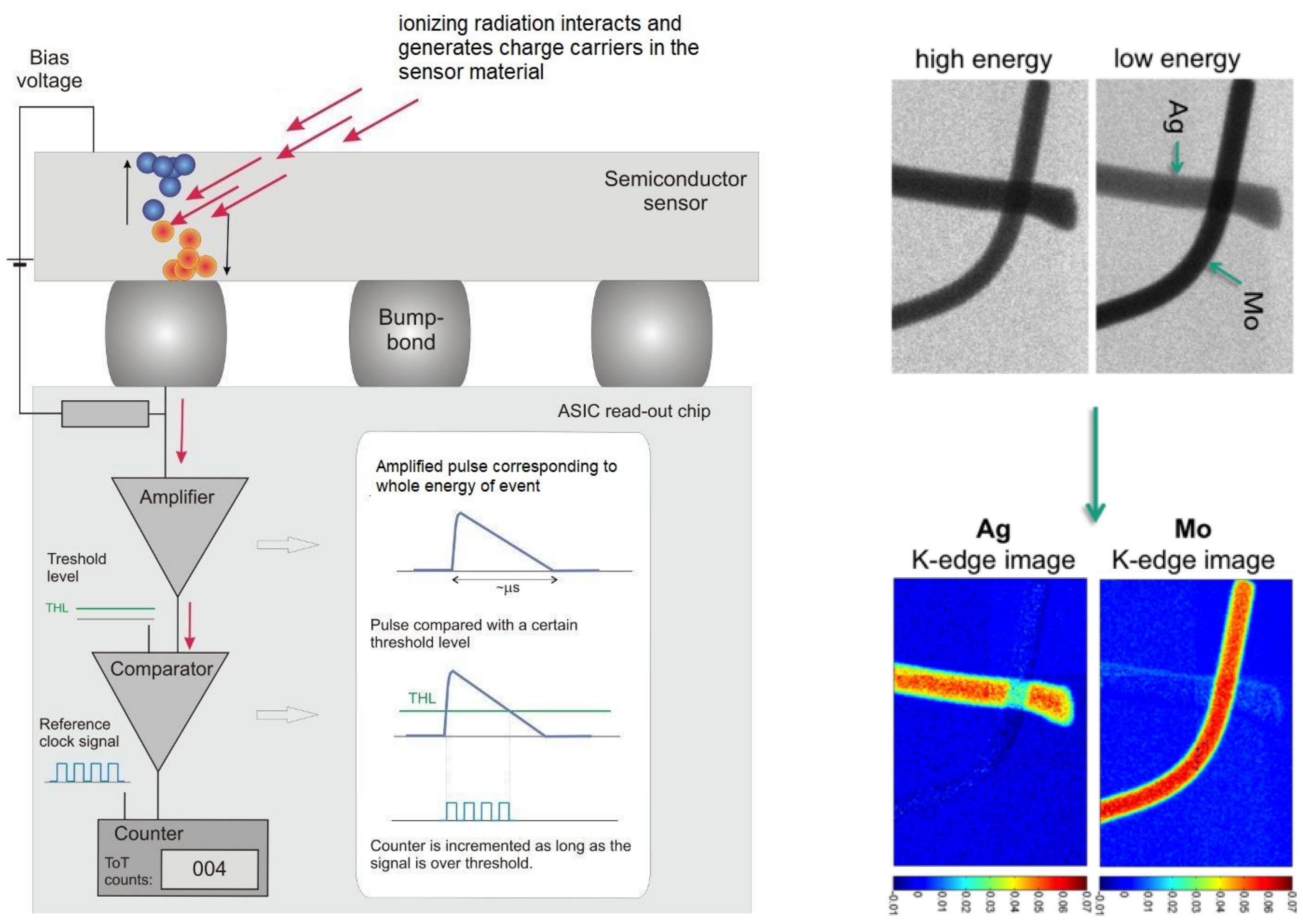


Figure 1: left; signal path of an event in ToT mode of the Timepix detector [3] , right; K-edges imaging with Ag and Mo threads with a Timepix1 detector [4].

Concept NanoCT

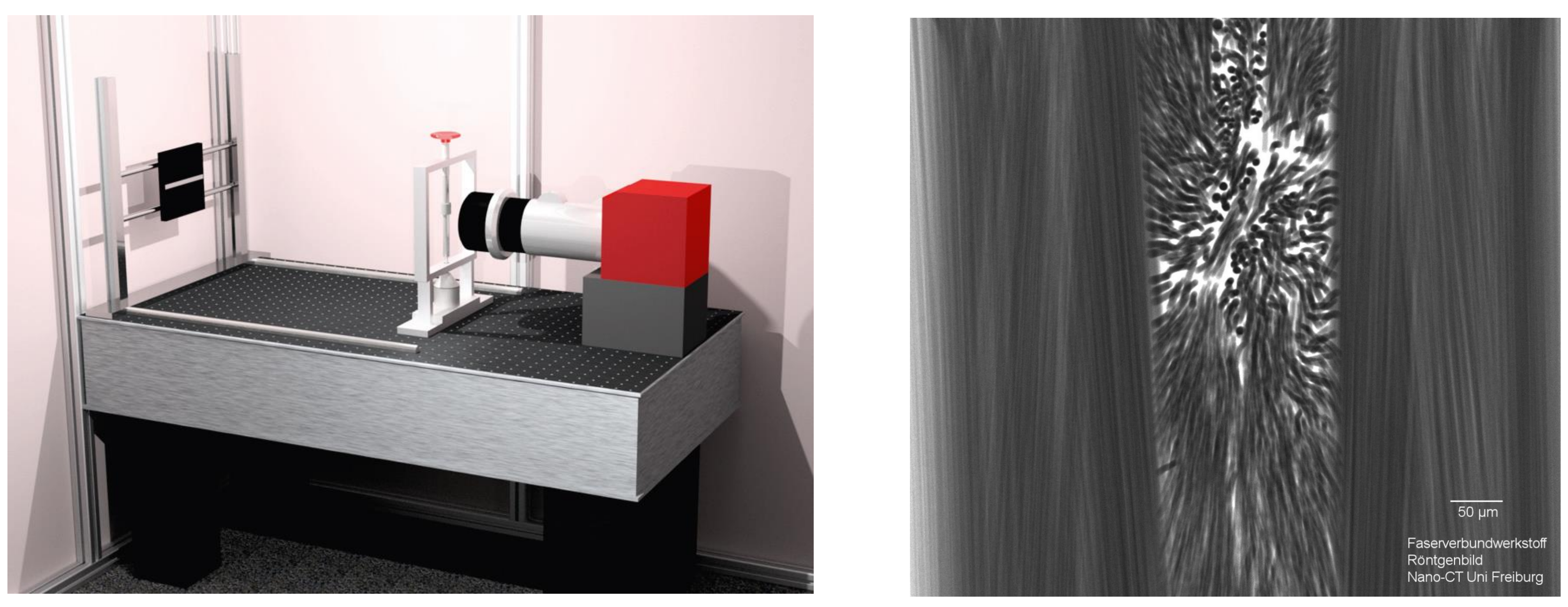


Figure 2: left; CAD concept of the nanoCT , right; first test image of a fiber composite material

Figure 2 (left) shows the conceptual design of the nanoCT consisting of a Hamamatsu L10711 (focal spot 250nm), sample stage and detector unit on cross stage. Compared to conventional CT images, the amount of data increases up to 10,000 times for fully spectroscopic images (Timepix3) depending on the energy thresholds used. This places high demands on the interfaces for communication and storage of the resulting amounts of data.

Timepix3 Detector Modul

Figure 3 (left) shows the Timepix3 Hybrid Pixel Detector (HPD). A detector module has a sensitive area of 1.94 cm² consisting of 256 x 256 pixels with a pixel size of 55 µm². Each pixel has an amplifier, a discriminator and a counter. *Figure 3 (right)* shows the schematic structure of the detector. Different sensor materials like Si, CdTe or GaAs can be bump-bonded to the ASICs.

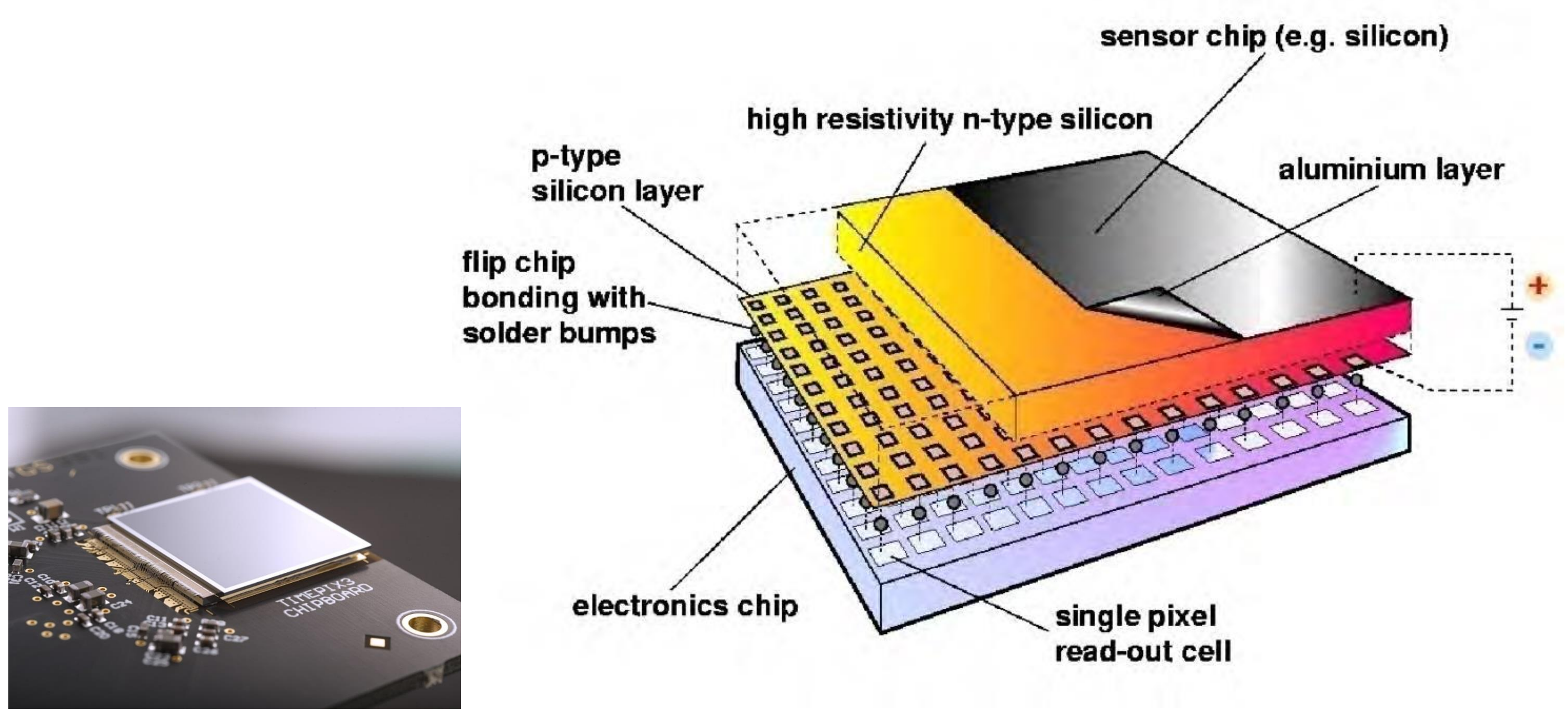
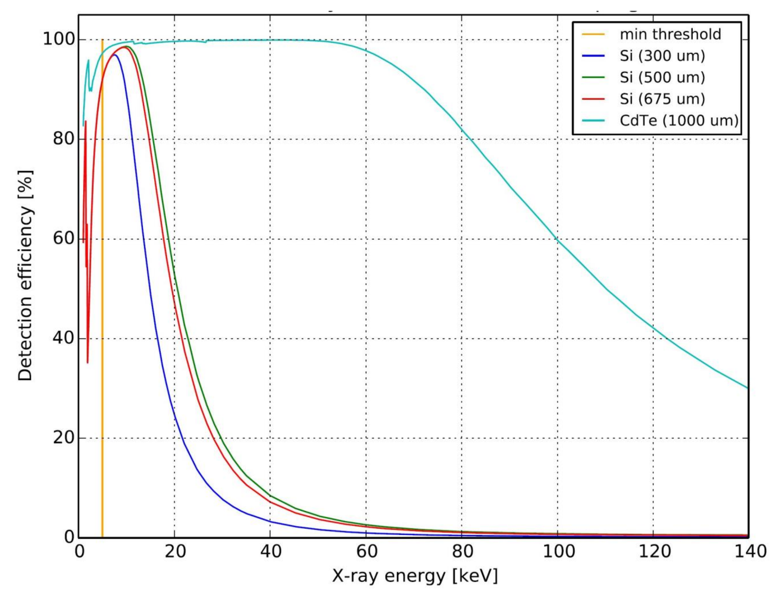


Figure 3: left; Timepix3 detector, right; schematic structure of a hybrid pixel detector using the example of a Timepix [1]

"High-Z" sensor materials such as cadmium tellurite (CdTe) allow an increase in the absorption efficiency of the detector to minimize the duration of CT measurements and to use the energy information of the entire X-ray spectrum, see *Figure 4 (left).*



	Timepix3
Pixel matrix	256 x 256
Pixel size	55 x 55 µm²
Technology	CMOS 130 nm
Measurement modes	• Simultaneous 10 bit TOT and 14 + 4 bit TOA • 14 + 4 bit TOA only • 10 bit PC and 14 bit integral TOT
Readout type	• Data driven • Frame based (both modes with zero suppression)
Dead time (pixel, data driven)	>475 ns (pulse processing + packet transfer)
Output bandwidth	40 Mbits/s – 5.12 Gbits/s
Maximum count rate	0.4 Mhits/mm²/s (data driven mode)
TOA Precision *	1.56 ns
Front end noise	60e- RMS
Minimum threshold	~500 e-

Figure 4: left; Absorption probability of different sensor materials [2] , right; Data sheet of Timepix3 detector [1]

Figure 4 (right) shows the data sheet of the Timepix3 detector. The Timepix3 has a time resolution of 1.56 ns per hit with > 475ns dead time. In addition, it offers the possibility to collect the energy information of the "Time-over-Threshold" (ToT) and the time information of the "Time-of-Arrival" (ToA) simultaneously. In this mode, not individual images are read out, but all events are continuously written out over the measurement period in tabular form.

Literature

[1] F. Krejci et al., „Pixel detector Timepix operated in pile-up mode for pulsed imaging with ultra-soft X-rays," *14th International Workshop on Radiation Imaging Detectors (2012), Figueira da Foz, Portugal.*

[2] F. Nachtrab et al., „Development of a Timepix based detector for the NanoXCT project," 17th International Workshop on Radiation Imaging Detectors (2015), DESY, Hamburg, Deutschland.

[3] M. Campbell et al., „Charged Particle detection using the Timepix and Timepix3 chips and future plans," Universität Oxford (2017), Oxford, England.

[4] ADVAPIX TPX3 Datasheet, https://advacam.com/system/wp-content/uploads/2017/08/AdvaPIX-TPX3-Datasheet-2017-11-16.pdf, Verfügbarkeit geprüft am 10.10.2019.