Fabrication of a phantom for material discrimination by X-ray spectroscopy with a 1 mm CdTe Medipix3RX detector

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Introduction

Spectroscopic X-ray imaging is of growing interest in many areas, such as medical imaging, differentiation of two contrast agents in a single X-ray image, non-destructive testing in materials science and homeland security. The absorption phantom presented here (Fig. 2) was designed and manufactured to investigate the possibility of discrimination between different materials for different fields of interest. The subsequent material discrimination investigations are performed with photon counting Medipix3RX [1] and Timepix3 [2] semiconductor detectors in combination with a 1 mm CdTe sensor.

Medipix3RX and Timepix3 detector

The Medipix3RX detector is a photon counting semiconductor detector device, which, like the Timepix3 detector, was developed by the Medipix3 collaboration of CERN. These hybrid pixel detectors consist of a pixelated readout chip (MPX3RX or TPX3) and a connected semiconductor sensor.

Incoming charged particles and photons interact with the sensor material and generate electrical signals which are processed by the readout chip. The MPX3RX has eight independent energy thresholds with which the energies of the incoming photons can be divided into different energy ranges. The TPX3 offers the possibility of resolving the complete energy spectrum of a radiation source with an accuracy of up to 1 keV.

Chosen materials

In order to investigate the possibility of material discrimination by spectroscopic X-Ray measurements, several materials were selected to form an absorption phantom. Selection criteria were the coverage of a wide energy spectrum over which the K-edges (Fig. 1) are distributed, the use of two materials with K-edges close to each other and the possibility of studying the distinguishability of two medical contrast agents.

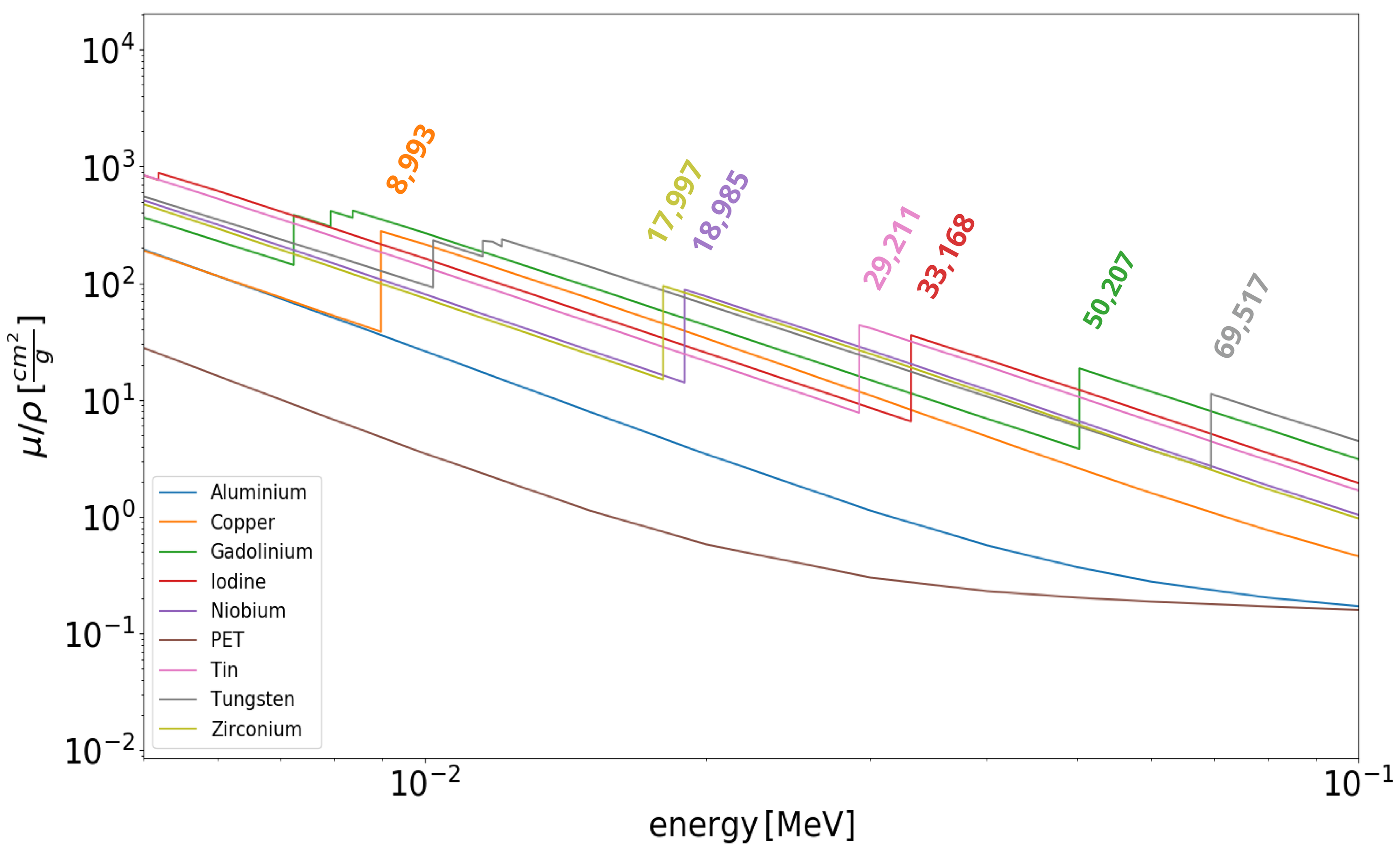

Figure 1: Absorption coefficients of the selected materials as a function of the energy of interacting photons. Data from [3].

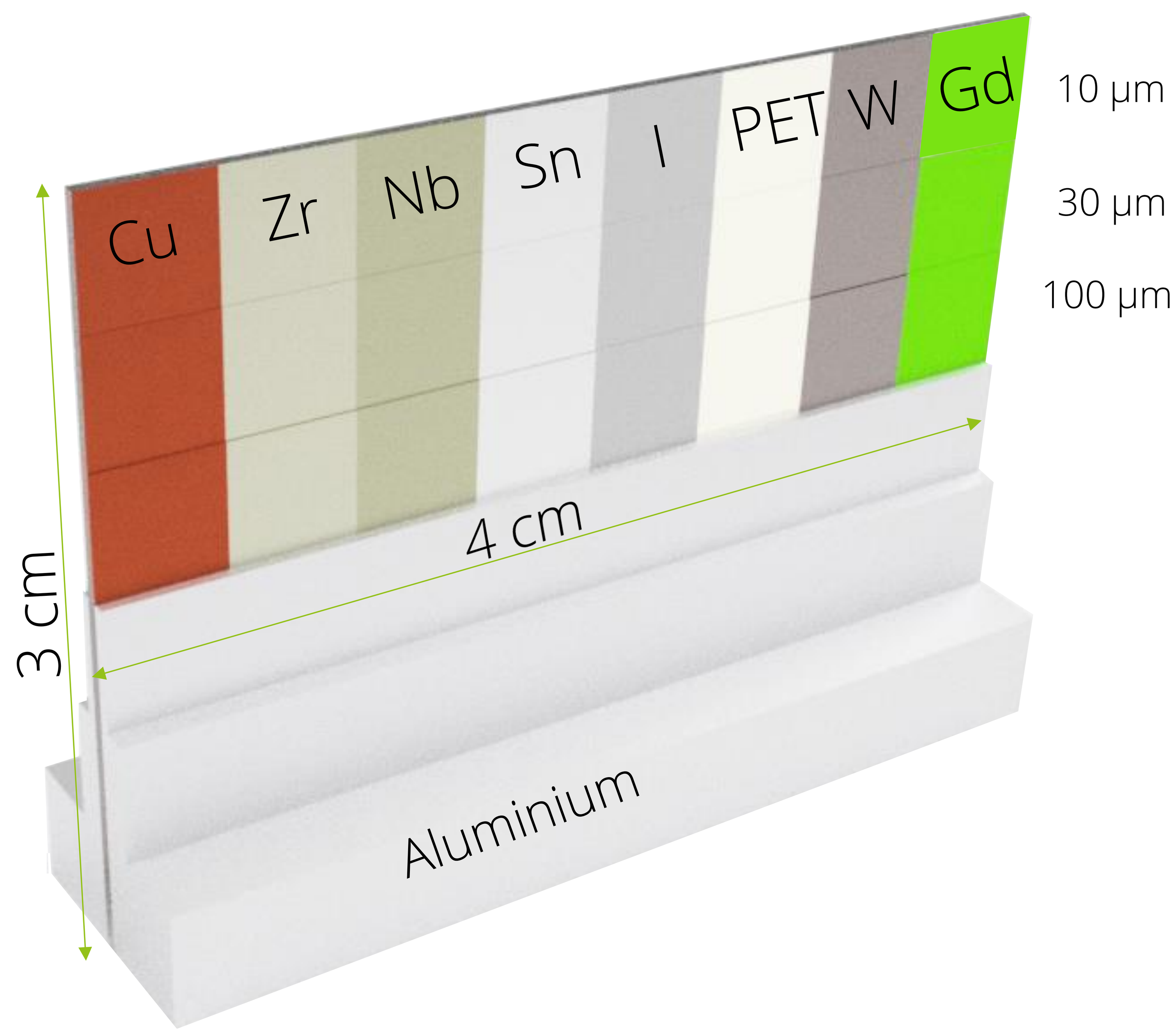

Figure 2: Schematic representation of the absorption phantom.

Structure

The materials of the phantom vary in a horizontal direction. Each field has an area of 5 mm x 5 mm. In vertical direction, the thickness varies from 10 µm in the first row to 30 µm in the second row to 90 µm in the third row. In the lower area, aluminum is applied as beam hardening in the thicknesses 1 mm, 3 mm and 10 mm. The thickness of the absorption materials in this range is constant at 30 µm. A 4 µm thick PET film was used as the carrier structure, as this promises very low absorption. The frame is 3D printed and has been added for better handling (Fig. 3).

Figure 3: Photography of the finished absorption phantom with and without added beam hardening by aluminium.

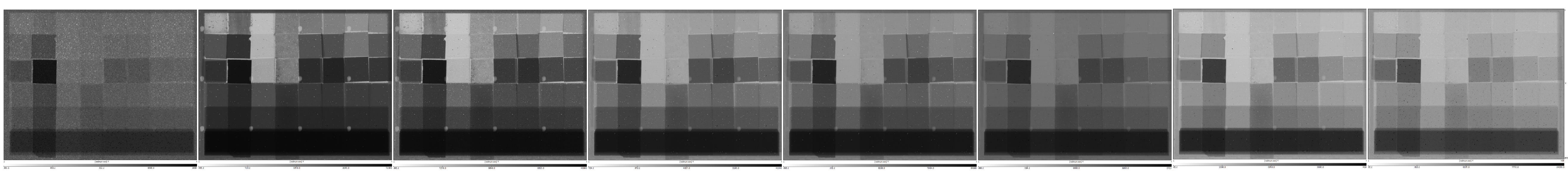

Figure 4: First measurements of the absorption phantom with different energy windows at 85 kV X-ray tube voltage. The recordings of the thresholds were normalized to the intensity of the 10 µm PET field.

Literatur

[1] R Ballabriga, et al.: The Medipix3RX: a high resolution, zero dead-time pixel detector readout chip allowing spectroscopic imaging, JINST 8 C02016 doi:10.1088/1748-0221/8/02/C02016, 2013
[2] Poikela, T. et al. (2014): Timepix3: a 65K channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout, JINST. 9 (05), C05013-C05013. DOI: 10.1088/1748-0221/9/05/C05013
[3] National Institute of Standards and Technology (NIST)