Compensation of temperature dependence on spectrometry of X-rays by MiniPIX Timepix3 SiC Detector

Nikola Kurucova[1,*], Carlos Granja[2], David Hladik[2], Andrea Sagatova[1], Bohumír Zatko[3]

[1.] Institute of Nuclear and Physical Engineering, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, Ilkovicova 3, 841 04, Bratislava, Slovakia
[2.] Advacam, U Pergamenky 12, 170 00, Prague, Czech Republic
[3.] Institute of Electrical Engineering, Slovak Academy of Sciences, Dubravska cesta 9, 841 04 Bratislava, Slovakia

* Corresponding author, nikola.kurucova@stuba.sk

The Timepix3 (TPX3) detector is a hybrid semiconductor pixelated detector [1] with a radiation sensitive sensor made of semiconductor materials such as Si, SiC, CdTe or GaAs of varying thickness. The detector is being used in a wide range of applications, including medicine, high-energy physics, neutron detection and outer space. Space applications are currently expanding and, in addition to radiation monitoring in Earth orbit and on the International Space Station (ISS), applications are planned for space weather measurements in lunar orbit, on the lunar surface and on other missions. These applications include operation in challenging environments in terms of radiation flux, complex composition, and temperature range.

Silicon carbide (SiC) is a promising semiconductor material for harsh environment applications due to its high atomic displacement energy (20 - 35 eV) resulting in high radiation hardness and wide bandgap (3.27 eV at 300 K for the 4H-SiC polytype) which ensures low leakage current while also enabling wide and high temperature operation. The SiC sensor has been fabricated and tested as an imaging radiation detector with the Timepix3 ASIC chip as the first MiniPIX Timepix3 SiC radiation camera [2] with a 4H-SiC sensor. The detector provides high-resolution spectral and tracking response for high-energy transfer particles [3].

For the use of Timepix detectors in harsh radiation environments, it can be challenging to maintain stable environmental conditions for measurements, such as the operating temperature of the detector. It is therefore necessary to examine the temperature dependence of these detectors under such conditions and ideally provide a correction. Therefore, the spectrometric performance of the MiniPIX Timepix3 radiation camera with a 4H-SiC sensor (80 μm epitaxial layer and 350 μm substrate) was investigated over a temperature range from 10 °C to 60 °C, using energy calibration at 20 °C. The sensor was operated with bias +200 V for an active volume thickness 65 μm. The detector was stabilized at different thermal conditions and then irradiated with characteristic X-rays and radioisotopes in the energy range from 8 to 58 keV. The results show that as the detector temperature increases, the detected energy spectrum shifts to lower values, which means that the accuracy of the measurement decreases. This effect becomes more significant as the energy of the incident radiation increases. This indicates that the distortion of the measured results does not only depend on the detector temperature, but also on the incident energy. Based on the absolute energy shift of the spectra (a few tens of eV), we found that the measurement accuracy deviation for lower energies (15.780 keV) was 2% at 10 ℃ and 12% at 50 ℃, and in the case of the higher energies (57.532 keV) the deviation was also only 2% at 10 ℃, but at a temperature of 50 ℃ it reached 19%. With regard to the analysis of the energy resolution, evaluated by the sigma value, the results indicate that the energy resolution of this detector shows a stable performance over the whole temperature range studied. In order to avoid the need to calibrate this detector for individual temperatures based on the desired applications, a compensation method has been proposed that reduces the temperature effect on the peak position.

[1] T. Poikela, et al., *JINST* **9** (2014), C05013
[2] B. Zatko, et al., *JINST* **17** (2022), C12005
[3] A. Novak *et al.*, 2023 *JINST* **18** C11004

Acknowledgements: This research was carried out at Advacam (Prague, Czech Republic) under the supervision of Hab. Prof. Ing. Carlos Granja, Ph.D. as a part of an internship funded by the Erasmus+ Programme and the Doctoral Programme of FEEI SUT in Bratislava.