A Thermal Neutron Detector Based on Planar Silicon Sensor with TiB_2 Coating

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Motivation

Neutron radiation as a non-ionizing radiation is particularly difficult to detect; therefore conversion materials are needed. Conversion materials convert neutrons into secondary charged particles to be detected in silicon sensors. The use of titanium diboride (TiB_2) as a conversion material deposited by electron beam-physical vapour deposition (EB-PVD) as a part of front side contact of planar silicon sensor will be presented. Effects of different front side contact material composition and conversion material thickness will be demonstrated and discussed. Sensor behavior will be examined using alpha particle spectroscopy and a Am-Be neutron source. Simultaneously, a Geant4 simulation will be executed to evaluate conversion layer functionality and to discover the conversion material thickness for the best neutron detection efficiency.

Theory

In this study we investigated TiB_2 as converter layer for thermal neutrons. This material is a good conductor and can be used in high temperature applications. The material can be deposited by EB-PVD, a standard technique for depositing contact electrodes in silicon technology[2] and processed using standard lithographic techniques commonly used during semiconductor detector preparation.

To confirm our expectation, simulation using GEANT4 was performed by David Krapohl (Fig 1.) and more complex results can be found on his poster.

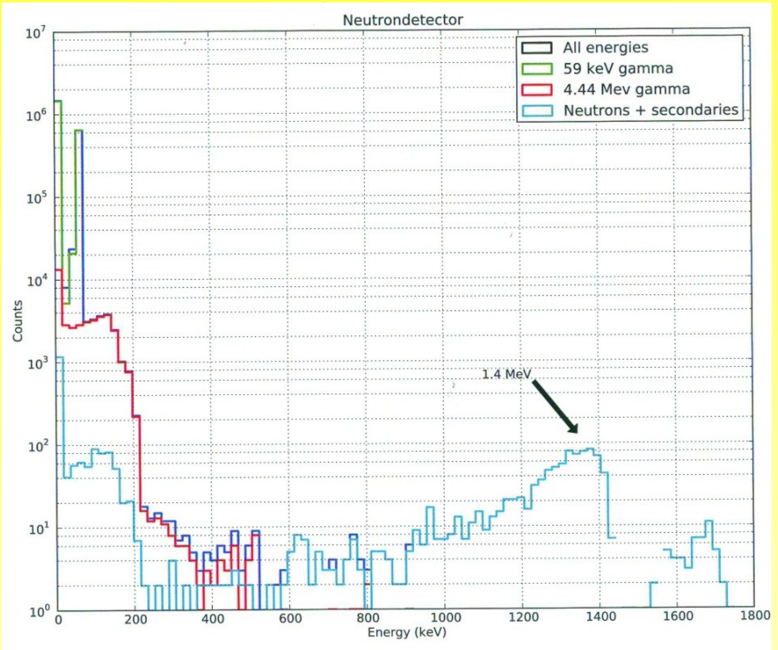

Fig 1. Simulated spectra in GEANT4

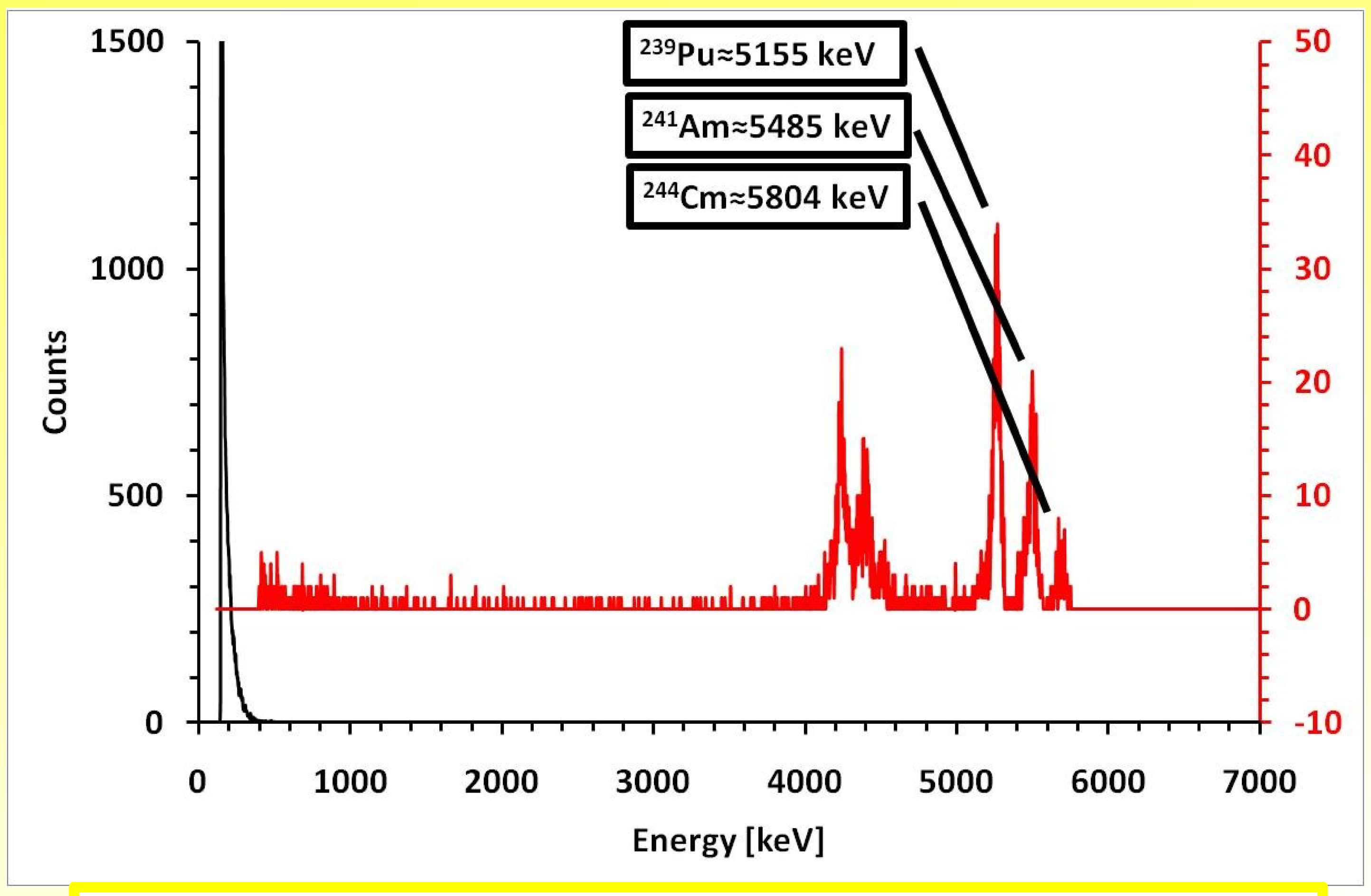

Fig 3. Spectra from **AmBe neutron source (black)** and **calibration peaks (red)** using detector **without converter**

Detector design

The detector is a silicon planar PN diode. In the clean rooms of Mid Sweden University (MIUN) we fabricated two four inch wafers. The front contact of first wafer is made from layers of Ti (500 Å), TiB2 (2000 Å) and Al (3000 Å) (Fig. 2.a) and b)). Layer of titanium between detector and converter is used to increase the adhesion of TiB_2. The front contact of second wafer is made from Al (3000 Å). The ohmic back contact of both wafers is made from Al (3000 Å). Second wafer was made to show difference in detection between detector with and without converter.

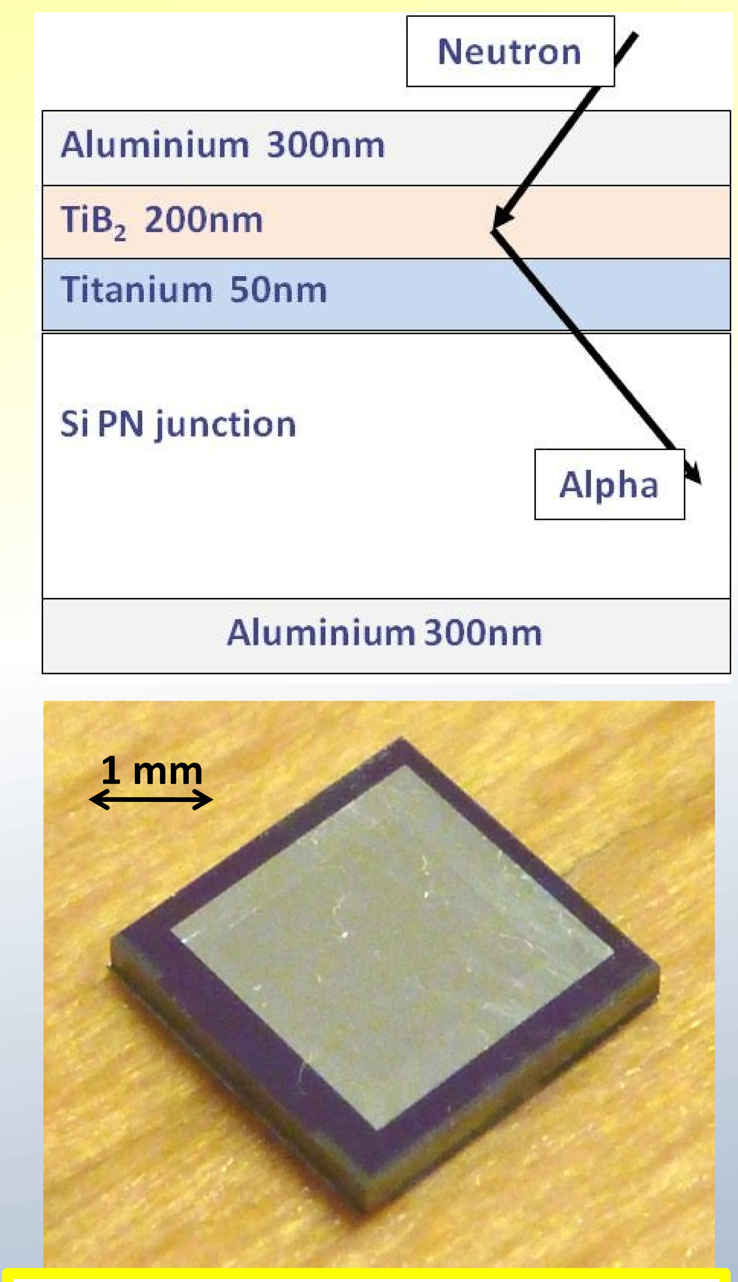

Fig 2. a) and b) schematic illustration and **photo of detector**

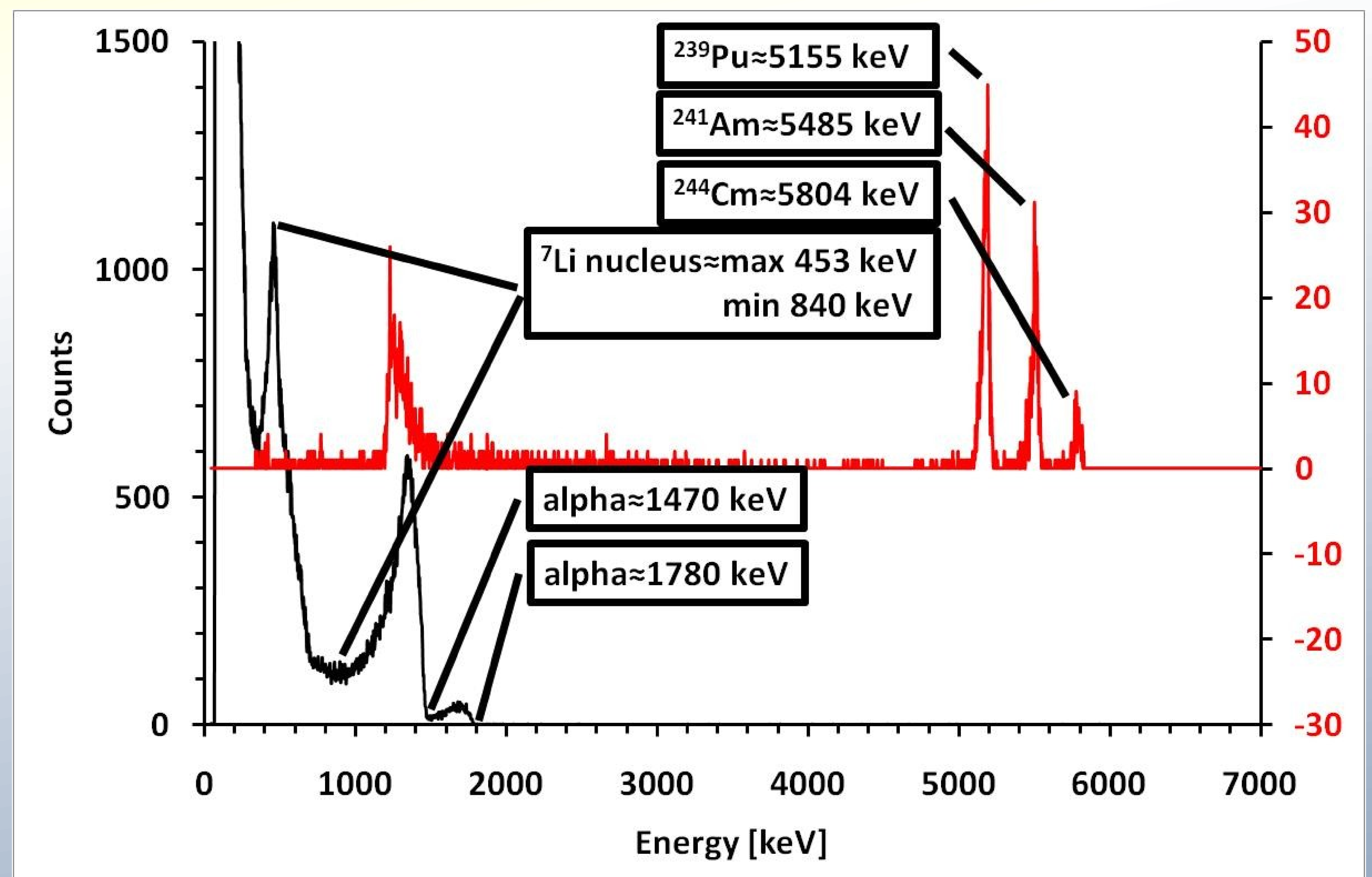

Fig 4. Spectra from **AmBe neutron source (black)** and **calibration peaks (red)** using detector **with converter**

Measurements and results

First detector tests were made with alpha sources (232U, 241Am, 239Pu and 244Cm) (red spectra in Fig 3. and 4.). Results from these measurements are used for energetic calibration of the detector. Alpha spectroscopy measure-ments were then followed with neutron detection tests using an AmBe neutron source. Measurements with neutrons were performed using source at Czech Metrology Institute (CMI) (Fig. 5 and 6). Fig 3. and 4. represents resulting spectra from this measurement. On Fig. 3 we can see only signal from background, no specific peaks. On Fig 4. we can see peak at 1470 keV from alphas generated by ^{10}B and peak at 840 keV from ^{7}Li nuclei with 94% probability along with peak at 1780 keV generated with 6% probability.

$$^{10}B + n \Rightarrow \alpha(1{,}47MeV) + {}^{7}Li(0{,}84MeV) + \gamma(0{,}48MeV)\ldots(94\%\,probability)$$

$$^{10}B + n \Rightarrow \alpha(1{,}78MeV) + {}^{7}Li(1.01MeV)\ldots(6\%\,probability)$$

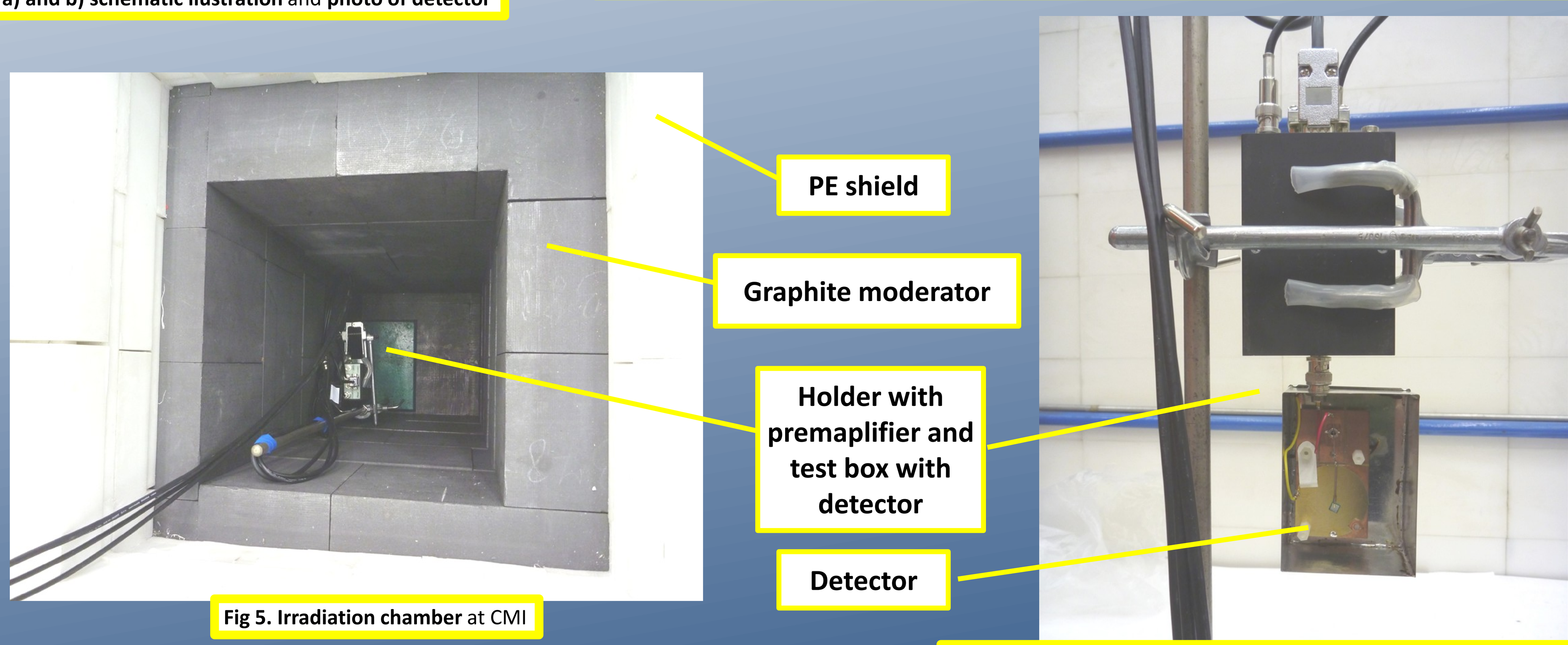

Fig 5. Irradiation chamber at CMI

Fig 6. Detector in test box connected **to charge sensitive premaplifier**

Conclusions

The idea of making a thermal neutron sensitive detector with TiB_2 converter as part of the detector contact was investigated by simulation using GEANT4. The detector was prepared in clean rooms of Mid Sweden University and tested using alpha spectroscopy with alpha and neutron sources. Sensitivity to thermal neutrons was confirmed but with low efficiency. Efficiency can be increased by making layer of TiB_2 thicker but increasing efficiency is contradictory to probability that alpha will reach sensitive layer and will be detected. An optimal thickness of converter layer can be determined using simulation [4]. Another way of increasing sensitivity is transition from planar technology to three-dimensional.

Evaluated technique will be used to prepare pixelated semiconducting detector sensitive to neutrons and three-dimensional surface for increased sensitivity.

Acknowledgments

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References

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