Gamma Spectroscopy with Pixellated CdZnTe Gamma Detectors

A. Shor[1], I. Mardor[1] and Y. Eisen[1]

(1) Soreq NRC Yavne, 81800 Israel, shor@soreq.gov.il

Keywords: Gamma-Ray Spectroscopy, Room-Temperature Gamma Detectors.

Introduction

Pixellated CdZnTe detectors are good candidates for room temperature gamma detection requiring spectroscopic performance with imaging capabilities. The CdZnTe materials possess high resistivity and good electron charge transport properties. The poor charge transport for the holes inherent in the CdZnTe material can be circumvented by fabricating the electrodes in any one of a number of structures designed for unipolar charge detection[1]. Recent interest in efficient gamma detection at relatively higher gamma energies has imposed more stringent demands on the CdZnTe material and on detector design and optimization.

We developed at Soreq a technique where signals from all pixels and from the common electrode are processed, and then a correction is applied for improving the energy resolution and the photopeak efficiency. For illumination with an un-collimated ^{133}Ba source , we obtain a combined detector energy resolution of 5.0 % FWHM for the 81 keV peak, and 1.5 % FWHM for the 356 keV peak. We discuss the importance of detector material with high electron $(\mu\tau)_e$ for thick pixellated detectors.

Description of Work

We have embarked on a program to design and test 1cm×1cm×1cm Pixellated CdZnTe gamma detectors. The main goal is detectors with sensitivity to higher energy gammas, especially the 511 keV peak, and with excellent spectroscopic properties and imaging capabilities. The design of the detector and electrode geometry was optimized with the help of a theoretical Monte-Carlo detector simulation code for segmented solid state detectors developed at Soreq and described in reference [2]. This code simulates the gamma interactions within the detector and calculates the induced charge as a function of gamma interaction depth, and as a function of $(\mu\tau)_e$. The code includes effects such as charge sharing among the pads the induced charge by gamma interactions near the edge of the detector. Our calculations show that even with course pad segmentation good spectroscopic performance can be achieved.

The experimental setup consisted of an electrostatic enclosure box containing the CdZnTe Pixellated detector and charge sensitive electronics. 16 pad signals, and one common signal, were fed to a peak sensing ADC, with the common signal used as the event trigger. This 17-fold coincidence enables us to perform correlation studies and detector performance optimization, including reconstruction of Compton re-interaction events. The CdZnTe detectors were 9.9mm×9.9mm×10mm detector with a 4×4 array of pads of 2.5 mm pitch and 0.2 mm spacing and were fabricated at eV-Products.

A useful experimental correlation for gamma detection is that between the signal of the pad and the common signal. A scatter plot between the pad signal and the common signal shows correlation bands for the various gamma lines. The common signal provides a measure of the depth of gamma interaction. A correction is applied so that the correlation band is projected onto the photopeak, thereby increasing the number of counts, reducing the low energy tail due to incomplete charge collection, and improving the energy resolution. This procedure, as applied to 3-5 mm thick detectors, has been described elsewhere by our group[2].

Results

The 10mm thick detectors require good electron mobility for optimum operation. The electron path length, given by $\lambda_e=(\mu\tau)_e\times E$, can be made large by a combination of high voltage and detector material with high $(\mu\tau)_e$. Our calculations show that for operation at or below V=1500, a minimum $(\mu\tau)_e$ of 5×10^{-3} cm^2/V-s is required. We determine the $(\mu\tau)_e$ by measuring the 30 keV line while varying the applied voltage and fitting the results to the Hecht equation. This measurement is made with the common electrode, since the pad induced signal is only sensitive to nearby charge carriers. To avoid complications from ballistic deficit, a shaping time of 10 μs was applied. The $(\mu\tau)_e$ for these detectors range from 3.0×10^{-3} up to 10.0×10^{-3} cm^2/V-s.

Figure 1 shows the combined spectrum of all sixteen corrected pad signals for a 1cm×1cm×1cm detectors illuminated with a ^{133}Ba source. The 81 keV peak has an energy resolution of 5 % FWHM, while the 356 keV peak has 1.5 % FWHM, with a peak to valley ratio of about 20 to 1.

Conclusions

We have shown that good spectroscopy can be obtained from thick Pixellated CdZnTe detectors, even with coarse segmentation.

[1] P.N. Luke IEEE Trans. Nucl. Sci., NS-42(1995)207.
H.H. Barret et al., Phys. Rev. Lett. 75 (1995) 156.
[2] A. Shor, Y. Eisen, and I. Mardor, Nucl. Inst. Meth. A458 (2001) 47.

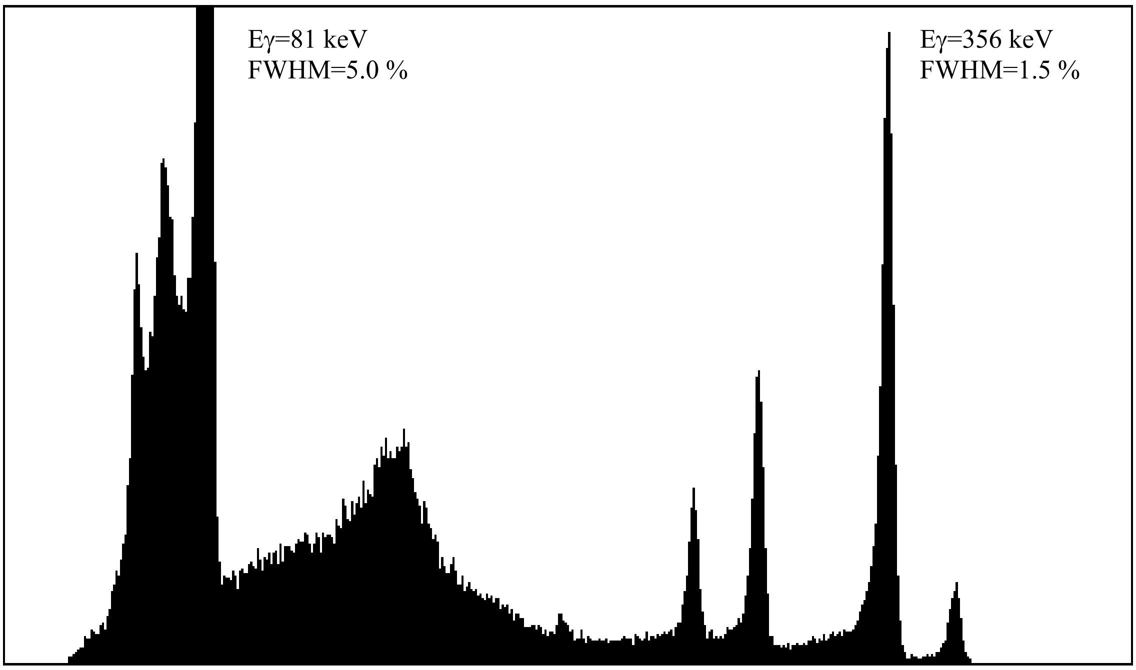

Figure 1. Combined spectrum of corrected pad signals for 1cm×1cm×1cm Pixellated CdZnTe Gamma Detector illuminated with a ^{133}Ba source.