Characterization and utilization of a small volume cadmium-zinc-telluride detector

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Introduction

Cadmium-zinc-telluride (CZT) gamma detectors are largely used in gamma spectroscopy, coincidence studies, pulse shape analysis, environmental monitoring, etc. This detector may be obtained in large volume as well as in volumes smaller than 1 cc with appreciable efficiency. In this work we aimed to characterize the newly procured gamma spectrometer based on CZT detector with respect to the energy dependence of efficiency, resolution, variation of intrinsic efficiency with solid angle. We also aimed to determine the radioactivity present in a soil sample.

Experiment

This experiment used a gamma ray spectrometer GR-1A procured from Kromek, UK. It is based on a CZT detector with active volume 1 cc. The detector was connected to the Dell workstation and data acquired in it. The spectra were analysed using Kromek K-Spect software. For the first part of the experiment, ^{137}Cs, ^{60}Co and ^{152}Eu were placed at a distance of 4.1 cm from the centre at the front face of the detector to determine the energy resolution and efficiency.

In the second part of the experiment we aimed to study the variation in intrinsic efficiency of the detector, if any, with distance between the source and the detector. The detector was placed at different distances between 2 cm and 12 cm from the source for this purpose. The variation of the intrinsic efficiency with energy was studied for uncollimated beams of gamma rays incident on the front face of the detector. The runtime of all the measurements was 7200 seconds. The detector was calibrated for energy response before recording the spectra. The spectrometer was allowed to stabilize for five minutes before collecting the data. All the gamma ray sources were properly shielded with lead brick.

In the last part of this work radioactivity present in the soil sample, collected from Kalyani, Nadia, WB, was determined. The soil sample was placed in a container simulating a Marinelli beaker with the detector placed at the centre. Data were taken for 6 hours.

Results and discussion

The variation of energy resolution for the CZT spectrometer in the energy range of 121 keV to 1408 keV is shown in Fig. 1. In this energy range the resolution varies from 10% to 0.7%. The resolution (R) of the spectrometer can be expressed as a linear function of the gamma ray energy (E_γ) of the form $R = 15.14E_\gamma - 1.01$

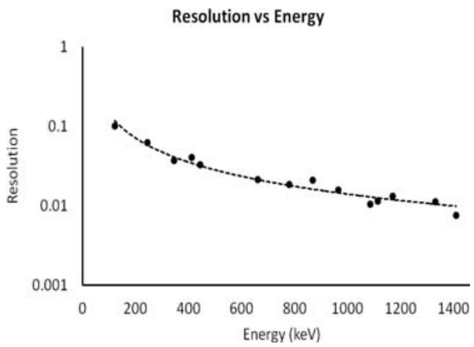

Fig. 1 Variation of resolution with energy for the CZT based GR-1A spectrometer

In figure 2 the absolute efficiency (ε_p) of the spectrometer for the full energy peak (FEP) and for the counting set-up mentioned is plotted as a function of energy E_γ. From the figure we observe that the efficiency varies between 2.8 x 10^{-3} and 4.5 x 10^{-5} in the energy range of 121 keV to 1408 keV. The FEP efficiency ε_p can be fitted with a polynomial of the form $\varepsilon_p = 32.24E_\gamma^{-1.87}$

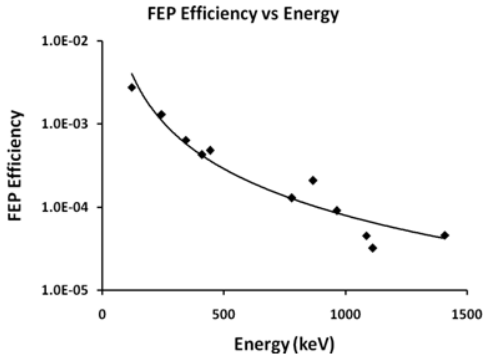

Fig. 2 Variation of FEP efficiency with energy for the CZT based GR-1A spectrometer

In the second part of this work we studied the variation of intrinsic efficiency (ε_i) of the GR-1A spectrometer with energy for different source to detector distances (SD). These results are presented in figure 3 for SD = 2 cm, 6 cm and 12 cm. and E_γ = 121.78 keV, 661.64 keV and 112.08 keV. Here we observe that for all the three energies considered ε_i at 2 cm is lower than that at 6 cm. This is explained from the fact that when the source is placed close to the detector a fraction of the incident gamma rays may escape the detector without depositing their full energy. On the other hand the intrinsic efficiency for SD = 6 cm has the same value as that at SD = 12 cm for the first two energies considered. But at E_γ = 1112.08 keV ε_i has a higher value for SD = 6 cm than that at SD = 12 cm. This variation needs to be investigated in more detail in order to understand the performance of the spectrometer.

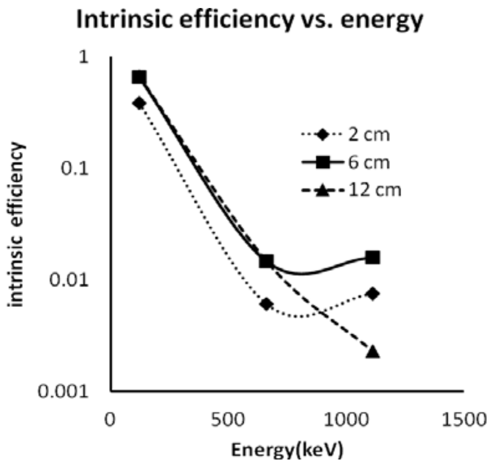

Fig. 3 Variation of intrinsic efficiency with energy for source to detector distances of 2 cm, 6 cm and 12 cm

After characterization of the spectrometer we aimed to determine the radioactivity present in the soil sample using this GR1A spectrometer. Analysis of the acquired background subtracted γ spectrum of the soil sample indicated the presence of radioisotopes which are listed in Table1.

Table 1. Isotopes detected with their half-lives.

Isotope	Half-life[2]
^{228}Ac	6.1 hours
^{228}Pa	22 hours
^{40}K	10^9 years
^{86}Rb	8 hours
^{172}Er	49.3 hours
^{247}Cm	1.56 x 10^7 years
^{176}Lu	10^{10} years
^{126}I	13.11 days
^{203}Pb	51.87 hours

Besides the long-lived isotopes, in table 1 we also observe the presence of some isotopes with half-lives of the order of few hours to few days. Of these ^{228}Ac is a member of Thorium series while ^{228}Pa may be formed from double β decay of ^{228}Ac. ^{86}Rb is used as a radiotracer in many application [1]. ^{126}I and ^{203}Pb may be formed through activation of stable nuclides [2].

Conclusion

In this work, we have studied the resolution and efficiency of the GR-1A spectrometer based on a small volume CZT detector. Energy resolution varies between 10% and 0.7% in the energy range of 121 keV to 1408 keV. The variation of intrinsic efficiency with source to detector distance needs to be studied in further detail. Analysis of the gamma spectrum of the soil sample collected indicates the presence of 9 different radioisotopes.

References

[1] A. B. Tugrul, *et al.*, Defect and Diffusion Forum **353**, DOI: 10.4028/www.scientific.net/DDF.353.199 (2013)

[2] K. Yong, M. W. Brechbiel, Dalton Trans., **40**, 6068 (2011)