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Characteristic Analysis of a CdZnTe Detector through the Simultaneous Measurement of Low Energy Gamma-ray and Alpha Particle

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1. Introduction

Cadmium Zinc Telluride (CZT) is the most suitable material for the detection of gamma rays due to its enough bandgap energy and a large cross-section for photoelectric absorption of gamma rays[1]. However, due to the low transport properties of carriers, electron-hole pairs generated in CZT sensor cannot be completely collected on each electrode (i.e., cathode and anode)[2]. This phenomenon leads to a significant distortion of the spectrum. Therefore, the transport properties of carriers should be considered to analyze correct characterization of CZT detector.

A common method to determine the transport properties in detectors is based on their response to α particle[3]. This method is an effective tool for studying mobility-lifetime products of carriers due to the short mean free path of α particle, whereas it is very sensitive to the experiment condition and surface condition of the detector. Measured values published by different authors have also been shown with a considerable difference[4].

In this study, simultaneous measurement of α particle and low energy gamma-ray was performed to evaluate the sensitivity of α particle method and to analyze the efficiency of the method using low energy gamma-ray. The measured result was also compared with the energy spectrum calculated by MCNPX code[5] to confirm the accuracy of experimentally obtained values.

2. Methods and Materials

In order to determine the mobility-lifetime products of carriers, measured energy spectrums under various bias voltages are required and specific variation of these spectrums should be fitted by a suitable model. Hence, the experiments in this study were progressed as the bias voltage is changed from -110 V to 110 V. A planar CZT detector ($5 \times 5 \times 2$ mm^3) manufactured by eV Products was selected to analyze the charge transport properties. This detector was also irradiated with low energy gamma-rays and 5.5 MeV α particles emitted from ^{241}Am isotope through the cathode surface. A specialized apparatus that allows the radiation source to be in close proximity to the detector was not used to analyze the influence of experiment condition on mobility-lifetime products.

The single-particle Hecht equation[6] was employed to derive the mobility-lifetime products from the peak variation of measured spectrums. This model can be written by following:

$$\eta(x) = \frac{(\mu\tau)_e \cdot V}{D^2}\left[1 - e^{-\frac{D^2}{(\mu\tau)_e \cdot V}}\right], \qquad \eta(x) = \frac{(\mu\tau)_h \cdot V}{D^2}\left[1 - e^{-\frac{D^2}{(\mu\tau)_h \cdot V}}\right]$$

where, η is the charge collection efficiency (i.e., the rate of charge carriers induced at the electrodes to the total number of carriers created by the radiation interaction), D is the detector thickness, and $(\mu\tau)_e$ and $(\mu\tau)_h$ are the mobility-lifetime products for electron and hole, respectively. E is the strength of the electric field in CZT sensor.

The brief flow chart to evaluate performance of CZT detector was shown in Figure 1. The mobility-lifetime products were obtained by the above-mentioned method, and deposited energy along to interaction position of incident radiations was calculated by using MCNPX code. Induced energy on each electrode was also calculated by a combination of deposited energy and charge collection efficiency at a specific position. Finally, energy spectrum was obtained through the accumulation of collected energies on the electrodes.

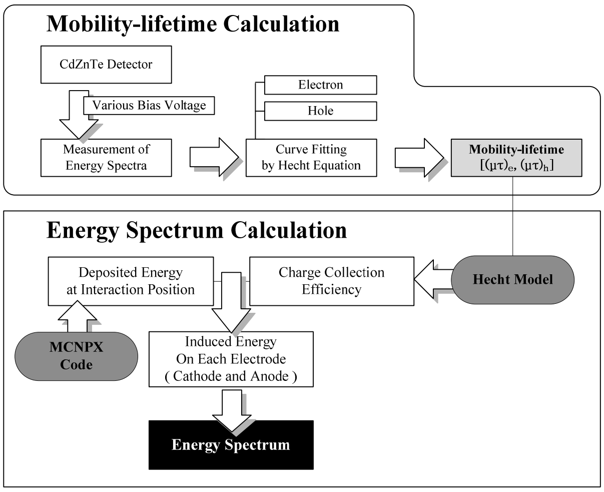
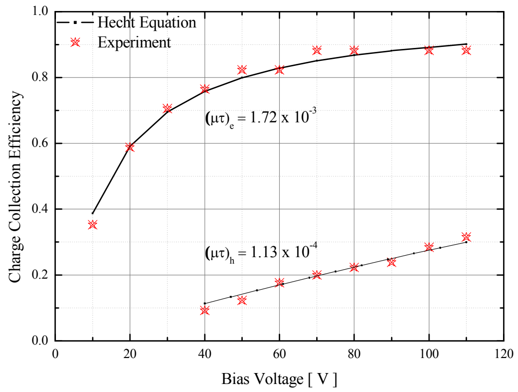


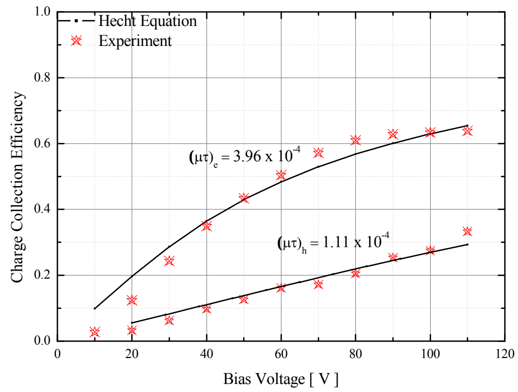
FIG. 1. The Brief Flow Chart to Evaluate the Performance of Semiconductor Detector

3. Results and Discussions

Figure 2 shows the charge collection efficiency as a function of bias voltage for the full-energy peaks of gamma-ray and α particle emitted from ^{241}Am isotope. Also, the solid lines in the figure indicate the results fitted by the Hecht equation. It is found that hole mobility-lifetime derived from two radiations is almost the same, whereas electron mobility-lifetime obtained by gamma-ray is about 4 times higher than the evaluated value by α particle. However, in Figure 2 (b), fitting graph to obtain the electron mobility-lifetime was not properly matched with experimental results.



(a) Gamma-ray



(b) Alpha Particle

FIG. 2. Determination of Electron and Hole Mobility-lifetime Products from the Bias Dependence of Gamma-ray and α Particle Response

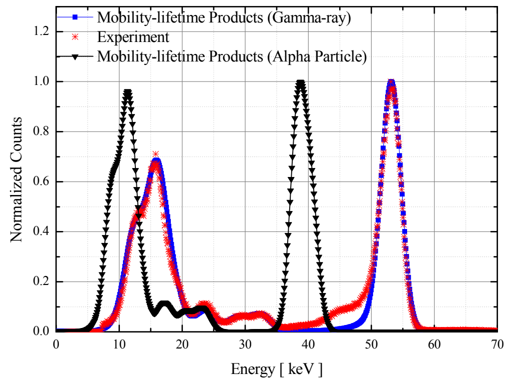


FIG. 3. A Comparison of Experiment and Simulated Results by Considering Transport Properties of Carriers

Under consideration of transport properties for electron-hole pairs, the energy spectrum of gamma-rays emitted from ^{241}Am isotope was calculated and compared with the experimental result as shown in Figure 3. In the case of energy spectrum derived from α particle method, it is found that main peak positions and pulse height are considerably different to those of measured result due to the difference of $(\mu\tau)_e$. Therefore, it is recognized that the method using low energy gamma-ray is more efficient to investigate the transport properties of semiconductor detector.

4. Conclusions

Simultaneous measurement of two different radiations emitted from ^{241}Am isotope was performed to investigate the sensitivity of α particle method and efficiency of the method using low energy gamma-ray. Also, energy spectrum considering the transport properties of CZT detector was simulated to compare the accuracy of extracted values with the experimental result. It is confirmed that low energy gamma-ray is more useful to obtain the transport properties of carriers than α particle because the method using gamma-ray is less influenced by experiment conditions than other ones. The analysis system in this study, which is configured by a combination of Monte Carlo simulation and the Hecht model, is very reliable to reconstruct the actual spectrum and to study the characteristics of CZT detectors.

ACKNOWLEDGEMENT

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