Performance of a Single-channel Module for a CdZnTe Radiation Detector

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1. Introduction

Semiconductors are very attractive materials mainly due to their high quantum efficiency, a compact size, and an integration of a detector with electronics in a board. Silicon based semiconductor radiation detectors, which are strip or pixellated electrode structures, are still used to apply a 2 or 3 dimensional detection or imaging application by virtue of their good energy resolution. An HPGe radiation detector is also used to detect the radioisotopes in environmental samples due to its unique high energy resolution. But An HPGe detector has constraints for a necessity of cooling by liquid nitrogen. In the past recent decade, compound semiconductors such as CdTe and CdZnTe have been studied actively as alternative semiconductor radiation detectors in a gamma and X-ray spectroscopy [1-8]. A CdZnTe has better quantum efficiency than other semiconductor materials due to its high atomic number and high density. A CdZnTe detector can be fabricated in an array configuration for an imaging system. Another advantage of CdZnTe material as a radiation detector is a high resistivity, which can minimize a leakage current and can contribute to be a better energy resolution. In semiconductor radiation detectors, signals are essentially charges produced by a radiation. Therefore, the use of a charge sensitive amplifier (CSA) system is naturally the best way to extract the signals. Appropriate electronics must be developed together with the semiconductor detectors due to the different capacitances of s. We developed a single-channel amplifying system, which consisted of a preamplifier and an amplifier, for a CdZnTe radiation detector by using an appropriate filter circuit to achieve a better signal to noise ratio (S/N). A 60 keV gamma-ray energy spectrum was measured by using the developed electronics and by using a commercially available NIM module.

2. Experimental

2.1 Performance of a Single Channel Module

Generally, the noise of the CSA is classified into internal and external noise. The internal noise is originated in nature from fluctuation of carriers in electronic devices and parts. The external noise is originated from external sources such as switching noise, micro-phonics, and mechanical vibrations. The noise of the CSA is represented by the concept of an Equivalent Noise Charge (ENC). The internal noises of the CSA depend on the characteristics of the transistor, the resistance and the capacitance connected to the input of the transistor including the detector, and the leakage current of the detector. So, these noises must be suppressed on a case by case basis.

2.2 Single Channel Module for CdZnTe detector

A CdZnTe, which has a spectroscopic grade and is a 3 ×3×7 mm bulk type produced by eV-Products, was used to develop the electronics. We used an eV-5093 low noise CSA hybrid-chip manufactured by eV-Products, whose open loop gain was ~10mV/V. An Eurorad PR-16 shaping amplifier, which can increase the gain by using an external potentiometer, was also used. A circuit diagram of the single-channel module is shown in Figure 1.

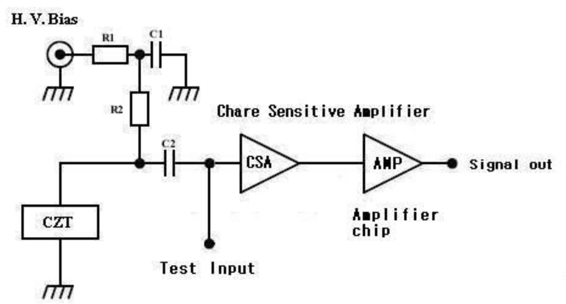

Figure 1. Circuit diagram of the single-channel module for the CdZnTe detector. Resistances R1 and R2 were 10 and 100 MΩ , respectively. And Capacitances C1 and C2 were 1500 pF and 1000 pF. Open loop gain of the charge sensitive amplifier was ~ 10 mV/V. Output voltage range of a shaping amplifier is ±2 V.

A circuit and CdZnTe detector were mounted in a RFI/EMI shielding box and the co-axial cables were net-shielded to block the external noise source. The DC voltage, which must be fed to the CSA and the shaping amplifier, was supplied by the 9-pin terminal from an ORTEC-572 amplifier and an appropriate filter was added to a circuit to cut the noise from the DC voltage line. An ORTEC-480 pulser was used to test the CSA and to measure the noise level of a preamplifier.

2.3 Performance of a Single Channel Module

To measure an energy spectrum, an ULS 1202 multi-channel analyzer (MCA) was used. The amplitude gain and shaping time of the amplifier were set at 1K and 1 μsec, respectively. The detector was biased with an ORTEC 659 high voltage supplier. A CdZnTe detector shows a better energy resolution when it is negatively biased on the face of an incident radiation or vice versa due to a difference of the mobility-life time product for the electrons and holes [5]. Also a better energy resolution was measured when a CdZnTe detector was biased at – 500V. Before measuring the energy spectrum, the background noise spectrum was also measured. The measured energy spectrum for a 60 keV gamma-ray from ^{241}Am is shown in Figure 2 by using the developed electronics. The calculated energy resolution was 5.7 %. We compared the energy spectrum measured with the homemade Single channel module CZT detector and that with commercially available NIM modules.

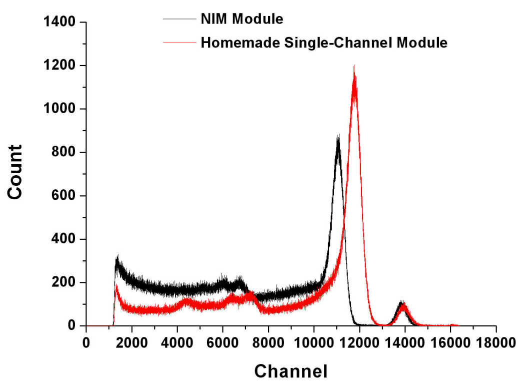

Figure 2. Comparison of gamma-ray energy spectra taken with the present single-channel module and commercially available NIM modules. A used CZT detector is same. The observed energy resolutions were 5.7 % and 5.8 %, respectively, for 60 keV gamma-ray.

3. Conclusion

The CdTe and CdZnTe detector have been widely applied to medical imaging, energy dispersive security radiographic systems, and relatively large-volume single-element detectors for safeguard measurements. To apply them to these fields, electronic devices, which have a better S/N ratio and an optimum size in consideration of their application, must be developed together with the CdZnTe detectors. In this paper we have developed a single-channel module consisted of a CSA and a shaping amplifier. The measured energy resolution was 5.7 %. For a future work, a portable CdZnTe radiation detector equipped with a miniaturized high voltage supplier will be studied for an application. And a strip CdZnTe gamma-radiation detector with a multi-channel module will also be studied.

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