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A Preamplifier for a CdZnTe Radiation Detector

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1. Introduction

Among the semiconductor materials of a wide band gap, CdTe and CdZnTe have attracted most attention as room temperature X-ray and gamma-ray detectors, especially, in the homeland security field [1-8]. In these 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 those signals [9]. Appropriate electronics must be developed together with the detector due to the different capacitances of the radiation detectors. We developed a single-channel preamplifier 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 also measured and compared with that from a commercially available preamplifier.

2. Experimental

To achieve a better S/N ratio, it is essential to block the noise from the source. The noise of the CSA is represented by the concept of an Equivalent Noise Charge (ENC) and it is expressed by:

$$\sqrt{ENC}^2 = \sqrt{ENC_s}^2 + \sqrt{ENC_p}^2 + \sqrt{ENC_{1/f}}^2 \quad (1)$$

Where, the ENC_s term is the equivalent series noise resistance and it relates to the input capacitance and the transconductance of the transistor. The ENC_p term is dependent on a resistor connected to the input and the leakage current of both the transistor and the detector. And the last term depends on the 1/f noise and the dielectric loss of the input capacitance.

In summary, the 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.

2.1 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 a preamplifier. And we used an eV-5093 low noise CSA hybrid-chip manufactured by eV-Products, whose open loop gain was ~10mV/V. A circuit diagram of the single-channel module is shown in Figure 1.

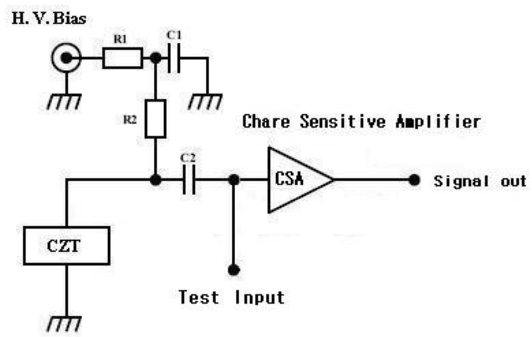

Figure 1. Circuit diagram of the single-channel module for the CdZnTe detector. Resistances R1 and R2 were 10 and 100 MΩ , respectively. And Capacitances C1 and C2 were 1500 pF and 1000 pF. Open loop gain of the charge sensitive amplifier was ~ 10 mV/V.

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, 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.

2.2 Performance of a Preamplifier

To measure an energy spectrum, an ORTEC 572 amplifier and an ULS 1202 multi-channel analyzer (MCA) were used. The amplitude gain and shaping time of an 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 the 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. The calculated energy resolution was 5.6%. We compared the energy spectrum measured with a homemade preamplifier and that with a commercially available eV550 preamplifier.

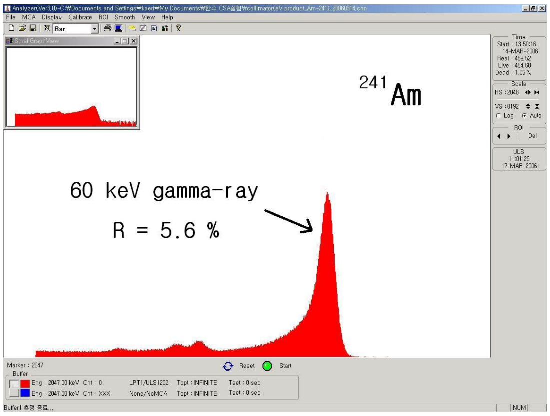

Figure 2. Gamma-ray energy spectrum taken with the present single-channel module. The observed energy resolution was 5.6% for 60 keV gamma-ray.

3. Conclusion

The CdTe and CdZnTe detector have been widely applied to X-ray Fluorescence (XRF) analysis, 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 the application, must be developed together with the CdZnTe detectors. In this paper we have developed a single channel preamplifier by using a CSA. The measured energy resolution was 5.6 %. However, the homemade preamplifier still leaves room for achieving a better energy resolution. For a future study, a portable CdZnTe radiation detector equipped with a preamplifier and a high voltage supplier will be developed for an application. And a strip CdZnTe gamma-radiation detector with a multi-channel preamplifier will also be developed.

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