Evaluation of Preamplifiers for a Multi-channel CZT Strip Detector

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1. Introduction

With the high demands in nuclear non-proliferation, home hand security and space sciences, wide band gap semiconductor materials, such as CdTe, CdZnTe and HgI_2, have gained more and more interest for the convenience of room temperature operation, high efficiency for gamma-ray detection and potential for good energy resolution. Among them, CdZnTe has gained particular interest. Single polarity charge sensing techniques, such as coplanar grids or pixellated anodes, had overcome the severe hole trapping problem and greatly improved the energy resolution of large volume CdZnTe detectors. In this study, various hybrid preamplifiers, which were produced by the eV products, the Amptek, and the Cremat companies, were tested and compared for a multi-channel strip CdZnTe to achieve high energy resolution.

2. Methods and Results

In this section characteristics of three hybrid preamplifiers were described and energy spectra for 59.9 keV were compared with one channel CdZnTe detector.

2.1 Characteristics of hybrid preamplifiers

Nominal characteristics of hybrid preamplifers, which were an eV-550 from the eV Products, an A250 from the Amptek, and a CR-110 from the Cremat, are summarized in Table 1 [1, 2, 3].

Table 1. Summary of hybrid preamplifiers

	eV-550	A250	CR-110
ENC for Si	1.3 keV (FWHM)	1.2 keV (FWHM)	1.7 keV (FWHM)
Rise time	20 ns @ C =2pF	3.8 ns @ C =0pF	7 ns @ C =0pF
Decay time constant	25 μs	300 μs	140 μs
Operating voltage	± 12 V	± 6 V	± 12 V
Power dissipation	·	14 mW	70 mW

The noise of the Charge Sensitive Amplifier (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 [4].

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.

2.2 Construction of a test circuit

A CdZnTe, which has a spectroscopic grade and is a 8 ×8×3 mm bulk type produced by eV-Products, was used to test hybrid preamplifiers. A circuit diagram of the single-channel module is shown in Figure 1.

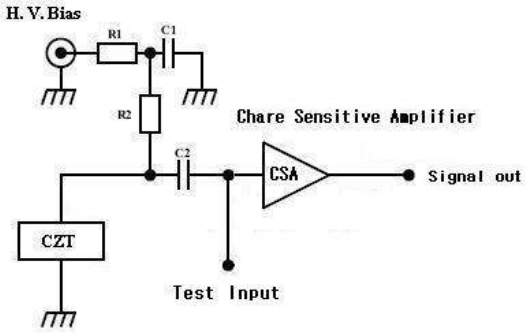

Figure 1. Circuit diagram of the single-channel module for the CdZnTe detector. Resistances R1 and R2 were 10 and 100 MΩ , respectively. And Capacitances C1 and C2 were 1500 pF and 1000 pF.

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 preamplifiers.

2.3 Measurement of energy spectra

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 4 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 –300V. Before measuring the energy spectra with three different hybrid preamplifiers, the background noise spectrum was also measured. The measured energy spectra with a CR-110 hybrid preamplifier for a 59.9 keV gamma-ray from ^{241}Am is shown in Figure 2.

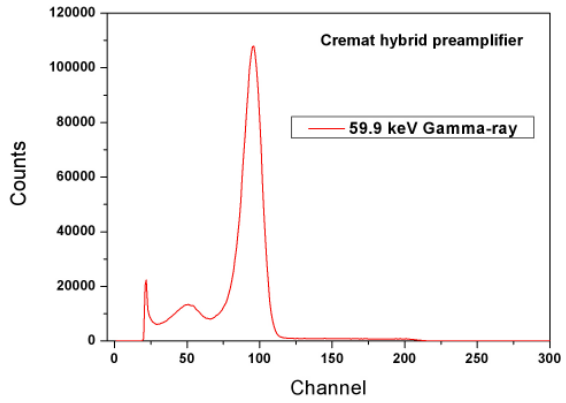

Fig. 2. Energy spectrum with a CR-110 hybrid preamplifier. Energy resolution and peak to valley ratio were 12.63% and 17.24.

3. Conclusions

Strip or pixellated anode arrays on CdZnTe can provide two-dimensional position information of gamma-ray interactions, which is required most in imaging application. Before we use a ASICs such as VA64TA2 or VA32TA4 for multi-channel processing, 8 hybrid preamplifiers were used to check a striped CdZnTe detector. To construct 8 channel strip module, three different commercially available hybrid chips were evaluated. In comparison with energy resolutions an A250 hybrid preamplifier showed the best energy resolution for 59.9 keV gamma-ray with the same CdZnTe detector.

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