

New Results for the CZT Drift-Strip Detector

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Abstract

The drift strip method for improving the energy response of a CdZnTe (CZT) detector to hard X and gamma rays is discussed. Results for a 10x10x3 mm³ detector crystal demonstrate a remarkable improvement of the energy resolution. The full width at half maximum (FWHM) is 2.18 keV (3.6%), 2.45 keV (3.0%), 2.86 keV (0.8%) and 3.89 keV (0.6%) at 60 keV, 80 keV, 356 keV and 661 keV, respectively. The resolution is limited by electronic noise below 100 keV.

Keywords: CdZnTe detector, drift-strip detector, detector response

Introduction

The next generation of X-ray astrophysics missions will seek to extend the energy range beyond the current limit of about 10 keV studied by ongoing X-ray missions such as ASCA, CHANDRA and XMM. The exploration of the 10 keV to 100 keV band, however, necessitates advances in the spectral and imaging capabilities of the semiconductor detectors and the associated X-ray optics.

The Danish Space Research Institute (DSRI) initiated in 1996 a program to develop CdZnTe (CZT) detectors for space applications. Compared to established Si and Ge, CZT semiconductors are attractive, since their high average atomic number ($Z \sim 50$) ensures a high sensitivity to hard X and gamma rays as well as a photoabsorption-to-Compton scattering ratio close to unity for energies up to 100 keV. Another advantage, in particular for space applications, is that CZT detectors operate at room temperature. However, present technology does not allow CZT crystals to be produced with the same high charge collection efficiency as Si and Ge. In particular, this is true for the collection of the positive charge carriers (holes). Consequently, CZT detectors generally have a spectral performance which is degraded compared to the theoretical Fano-limited resolution. This degradation is most severe at high energies (>50 keV) where absorption takes place deeper below the detector surface such that the holes with their low mobility will be collected inefficiently. Even for the best CZT material available, the detector response will therefore suffer from broad tails, which become more pronounced with increasing photon energy.

In 1997 the CZT detector research at DSRI resulted in the novel technique of Pamela and Budtz-Jørgensen (1998), the drift-strip method, which to a large extent circumvents the problem of hole trapping. The present paper discusses some recent results obtained with this technique.

The drift-strip method

A technique based on micro-strip electrodes has recently been developed at DSRI. The two main characteristics of the method are that the sensitivity to the trapping of holes is strongly reduced, and that it is possible to correct for the residual influence of the loss of holes.

The principle of the drift-strip method is shown schematically in [Figure 1](#). The structure consists of 5 drift

detectors. Each drift detector consists of 8 drift-strip electrodes and one anode readout strip. The drift-strip electrodes are biased by a voltage divider, whereas the anode strip is at ground potential.

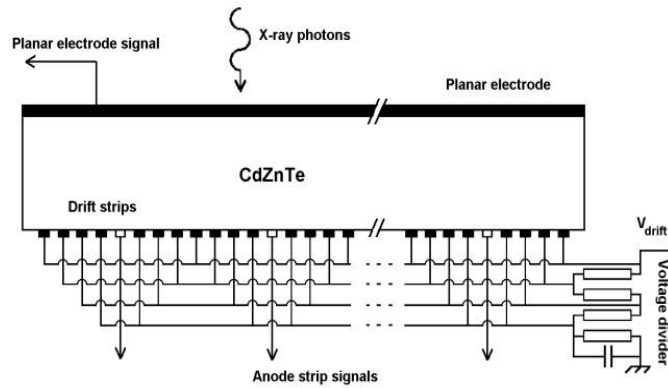


Figure 1.

The drift-strips provide an electrostatic shield so that the movement of the positive charge carriers will induce only a small signal at the anode strip, thus reducing the sensitivity to hole trapping. From the ratio

$R \equiv q_{\text{planar}} / q_{\text{strip}}$, i.e. the signal on the planar electrode (the cathode) divided by the signal on the anode strip, it is possible to correct for the residual contribution of the holes. This correction can be obtained from the bi-parametric distribution of q_{strip} and R as demonstrated by Pamelen and Budtz-Jørgensen (1998).

The drift-strip method also yields information about the interaction depth of the ionizing radiation. The depth information can be derived from the ratio R , which is close to unity for interactions close to the planar electrode or detector surface, and close to zero for interactions near the strip electrodes. Further details can be found in the recent paper by Kuvvetli *et al.* (1999). The depth information can be used to discriminate between gamma rays and charged particles. It will allow photons to be distinguished from electrons, since the depth profiles of the interactions are very different.

Results

A discriminator grade CZT crystal, $10 \times 10 \times 3 \text{ mm}^3$ in size, was fabricated as a drift strip detector at the Goddard Space Flight Center (GSFC). The structure consists of 100 mm wide strips and 200 mm pitch. Applying the surface passivation technique, developed at GSFC and described by Stahle *et al.* (1997), a high interstrip resistance of 7 GW was obtained.

Spectra of ^{241}Am , ^{133}Ba and ^{137}Cs were measured at room temperature. The spectra were recorded from one anode strip only, the other readout strips being AC-coupled to ground. The planar electrode bias voltage was -230V for the ^{241}Am spectra and -300V for the ^{133}Ba spectra. The drift voltage was -80V for both spectra. Preamplifiers eV-5094 from eV Products were used for the planar and anode strip electronic chains. The electronic noise at the anode strip readout was measured as 2.05 keV (FWHM) using a pulse generator.

The improved energy response of the detector when operating as a drift detector is evident from [Figure 2](#) (^{241}Am) and [Figure 3](#) (^{133}Ba). The full line shows the anode strip spectrum and the dotted line the planar electrode spectrum. The anode strip and the planar electrode spectra were recorded simultaneously and in coincidence. For the planar electrode, the tail on the low-energy side of the ^{241}Am 60 keV line is due to hole trapping. It is seen that for the anode strip, the tailing is strongly reduced. The energy resolution at 60 keV is 2.18 keV (FWHM) or 3.6%, which is essentially the noise contribution mentioned above.

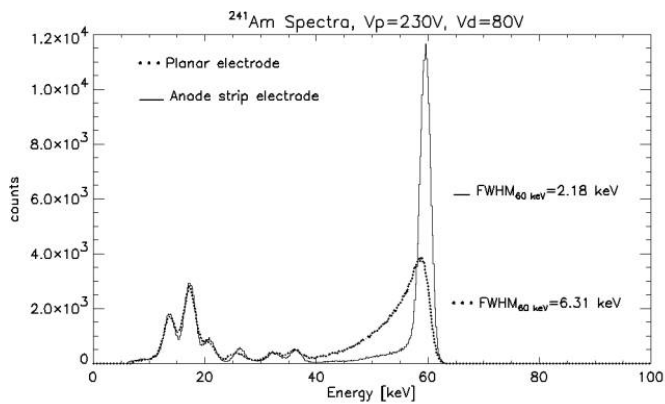


Figure 2.

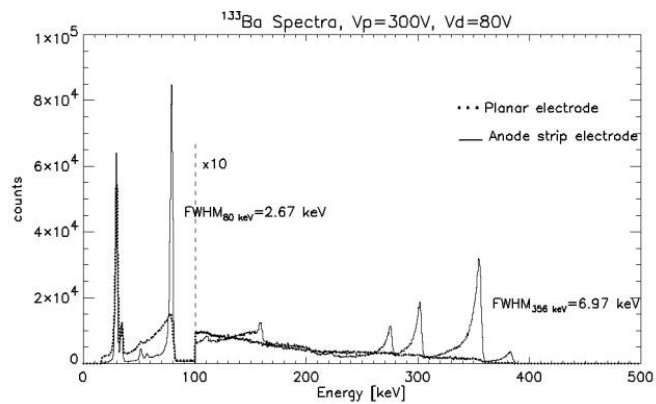


Figure 3.

As discussed earlier, the degradation of the detector response due to hole trapping becomes more pronounced with increasing energy. This can be seen from the planar electrode spectrum of ^{133}Ba , shown in Figure 3 where the lines above 80 keV are hardly visible at the planar electrode. For the anode strip, however, all ^{133}Ba lines are detected. The energy resolution (FWHM) is 2.67 keV and 6.97 keV at 80 keV and 356 keV, respectively.

The resolution can be further improved using the method of Pamelen and Budtz-Jørgensen (1998) as shown in Figure 4. The corrected spectrum contains all events ($\sim 75\%$) with R -values between 0.25 and 1.0. Energy resolution is now 2.45 keV (3.0%) and 2.86 keV (0.8%) at 80 keV and 356 keV, respectively. A similar analysis of ^{137}Cs data (not shown in the figure) gives an energy resolution of 3.89 keV (0.6%) and a peak-to-Compton ratio of 7:1 at 661 keV.

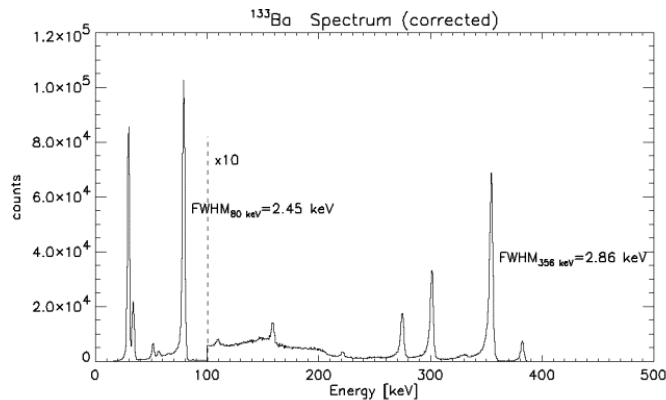


Figure 4.

Conclusion

The present measurements, especially below 100 keV, are strongly influenced by the electronic noise of the set-up. Therefore, future measurements will employ an improved scheme, where the field emission transistors of the preamplifiers are mounted close to the readout strips. The present gamma-ray results suggest that the drift-strip method can achieve energy resolutions which are within a factor of two of the Fano-limited resolution for the CZT material.

References

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