Design Studies of a CdZnTe γ-ray Detector with Three-Dimensional Position Sensitivity

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The II-VI compound semiconductor CdZnTe has following features: (1) the effective atomic number is 48, (2) the density is 5.78 g/cm^3, (3) the bandgap is 1.6 eV, and (4) the bulk resistivity is about $3\times10^{10}\Omega$cm. Due to these properties, the probability of photoelectric effect in the γ-ray detection is higher than Ge detector, and the detector can be used at room temperature. On the other hand, CdZnTe has a poor hole collection property. The mobility of holes is about 1/20 compared to that of electrons, and the trapping lengths are about 0.3 mm and 30 mm for holes and electrons, respectively, at the electric field strength of 1000V/cm.

We have designed a 20mm$\times$20mm$\times$10mm thick CdZnTe γ-ray detector with three-dimensional position sensitivity. The detection efficiency for the 500 keV γ-ray is about 50% with the thickness 10mm. A smaller size 10mm$\times$10mm$\times$7mm thick CdZnTe detector with similar function as the present one has already fablicated and tested by Luke et al.[1].

One plane of the detector is the cathode plane. A negative bias voltage is applied to this plane. On another plane (anode plane), three types of electrodes are placed. The first is 16 interconnected strip electrodes which collect the charge, and the signal is used as the γ-ray energy signal. These electrodes are kept at a slight positive potential. The second and third ones are electrodes used for position readout, and are placed at both sides of the charge collecting electrodes. The potential of these electrodes is kept at the (virtual) ground level. For the x-position readout, 16 strip electrodes are placed, and 16$\times$16 pad electrodes interconnected to the direction perpendicular to the x-position electrodes are used for y-position readout. The induced charges on these electrodes are used as the position signals. By these arrangement of electrodes, 16 position signals for both x- and y-directions are obtained. Both the width and gap of the electrodes are 0.2mm in the x-direction, and the length and gap of pad electrodes are 1mm and 0.2mm, respectively, in the y-direction.

Since the hole collection property is very poor in CdZnTe detector as mentioned above, the charge induced on the cathode, S_c, is approximated as solely due to the electron motion. Thus S_c is proportional to the drifting length D of the electrons, along with the γ-ray energy, i.e., $S_c \propto D\cdot E_\gamma$. Here D means, by definition, the distance of γ-ray interaction point from the anode plane. On the other hand, by adopting above mentioned electrodes arrangement on the anode plane (coplanar-grid method), the collecting electrodes signal S_a can be approximated to be proportional to γ-ray energy, i.e., $S_a \propto E_\gamma$ [1]. The depth information (D) of the γ-ray interaction point is thus obtained by the ratio S_c/S_a.

The design of the readout electronics is now in progress. The CdZnTe detector with readout electronics will be fablicated in the next year.

References

[1] P. N. Luke, M. Amman, J. S. Lee and H. Yaver, Nucl. Instr. and Meth. **A439** (2000) 611