INFIERI2019@ HUST

A brief introduction of CZT detector and experimental design

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Abstract

CdZnTe detectors have been under development for nearly three decades, providing good stopping power for gamma rays, lightweight camera heads and improved energy resolution. For these days, the CZT room temperature nuclear radiation detector has obtain high detection efficiency and energy, resolution with a wildly use in environmental monitoring, medical diagnosis, industrial non-destructive testing, safety inspection, nuclear science and technology, astronomical observation and high energy physics.

However, the performance of this type of detector is limited primarily by incomplete charge collection resulting from the charge carriers trapping, especially for holes. There are several techniques for overcoming this issue such as irradiation direction configuration and pulse shape correction method. Also another important mission is electrode geometry design which can make a great difference to the detector's performance.

Unipolar detector design, however, has been developed to overcome the deleterious effect of hole trapping problem. The most effective and successful prototype models include the Frisch-grid device, pixelate detectors, coplanar grid detectors, hemispherical electrodes and strip detectors. Some of them are shown in Fig.1. This article is mainly about the introduction of several unipolar CZT detectors and experimental design of subsequent project.

Introduction

When the gamma ray interacts with the CZT crystal, electron-hole pairs are generated within crystal's depletion layer under the action of electric field. Negatively charged electrons and positively charged holes move to different electrodes respectively and produce induced current on the electrodes. The formation of current pulse carries induced information. Input the charge signal to sensitive preamplifier to get voltage pulse. Its height is proportional to the photon energy . Then filter out the noise and make the highest SNR. Use forming amplifier to shape voltage signal into gaussian pulse signal. Then the standard counting system or the multi-channel pulse analyzer will record pulse signal numbers, these numbers are corresponding to the pulse height. Then the data and graph will be given as the energy spectrum. A schematic diagram of the CZT detector and electronics is shown in Fig.2.

Compared to scintillators, CZT detectors are more reliable because they avoid the random effects associated with scintillation light production and have high energy and position resolution. And compared to Si and Ge detector, CZT is more promising with high atomic number, large band gap, the absence of significant polarization effect and can easy to carry working at a room temperature.

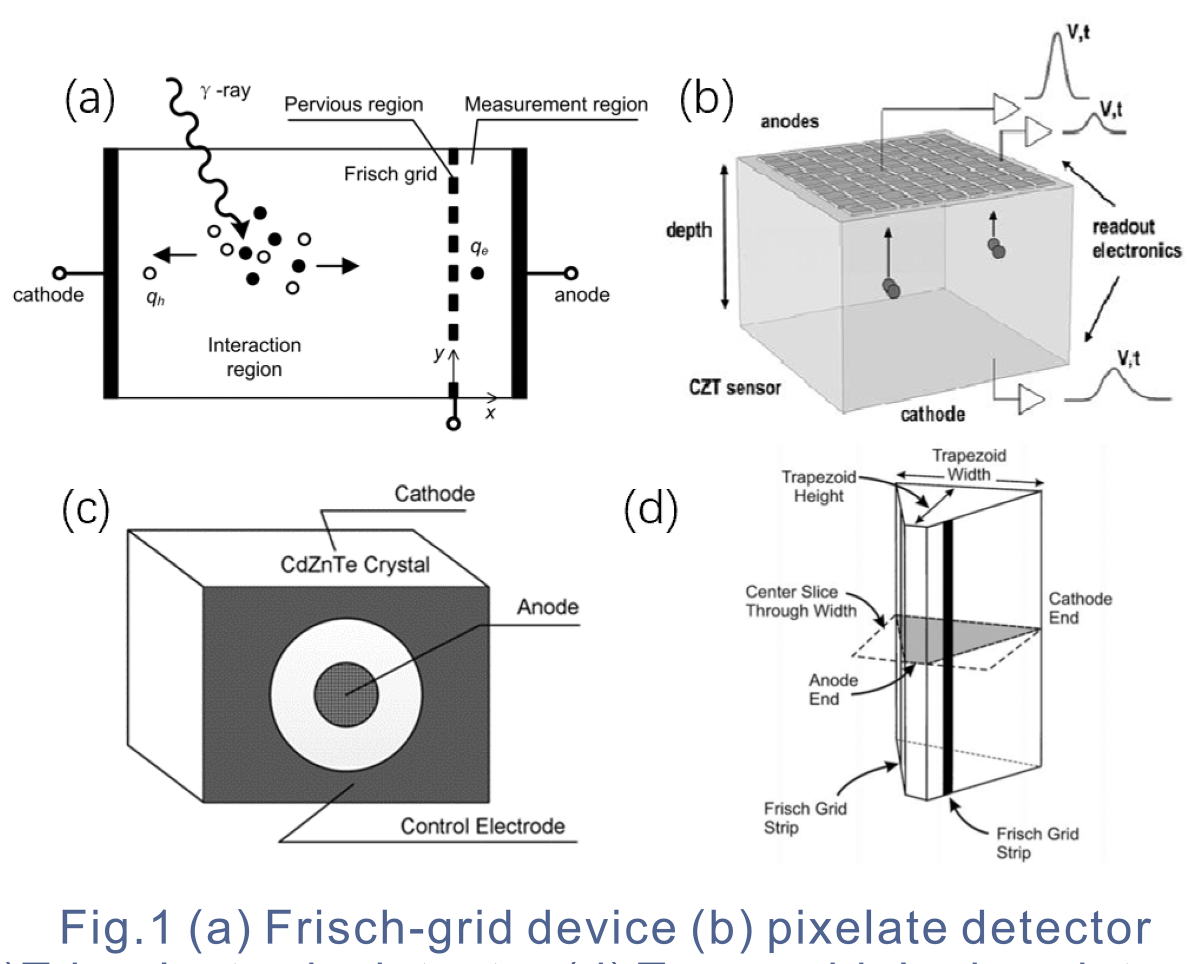

Fig.1 (a) Frisch-grid device (b) pixelate detector
(c)Trio-electrode detector (d) Trapezoidal prism detector

Detector design

Incise the CZT crystals into an appropriate shape. Both the top and bottom planes are rectangles, while the bottom plane is larger than the top one. And the lateral planes are in trapezoidal shapes.

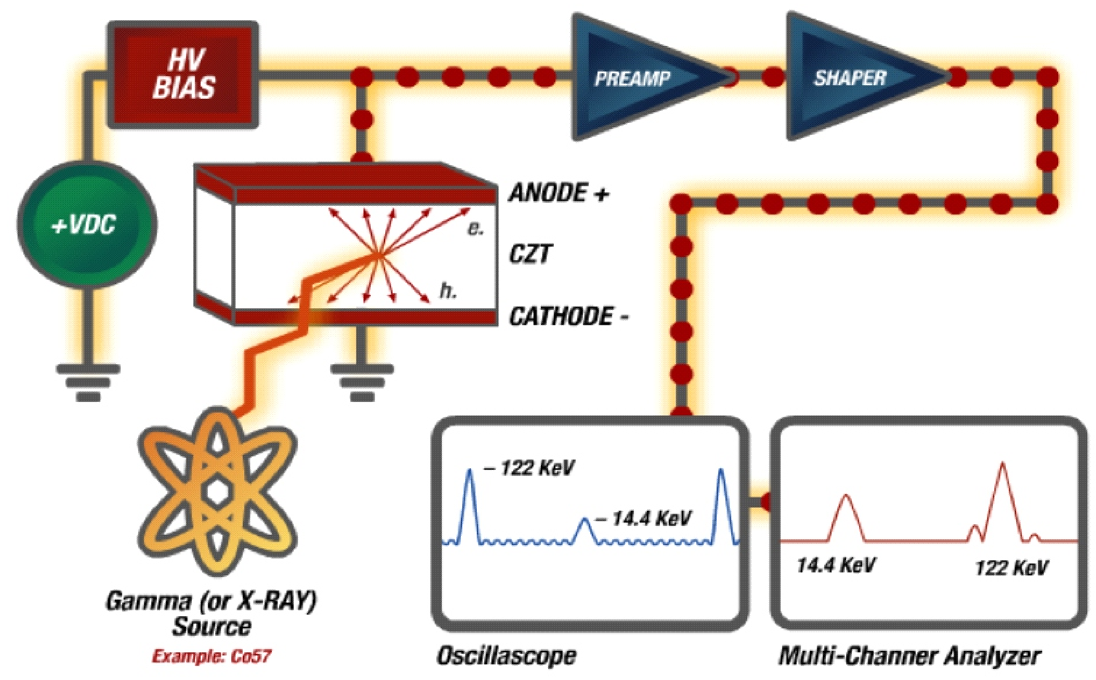

Fig.2 Schematic diagram of the CZT detector and electronics

The small-top-area will act as anode and the large-bottom-area plane will act as cathode. Prepare the pixels and grids on the anode. Set protection ring electrode around the anode and set lateral grid ring electrode on the lateral surfaces which is close to the anode and insulate against both cathode and anode. Cathode surface is as plane detector. It' s reasonable to incident the gamma ray with the method of cathode incidence. Give an impressed negative volatage on the cathode. The protection ring electrode and lateral grid ring electrode are connected to the ground , and the anode is given a slightly positive bias.

Advantages

- 1.High electron transfer rate and decrease the influence of holes'composition and recombination
- 2.Significant adaptability and flexible design process

The trapezoid pixel electrode design is diversified and can be adjusted according to different uses. For example, in medical treatment it can be configured with thin crystal layer to achieve high sensitivity, high resolution and fast response to low-energy gamma rays. Thick trapezoidal crystals can be used for the detection of high-energy gamma rays in the nuclear detection field. In addition, the trapezoidal crystal can also achieve 'splicing' within the space scope to make a large area detector which is known as the flexible detectors. This hetero-shape detector can be suitable for many special occasions. With the increase of sensitive elements, the detector's performance is supposed to be better than the traditional one's.

- 3.Combined performance

This designed new type of detector combine the advantages of frisch grid detector and pixel detector. So it is expected to achieve better detection performance by combining the advantages of the two types like high energy resolution, low leakage current, degradation of edge pixel performance, appropriate electric field distribution and so on.

Disadvantages

- 1.The workload of optimizing simulation process and programming algorithm design is massive.
- 2.The device preparation process is complex.
- 3.Require high matching accuracy of both crystals and electrodes.

Work plan

- 1.Design of electrode material, reduce the schottky contact, improve the ohmic contact, consider to select the best electrode materials by testing the performance of Au/Cr-CZT, Pt/Au-CZT, Au-CZT, In/CZT and so on;
- 2.Working parameters design. Find out the best matching of cathode, anode pixel, lateral grid and protection ring, optimize crystal size, electrode size, working voltage and so on;
- 3.Minimize the charge crosstalk between pixels, make reasonable design of pixel and grilles;
- 4.The noise is caused by electronic circuit and packaging increases. Simulating and optimizing will be done in advance, then perform an experiment to test it.
- 5.Prepare and make a gamma ray imaging CZT detector, test the detection performance and do some other characterization, what's more, conduct some detector stability tests.