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Radiation Sensing Using Thallium Bromide Crystals

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ABSTRACT

Radiation sensors using thallium bromide (TlBr) crystals were fabricated in this study. The TlBr crystals were grown by the traveling molten zone method. The sensors fabricated by constructing electrodes on the crystals exhibited good energy resolutions for gamma rays at room temperature.

1 Introduction

Thallium bromide (TlBr) is a very promising semiconductor material for radiation detector fabrication. Because it has high atomic numbers (81 and 35) and high density (7.56 g/cm^3), radiation sensors using TlBr crystals exhibits high detection efficiency for gamma rays. Fig. 1 shows linear attenuation coefficients for TlBr, CdTe, Ge, and Si [1]. TlBr exhibited the highest photon stopping power amongst the semiconductors for photon energies between 0.1 MeV to 10 MeV.

The bandgap energy of TlBr is 2.68 eV, resulting in high resistivity of the crystals at room temperature. Zone-purified TlBr crystals exhibited good charge transport properties. Thus, TlBr has been studied for radiation sensor materials [2].

In this study, TlBr detectors were fabricated for gamma-ray sensing. The crystal growth method, detector fabrication, and characterization of the sensors are described in this paper.

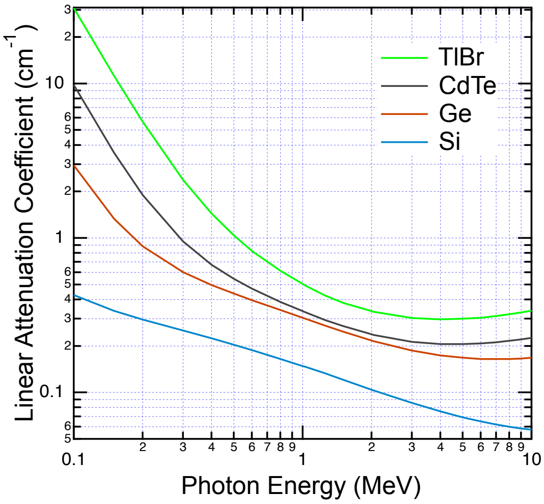

Fig. 1 Linear attenuation coefficients for TlBr, CdTe, Ge, and Si [1].

2 Experiment

2.1 Crystal Growth and Detector Fabrication

High resistivity and good charge collection efficiency are requisite for fabricating semiconductor radiation detectors. In this study, commercially available TlBr material with purity of 99.999% was employed as the starting material for the crystal growth. The material was purified by the zone-melting method. After the purification, single zone pass was performed for growing the crystal.

The pure end of the crystal was used for detector fabrication. A diamond wire saw was used for cutting the crystal into cubes with a dimension of approximately 5 mm × 5 mm × 5 mm. Two surfaces facing each other of the crystals were polished mechanically. The electrodes were constructed on the polished surfaces by vacuum evaporation of Tl. The cathode had a simple planar structure. The anode consisted of a small electrode (1.5 mm × 1.5 mm) surrounded by a guard electrode. Thin gold wires were attached to the electrodes with a carbon adhesive for connecting the sensor to the external circuit.

2.2 Detector Testing

Charge sensitive preamplifiers (Clear Pulse 580K) were connected to the cathode and anode of the TlBr device. The guard electrode was connected to the ground. Negative bias voltage of 500 V was applied to the cathode. The anode was maintained at the ground potential.

The device was irradiated with a radiation source at room temperature. The output signal waveforms from the preamplifiers were acquired with a digitizer (Clear Pulse 1819-16). A digital trapezoidal filter was used to perform pulse height analysis of the waveforms and obtain the energy spectrum of the incident radiation. The cathode pulse height exhibits gamma-ray interaction depth dependency. On the other hand, the anode pulse height exhibits small depth dependency except for near anode events due to the small pixel effect [3]. Thus, gamma-ray interaction depth can be determined by taking anode to cathode signal ratio [4]. Event selection based on the depth of interaction was performed for obtaining gamma-ray spectra only with near cathode events to improve the energy resolutions.

3 Results and Discussion

Fig. 2 shows a ^{137}Cs gamma-ray spectrum obtained from a TlBr detector at room temperature. The device exhibited an energy resolution of 1.3% FWHM with the event selection based on the anode to cathode signal ratio at room temperature. The peak accompanied by the 662-keV peak is an X-ray escape peak for characteristics X-rays of Tl.

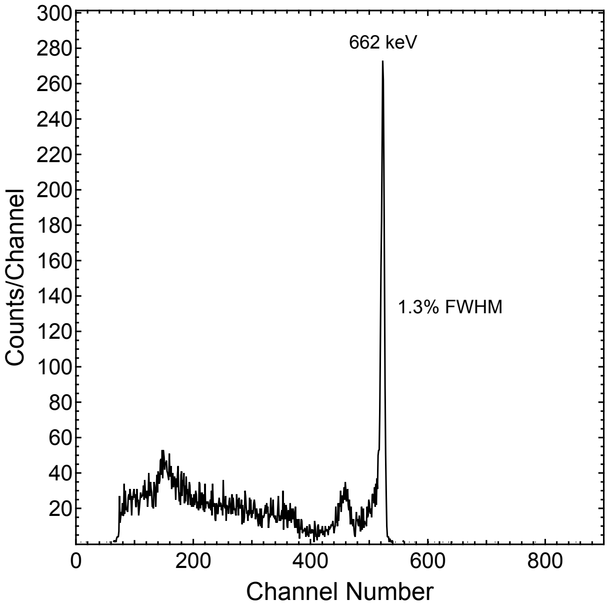

Fig. 2 ^{137}Cs gamma-ray spectrum obtained from a TlBr detector at room temperature. The near cathode events were selected based on the anode to cathode ratio for constructing the spectrum.

The detector was irradiated with a gamma-rays from thoriated tungsten electrodes at room temperature. The pulse height spectrum obtained from the detector is shown in Fig. 3. Event selection based on the gamma-ray interaction depth was performed to acquire the spectrum. The acquisition time was approximately 22 h. The Tl electrodes effectively suppress accumulation of Tl$^+$ and Br$^-$ ions under the electrodes causing performance degradation [5], [6].

As can be seen from the figure, the detector successfully detected gamma-rays from the source. Because the detector had a good energy resolution, close peaks such as 911 keV and 969 keV can be resolved in the spectrum. Although the active volume of the detector (approximately 1.5 mm × 1.5 mm × 5 mm) was small, the detector exhibited clear full-energy peaks for gamma rays because of the high photon stopping power of the material.

4 Conclusions

TlBr detectors exhibited high detection efficiencies and good energy resolutions for gamma rays. Thus, the applications of TlBr detectors can be found in various fields including nuclear engineering, nuclear physics, and nuclear medicine.

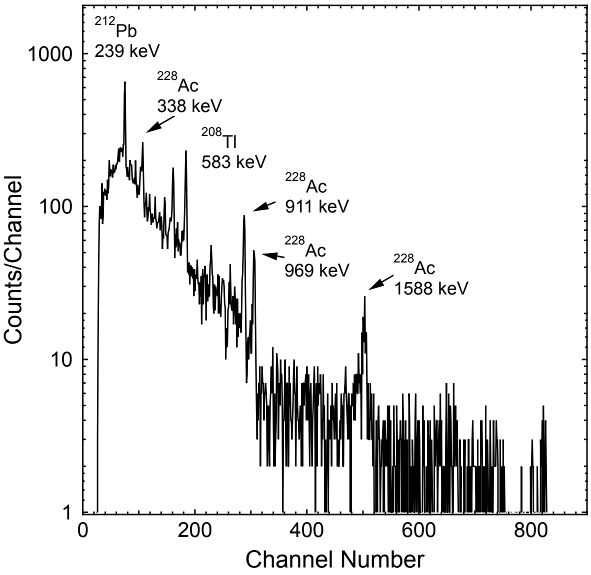

Fig. 3 Gamma-ray spectrum of thoriated tungsten electrodes obtained from a TlBr detector at room temperature. The near cathode events were selected based on the anode to cathode ratio for constructing the spectrum.

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