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2 Development of room-temperature semiconductor gamma-ray detectors with very high detection efficiency

2.1 Abstract

In this study, room-temperature semiconductor gamma-ray detectors with very high detection efficiency were developed from a compound semiconductor, thallium bromide (TlBr). A 1-cm-thick TlBr detector was fabricated from a TlBr crystal grown by the traveling molten zone method using a zone-purified material. The TlBr gamma-ray detector fabricated from the crystal exhibited high energy resolutions at room temperature, reflecting the high charge transport properties of the material. The TlBr detectors are attractive for applications in gamma-ray spectroscopy and imaging.

2.1.1 Introduction

A gamma-ray is one of the most penetrative types of ionizing radiation. The applications of gamma-rays are found in various fields, including nuclear medicine, astronomy, in physics experiments, and in nuclear power plants. In order to detect gamma-rays efficiently, high atomic numbers and high density are required for the detector materials. Germanium (Ge) semiconductor detectors are commonly used for detecting gamma-rays with high energy resolutions. However, cryogenic cooling is required for operating Ge detectors by reducing the dark current noise originating from the low bandgap energy of Ge (0.67 eV). Although wide bandgap compound semiconductors such as cadmium telluride and cadmium zinc telluride have been studied and are commercially available as room-temperature semiconductor detectors, more efficient room-temperature gamma-ray detectors are required for nuclear sciences and medical imaging applications. We have studied a compound semiconductor, thallium bromide (TlBr), as a gamma-ray detector material with very high detection efficiency and the capability for room-temperature operation.

2.1.2 Thallium bromide

TlBr is a compound semiconductor with a wide bandgap energy of 2.68 eV; this wide bandgap energy allows TlBr detectors to operate at room temperature. TlBr detectors exhibit high detection efficiency for gamma-rays because of their high atomic numbers (81 and 35) and their high density (7.56 g/cm^3). Although TlBr has been studied as a semiconductor detector material [4], practical use of the detectors was limited, mainly due to the low charge transport properties and the instability of the detectors' performance.

We have succeeded in improving charge transport properties in TlBr crystals significantly by purifying the starting material by the zone melting method [5]. We found that improvement of the long-term stability of TlBr detectors was realized by application of thallium electrodes to the devices, which suppressed space charge accumulations under the electrodes caused by ionic conductions in the crystals [6].

2.1.3 Detector performance

A 1-cm-thick TlBr detector was fabricated from a TlBr crystal grown by the traveling molten zone method in our laboratory. In order to obtain a TlBr crystal with high purity, a commercially available TlBr material was purified by the zone purification method. The size of the detector crystal was approximately 5 mm × 5 mm × 10 mm. The electrodes of the device were constructed by vacuum evaporation of a thallium-based alloy on the crystal. The TlBr detector demonstrated excellent

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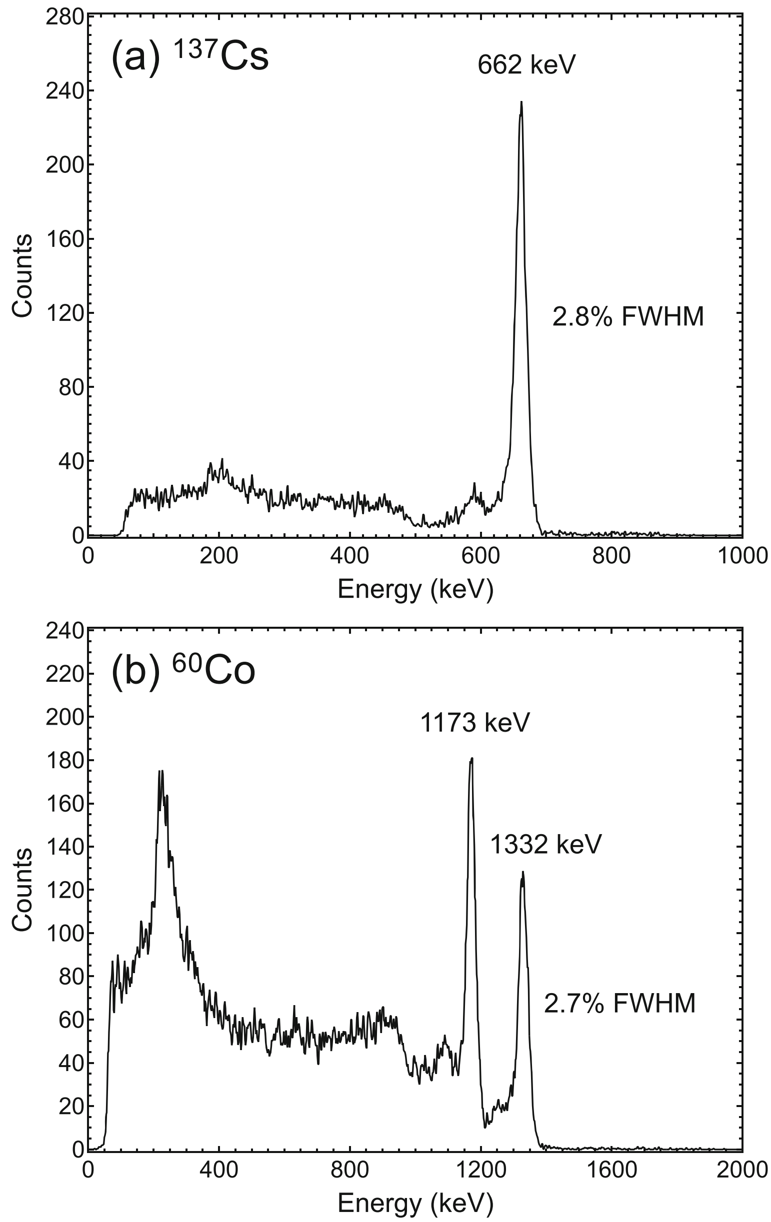

Fig. 4 ^{137}Cs (**a**) and ^{60}Co (**b**) gamma-ray spectra obtained from a 1-cm-thick TlBr detector with depth correction and rejection at room temperature

spectroscopic performance at room temperature reflecting the high charge transport prosperities of the crystal and exhibited a high peak-to-Compton ratio originating from the large crystal size and the high atomic number of the material, as shown in Fig. 4.

2.1.4 Conclusion

We have succeeded in growing high-quality TlBr crystals for gamma-ray detector fabrication. Because TlBr is extremely adept at stopping gamma-rays, the detectors are applicable to gamma-ray spectroscopy and imaging, especially for nuclear sciences and nuclear medicine. Future studies will be directed toward the implementation of TlBr detectors to practical instruments such as gamma-ray spectrometers and gamma cameras.