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Thallium bromide (TlBr) is a compound semiconductor promising for fabrication of efficient radiation detectors with high energy resolutions at room temperature. TlBr crystals exhibit high photon stopping power originating from its high atomic numbers (Tl: 81, Br: 35) and high density (7.56 g/cm^3). The wide bandgap energy (2.68 eV) results in the high resistivity of TlBr crystals (~10^{10} Ω·cm) at room temperature, enabling the device to operate with low noise. TlBr melts congruently at the melting point of 460 °C and has no destructive phase transition between the solidification and room temperature. Hence, purification and crystal growth of TlBr can be performed simply from the melt. Due to its attractive physical properties, semiconductor detectors fabricated from TlBr crystals were studied by numerous researchers[1-8].

One of the most important physical properties for semiconductor radiation detector material is the drift mobility (μ) which determines the charge collection efficiency and the pulse rise time of the device. In a conventional method for measuring drift mobility in semiconductor detectors, planar detectors are irradiated with alpha particles or low energy X-rays creating electron-hole pairs near the incident surface in order to make electrons or holes drift across the entire detector thickness. Then, the carrier drift time is measured from the pulse waveform obtained from the output of the preamplifier connected to the planar device. The drift mobility can be derived from the equation:

$$\mu = \frac{d}{E \cdot t_{drift}}, \qquad (1)$$

where d is the detector thickness, E is the electric field inside the device and t_{drift} is the carrier drift time. The conventional method is susceptible to error although the measurement is easy to implement. The values of drift mobility measured using alpha

particles can be affected strongly by the surface condition of the detector. Low energy X-rays produces small number of electron-hole pairs in the device, resulting in low signal to noise ratio for the mobility measurement.

In order to overcome the problems mentioned above, the direct measurement method was developed and implemented to CdZnTe devices[9]. In the method, the device is irradiated with the high energy gamma-rays (662 keV) and the gamma-ray interaction position is determined by the depth sensing technique[10]. The carrier drift time is then measured from the pulse waveform originating from the near cathode event selected based on the depth of interaction information.

In this study, the direct measurement method was applied to TlBr Frisch collar detectors in order to measure the electron drift mobility. The crystal growth, detector fabrication and mobility measurement are described in this paper.

Commercially available TlBr powder with purity of 99.999% was employed for the crystal growth. Further purification of the starting material was performed by the zone refining method. After the purification, TlBr crystals were grown by the traveling molten zone method.

Frisch collar detectors were fabricated from the grown crystals. Bar-shaped crystals with the dimensions of 2 mm×2 mm×4.4 mm were cut from the grown TlBr ingot using a diamond wire saw. The 2 mm×2 mm surfaces were polished mechanically in order to remove the damaged surface layers originating from the cutting process. Planar electrodes were formed on the 2 mm×2 mm surfaces by vacuum evaporation of Tl. Applying Tl electrodes to TlBr detectors is effective for suppressing the polarization phenomena at room temperature[11]. Since Tl is susceptible to oxidation, Al was evaporated onto the Tl electrodes to form an overcoat. The side surfaces of the bar-shaped crystal were wrapped with Teflon tape. A Frisch collar electrode was constructed by wrapping Al foil around the side surfaces. The Frisch collar covered the entire side surfaces of the device. Figure 1 shows the fabricated TlBr planar detector and TlBr Frisch collar detector. The device was mounted on a substrate and thin Pd wires were attached to the electrodes (cathode, anode and Frisch collar) with conductive adhesive. Frisch collar detectors operate as a single polarity charge sensing device, in which the induced charge on the anode depends mainly on the collection of electrons and scarcely affected by the hole movement. The Frisch collar detector design was applied to CdZnTe and the detectors exhibited excellent spectroscopic performance[12].

Performance of the TlBr Frisch collar detectors was evaluated at room temperature. The TlBr Frisch collar detector was placed in a shield box. The cathode and the anode were connected to charge-sensitive preamplifiers (CLEAR PULSE 580 K). The Frisch collar electrode and the cathode were maintained at ground potential. Positive bias voltage of 500 V was applied to the anode. The cathode was irradiated with a ^{137}Cs calibration source. The output signals from the preamplifiers were fed into shaping amplifiers (CANBERRA 2025 for the cathode and ORTEC 673 for the anode). The shaping times for the cathode and the anode were 6 μs. The peak amplitude for the cathode and anode pulses was analyzed by a multi-channel ADC board. The data were analyzed on a PC event by event to obtain pulse high spectra as a function of the cathode to anode signal ratio. The gamma-ray interaction depth is determined by taking the cathode to anode signal ratio in single polarity charge sensing devices[10]. The cathode to anode signal ratios were grouped into 21 bins in the measurements.

Figure 2 shows ^{137}Cs spectra obtained from a 2 mm×2 mm×4.4 mm TlBr Frisch collar detector. The acquisition time was 2 hours in real time. The anode spectrum exhibited an energy resolution of 2.9% FWHM at 662 keV. The Tl X-ray escape peak and the backscatter peak are discernible in the spectrum. The K X-rays of Ba from the ^{137}Cs source were detected by the detector, which confirmed that the electrons created by the Ba K X-rays near the cathode surface traversed the entire detector length, implying less electron trapping in the crystal.

Measurement of electron drift mobility in the TlBr Frisch collar detector was performed by measuring the preamplifier output waveforms for the near cathode event as shown in Fig. 3. The carrier drift time was measured to be 16 μs in the waveforms. Using the equation (1), the electron drift mobility was estimated to be 24.2 cm^2/V·s. The obtained mobility value is consistent with the reported data[13].

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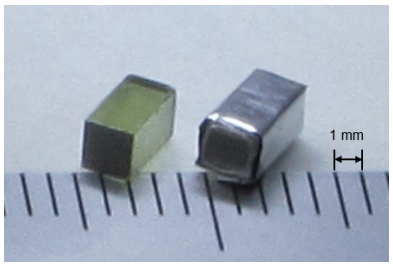

Figure 1. A TlBr planar detector (left) and a TlBr Frisch collar detector (right). The dimensions of the crystals were 2 mm×2 mm ×4.4 mm.

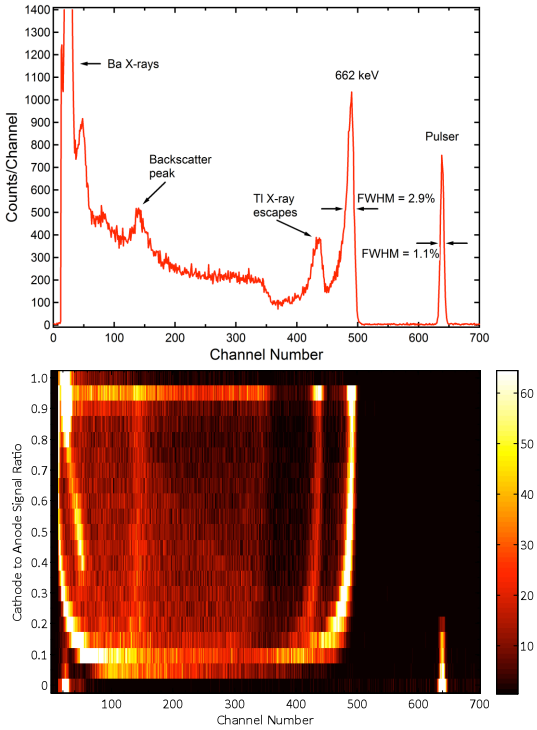

Figure 2. ^{137}Cs spectrum obtained from the anode of a 2 mm×2 mm×4.4 mm TlBr Frisch collar detector (top) and the relationship between the anode pulse height and the cathode to anode signal ratio (bottom).

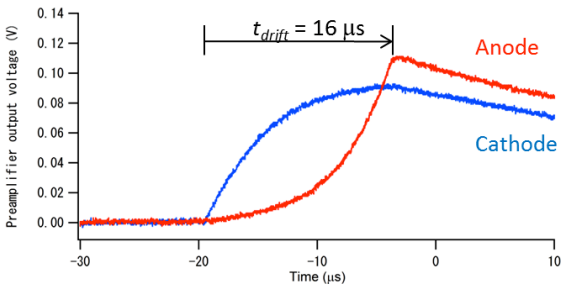

Figure 3. Pulse waveforms obtained from the anode and cathode of a TlBr Frisch collar detector. The gamma-ray interaction position was near the cathode surface.