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Nuclear Instruments and Methods in Physics Research A 578 (2007) 235–238
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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# Pixellated TlBr detectors with the depth sensing technique

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Received 8 March 2007; received in revised form 16 April 2007; accepted 7 May 2007
Available online 16 May 2007

**Abstract**

The depth sensing technique has been introduced to a 1.8 mm thick pixellated thallium bromide (TlBr) detector in order to enhance the performance of the device. Significant improvement of the energy resolution has been achieved with the device. An energy resolution of 2% FWHM at 662 keV was recorded with the device after the depth correction and rejection.


*PACS:* 07.85.Nc; 29.40.Wk; 81.10.Fq

*Keywords:* Thallium bromide; Semiconductor detectors; Position-sensitive detectors

## 1. Introduction

Thallium bromide (TlBr) is a very promising compound semiconductor for fabrication of X- and gamma-ray detectors operating at room temperature. The attractive physical properties of TlBr lie in its high atomic number (Tl: 81, Br: 35), high density (7.56 g/cm$^3$) and wide bandgap energy (2.68 eV). Radiation detectors fabricated from TlBr crystals exhibit photon-stopping power higher than that of BGO scintillators. The wide bandgap of TlBr permits the device low-noise operation at room temperature. In addition, TlBr melts at relatively low temperature (460 °C) and shows no destructive phase transition below the melting point. Purification and crystal growth of TlBr, hence, can be performed simply from the melt in quartz ampoules.

The physical properties of TlBr have attracted attentions of various researchers in the field of room temperature radiation detectors [1–3]. Thin planar TlBr detectors with thickness less than 1 mm have exhibited good energy resolutions [2]. However, planar TlBr detectors generally suffer from incomplete charge collection due to low-hole transport properties. Pixellated TlBr detectors have been investigated in order to minimize the degradation of energy resolutions by the hole trapping in TlBr detectors [4,5].

The depth sensing technique has improved the energy resolutions of CZT and $HgI_2$ detectors dramatically [6,7]. In this study, the depth sensing technique has been introduced to the pixellated TlBr detectors in order to enhance the performance of the devices. This study involved crystal growth, detector fabrication and evaluation.

## 2. Experiment

### 2.1. Crystal growth

Commercially available TlBr powder with nominal purity of 99.99% was used as the starting material for the TlBr crystal growth. The TlBr powder was loaded into a quartz ampoule and sealed in hydrogen bromide atmosphere at around 1 atm. The conventional multi-pass zone purification method was applied on the starting material 300 times at the furnace movement speed of 5 cm/h. After the purification, the horizontal traveling molten zone method with a slower furnace movement rate of 5 mm/h was carried out to grow the TlBr crystal.

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doi:10.1016/j.nima.2007.05.113

### 2.2. Device fabrication

To fabricate TlBr detectors, the crystal was cut into wafers with a diamond wire saw. The wafers were then polished mechanically to remove the damaged surface layers that originated from the cutting process. The thickness of the resultant wafers was around 1.8 mm. The electrodes of the device were deposited by vacuum evaporation of gold through shadow masks. The device had a continuous cathode (3 mm × 3 mm) and four pixellated anodes surrounded by a guard ring. Fig. 1 shows top view of the anode configuration. The area of the pixel was 1 $mm^2$ (1 mm × 1 mm).

### 2.3. Experimental setup

The cathode and one pixellated anode on the detector were connected to charge-sensitive preamplifiers (CLEAR PULSE 580 K). Negative bias voltage of 300 V was applied to the planar cathode and all anode electrodes were electrically grounded in order to move electrons toward the anodes of the detector. The cathode surface was irradiated with a $^{137}Cs$ source. The output signals from the preamplifiers were fed into shaping amplifiers (Aptec 6300 and CANBERRA 2025). The amplifier shaping times for the cathode and anode were 6 μs. The peak amplitude of the shaped pulse was held by a peak-hold circuitry to sample the pulse amplitude using a multi-channel ADC board. The data were analyzed on a PC. The data acquisition time was 30 min in real time. All measurements were performed at room temperature.

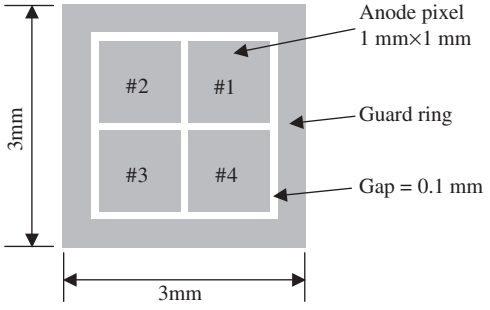


Fig. 1. Top view of the anode configuration of the device.

### 2.4. Depth sensing

The induced charge on the pixel anode from a gamma-ray interaction in the detector mainly depends on the collection of electrons and is scarcely affected by the depth of interaction sites, due to the small pixel effect [8]. On the other hand, the output pulse amplitude from the planer cathode depends on the depth of interaction due to the incomplete charge collection of holes. The interaction depth, therefore, can be determined by taking the cathode to anode signal ratio [6]. In this study, the calculated interaction depth was grouped into 10 bins (10 depth indices), and the energy spectra were acquired as a function of the interaction depth. The photopeak amplitude of the energy spectra varied at different depth indices due to the electron trapping and the variation of the weighting potential. These depth dependences on the energy spectra can be corrected by aligning the photopeak centroids to form overall energy spectrum in order to improve the energy resolution. In addition to the depth correction, the spectra with distorted energy resolutions can be rejected based on the depth information to construct the energy spectrum with a better resolution.

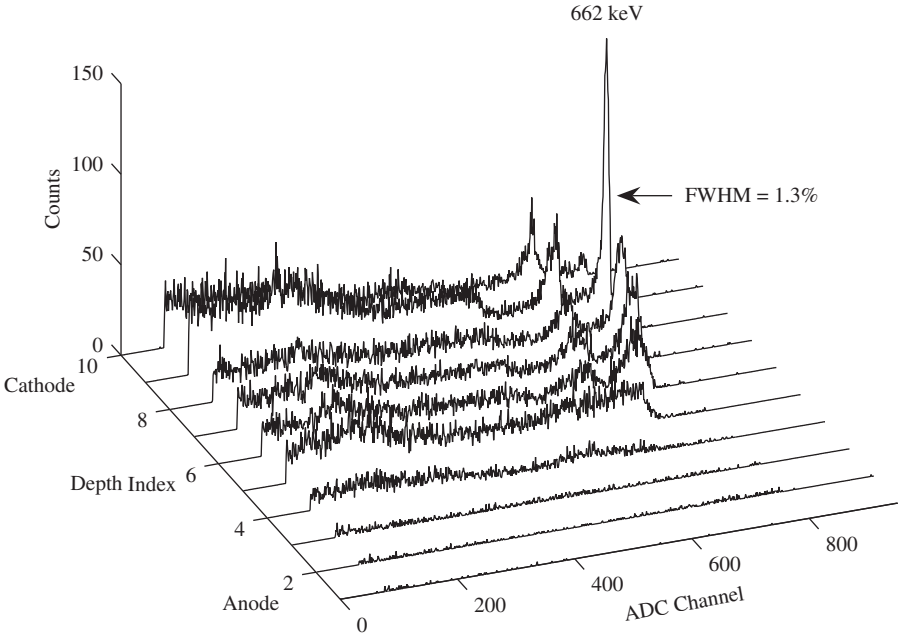


Fig. 2. $^{137}Cs$ spectra obtained from the anode pixel of the TlBr detector as a function of the gamma-ray interaction depth (depth index).