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Effect of annealing temperature on the performance of Au/TlBr/Au semiconductor radiation detectors

Seung Hee Lee, Joon-Ho Oh, Young Soo Kim, Chang Goo Kang, Jeongmin Park, Soo Mee Kim, Ah Hyun Park, Seung-Jae Lee and Han Soo Kim*
Advanced Radiation Technology Institute, Korea Atomic Energy Research Institute, Jeongup-si, Jeollabuk-do, Korea
**Corresponding author: khsoo@kaeri.re.kr*

1. Introduction

For any semiconductor to be used in the radiation detection applications, one should have a high density together with high effective atomic number (Z) for higher photon stopping power, large bandgap for room temperature operations, and good transport characteristics (i.e. mu-tau products), leading to good spectral performances **[1]**. In this regard, TlBr semiconductor can be considered as a strong candidate material due to its high density of 7.56 g/cm^3, high atomic number of the constituent atoms (i.e., Tl: 81, Br: 35), large bandgap of ~2.7 eV, and good hole and electron mobility-lifetime products of 1-2 x 10^{-4} and 4-9 x 10^{-5} cm^2/V, respectively **[2]**. To realize full potentials of this highly promising high-quality semiconductor single crystals for subsequent device fabrication uses, some research groups have worked on the optimization of purification and/or growth processes of ingots **[3-5]**, surface treatments **[6]**, post-growth annealing **[7,8]**, and so forth.

In this presentation, we report on the effect of different annealing temperatures on the performance of TlBr radiation detectors. Radiation detection spectra were measured with ^{241}Am for Au/TlBr/Au metal-semiconductor-metal structured radiation detectors.

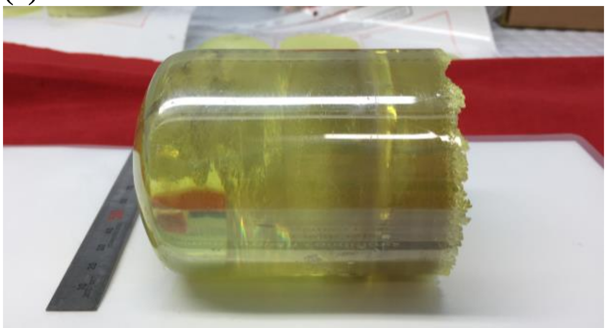
2. Methods and Results

2.1 Experimental methods

TlBr crystal (3 inches in diameter) was grown by using Bridgman method. The grown TlBr ingot was sawn into several thick wafers with a diamond wire-saw, and then parallelepiped specimen diced by a diamond wire-saw were mechanically polished using various SiC papers. The chemical etching was carried out using diluted HCl in methanol solution and subsequently rinsed with methanol. After etching, the thermal annealing was performed in air at 200, 250 or 300 ℃ for 24hrs for some of the specimens to improve the crystallinity of the TlBr crystals. Subsequently, Au electrodes were deposited on the both sides by a thermal evaporator. Hereafter, radiation detectors made with TlBr crystals which were as-fabricated or annealed at 200, 250, 300 ^{o}C for 24 h in air are referred to as Au/TlBr(as-fab.)/Au, Au/TlBr(200)/Au, Au/TlBr(250)/Au, Au/TlBr(300)/Au, respectively.

Electrical characteristics of Au/TlBr/Au detectors were measured by using a Keithley 4200-SCS parameter analyzer system. Radiation response measurements with ^{241}Am gamma-source (59.5 keV) performance were performed by using eV-550 preamplifier (eV products Inc.), 572A Amplifier (ORTEC Inc.) and MCA(multi-channel analyzer).

(a)



(b)

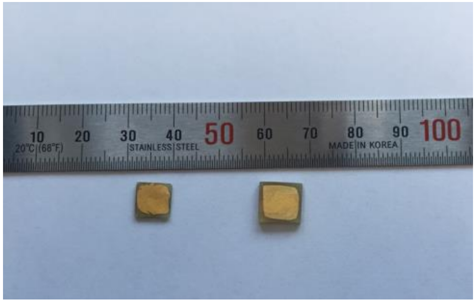


Fig. 1(a) TlBr ingots, 3 inches in diameter grown by Bridgman method, (b) fabricated representative Au/TlBr/Au detectors.

2.2 Results

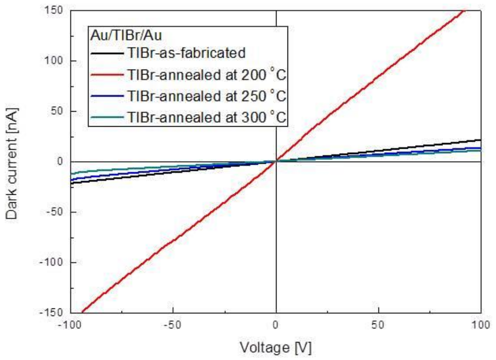


Fig. 2. Current-voltage (I-V) characteristics of Au/TlBr/Au

radiation detectors as a function of annealing temperature.

Figure 2 shows the current-voltage (I-V) characteristics of four Au/TlBr/Au radiation detectors as a function of different TlBr annealing temperatures in air. All of the four samples showed linear I-V characteristics, which is an indication of good ohmic character of Au/TlBr/Au back-to-back contacts in this study. It is observed that (except the one annealed at 200 ^{o}C), slope and the dark current of the I-V curve decreases as annealing temperature increases. For example, dark currents at a voltage of 100 V were 21.36 nA, 13.82 nA, and 10.94 nA for Au/TlBr(as-fab.)/Au, Au/TlBr(250)/Au, and Au/TlBr(300)/Au radiation detectors, respectively.

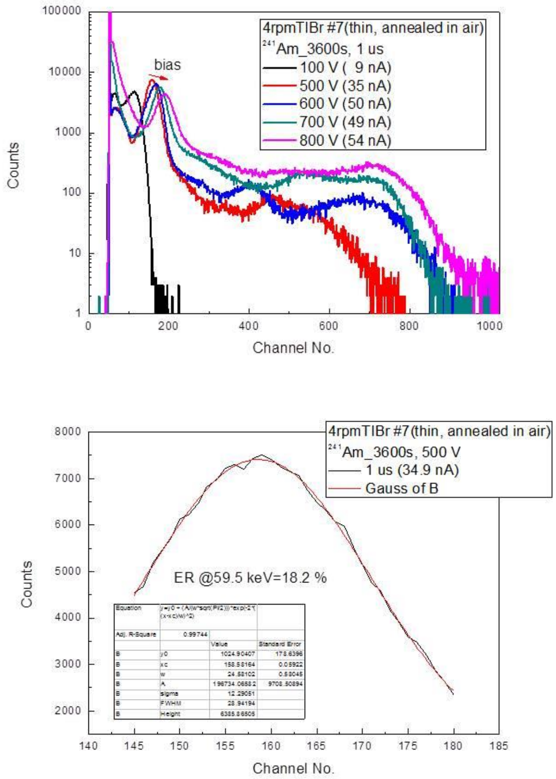


Fig. 3. (a) Radiation response spectra against ^{241}Am for Au/TlBr(250 ^{o}C-annealed)/Au radiation detectors radiation detectors as a function of annealing temperature.

When the measurements were performed for four Au/TlBr(as-fab.)/Au, Au/TlBr(200)/Au, Au/TlBr(250)/Au, Au/TlBr(300)/Au radiation detectors, Au/TlBr(as-fab.)/Au detectors exhibited poor spectral response characteristics (not shown), possible due to the poorer material quality. In addition, energy resolutions at 59.5 keV (gamma radiation energy from ^{241}Am) were 22.9 %, 18.2 %, 31.3 % for Au/TlBr/Au when TlBr samples were annealed at 200, 250 and 300 ^{o}C, respectively. For example, Fig. 3 shows ^{241}Am spectra for Au/TlBr(250)/Au radiation detectors as a function of applied bias. Best energy resolution was obtained at an applied bias of 500 V (as also shown in Fig. 3 (b)).

3. Conclusions

TlBr detectors were fabricated from the 3-inch crystal grown by Bridgman method. The radiation detectors were fabricated with TlBr specimen which were as-fabricated or annealed at 200, 250 or 300 ^{o}C for 24 h in air.

Substantial improvement in the energy resolution was achieved with the annealing. On the other hand, the specimens without annealing resulted in no spectrometric results. These results demonstrate that proper annealing improve the crystallinity of the crystal.

ACKNOWLEDGEMENTS

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