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Annealing effect on TlBr crystal for gamma-ray detectors

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Introduction

Thallium Bromide (TlBr)

Atomic number Tl: 81, Br: 35 → High detection efficiency

Density 7.56 g/cm^3

Band-gap energy 2.68 eV → Room temperature operation

$\mu_e\tau_e$ ~10^{-3} cm^2/V

$\mu_h\tau_h$ ~10^{-4} cm^2/V → High energy resolution

Melting point 460 °C → Easy to grow

Phase transition No

→ Promising material for gamma-ray detectors

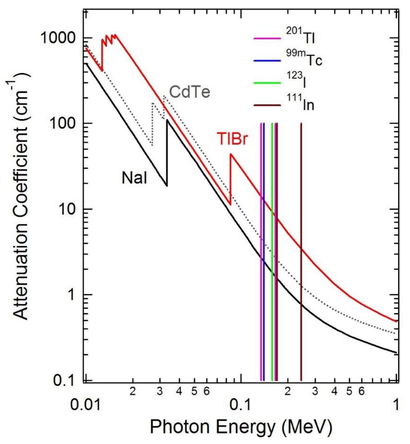


Fig. 1. Linear attenuation coefficient for TlBr and typical detector materials (NaI, CdTe), and gamma-rays energy used in SPECT diagnosis.

Thallium bromide (TlBr) is a compound semiconductor characterized with high atomic numbers (Tl: 81, Br: 35), high density (7.56 g/cm^3) and wide band gap energy (2.68 eV). Due to these properties, TlBr detectors can operate at and above room temperature, and exhibit high detection efficiency for high energy X-and gamma-rays (Fig.1). Thus, TlBr has been regarded as a promising new detector material in application of X- and gamma-ray spectroscopy and nuclear medical imaging such as SPECT (Single photon emission computed tomography).

Crystal characteristics of TlBr wafers

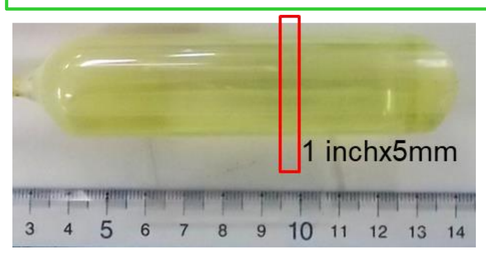


Fig. 2. TlBr crystal (ϕ1 inch) grown by the Bridgman method and a wafer for crystal evaluation.

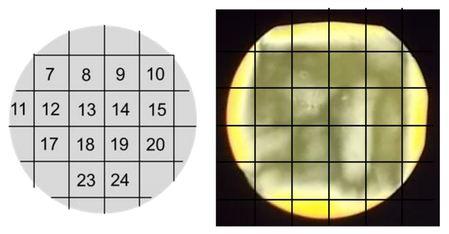


Fig. 3. Strain distributions inside the TlBr wafer taken from the ingot.

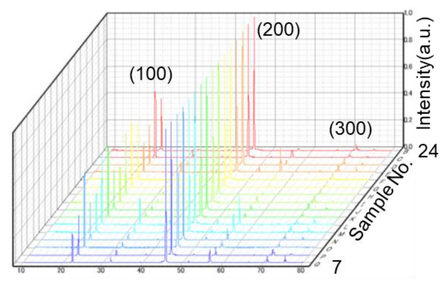


Fig. 4. X-ray diffraction patterns obtained from the TlBr crystals.

(μτ) for electrons

	1.1E-04	2.5E-04	2.3E-04	1.6E-04
ND	ND	3.3E-04	1.8E-04	1.4E-04
	ND	2.4E-04	2.7E-04	3.3E-04
	ND	2.4E-04	3.9E-04	

(μτ) for holes

	ND	5.8E-05	7.9E-05	ND
ND	ND	ND	1.3E-04	9.0E-05
	ND	6.0E-05	7.2E-05	9.9E-05
	ND	ND	8.4E-05	

Fig. 5. Variation of charge transport properties in the TlBr wafer.

Challenge

Annealing process has been performed to improve uniformity and device characteristics of TlBr gamma-ray detectors.

Annealing process

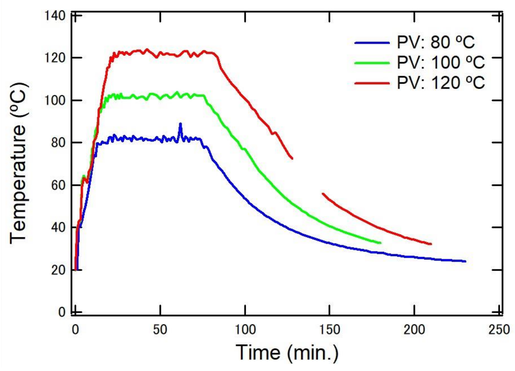


Fig. 6. A furnace used for annealing process and temperature profiles.

TlBr crystals (thickness: 1.5 mm)

Strain observation

^{137}Cs energy spectrum response

Polishing(#4000,Al_2O_3 0.3μm,Al_2O_3 0.05μm)

Strain observation

X-ray diffraction

Annealing (N_2 atmosphere) : 80℃,150℃,200℃,225℃, 250℃,300℃,350℃

Strain observation

X-ray diffraction

^{137}Cs energy spectrum response

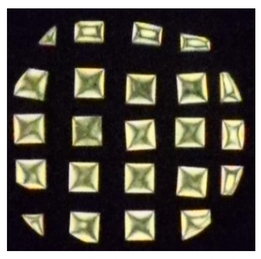


Fig. 7. Strain images of TlBr crystals before annealing.

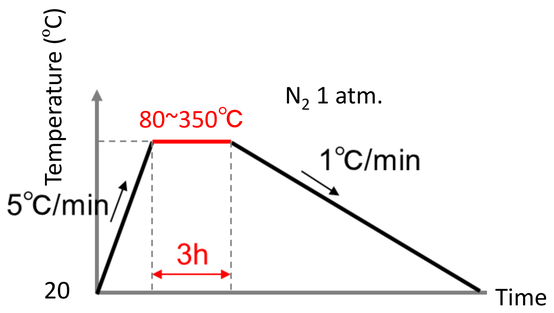


Fig. 8. Experiment scheme and annealing profile.

Experimental Results

Strain observation

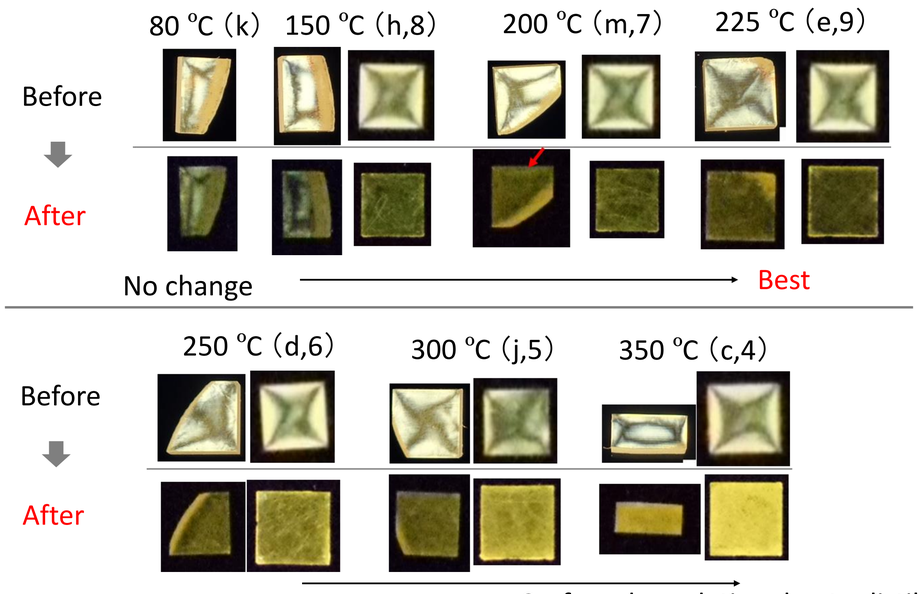
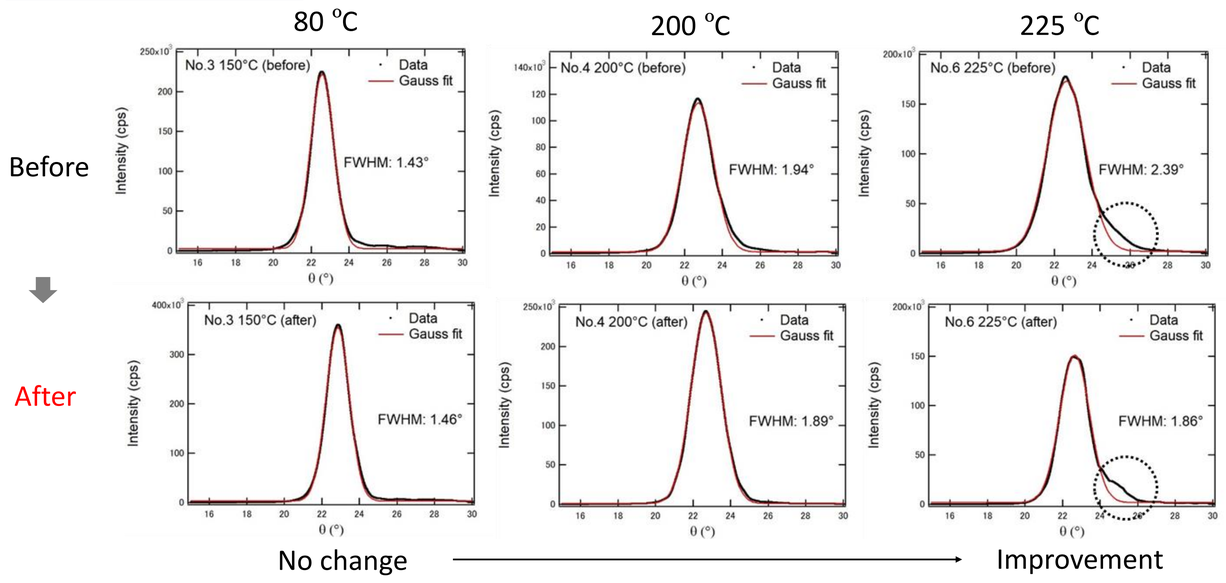


Fig. 9. Results in strain observation of TlBr annealed at 80-350 °C.

Rocking curves



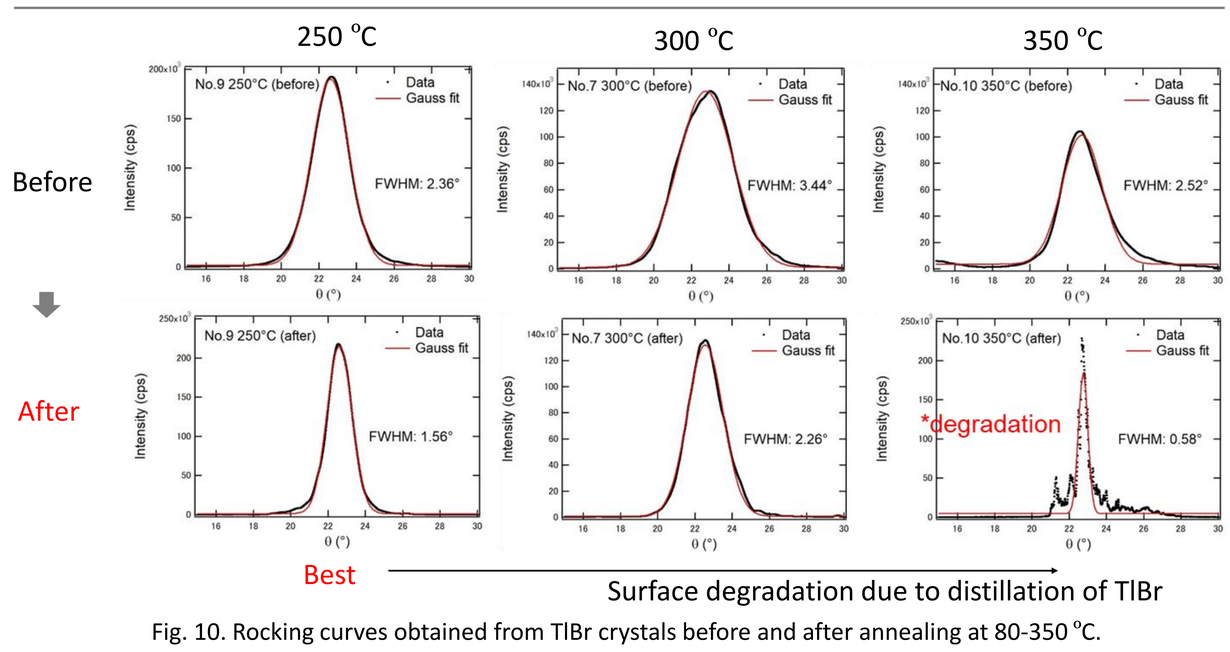


Fig. 10. Rocking curves obtained from TlBr crystals before and after annealing at 80-350 °C.

^{137}Cs gamma-rays energy spectra

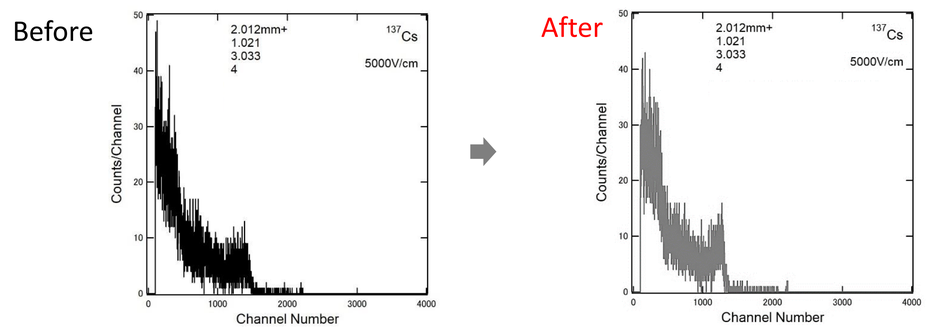


Fig. 11. ^{137}Cs gamma-ray energy spectra obtained from TlBr detectors before and after annealing at 225 °C.

Energy resolution observed in energy spectrum obtained from the TlBr detector slightly improved comparing with the TlBr detector without the annealing.

Conclusions

○Strain inside TlBr crystals have been reduced by annealing at between around 200-225 °C and FWHM of the rocking curves minimized at around same annealing temperature.

○Spectral response characteristics exhibited that annealing temperature at around 225 °C is effective for improving charge transport of TlBr detectors.

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