Crystallographic properties of TlBr crystals grown by the Bridgman method for gamma-ray detectors

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Introduction

Thallium Bromide (TlBr) semiconductor

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

Density 7.56 g/cm³

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

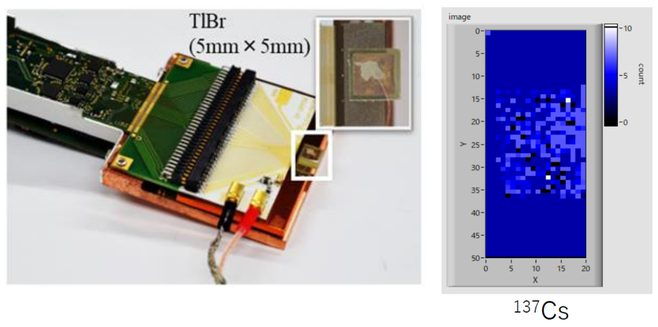
Melting point 460 °C

Phase transition No → Easy to grow

→ Promising material for gamma-ray detectors

Gamma-ray imaging using TlBr

Prototype TlBr imaging detector



^{137}Cs

Fig. 1. Prototype of 2 dimensional imaging detector using a TlBr crystal (5 mm x 5 mm) and obtained image by ^{137}Cs gamma-ray irradiation at JASRI.

Future applications in medical imaging

*1GE Discovery NM/CT670CZT

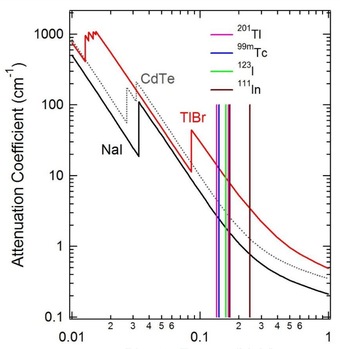


Fig. 2. Linear attenuation coefficient for TlBr and typical detector materials (NaI, CdTe), and gamma-rays energy used in SPECT diagnosis.

*1: GE Healthcare

Challenge

■Large area TlBr wafers at least 2 inch in diameter are necessary for fabrication of Imaging detectors.

■Evaluation systems of crystallographic properties such as crystal orientation distribution, crystallinity and defect in TlBr wafers has to be built to grown high quality TlBr crystals for imaging detectors.

■Crystallographic properties of TlBr wafers have been evaluated by measuring pole figure and rocking curves of TlBr wafers using X-ray a diffractometer (XRD).

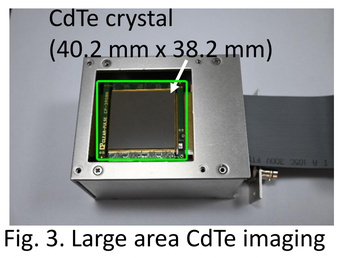


Fig. 3. Large area CdTe imaging detector with ASIC developed at JASRI for X-ray imaging.

Fig. 4. Comparison with size of a CdTe crystal on imaging detector between size of TlBr wafers on experimental sturdy.

Sample and Evaluation system

TlBr crystal

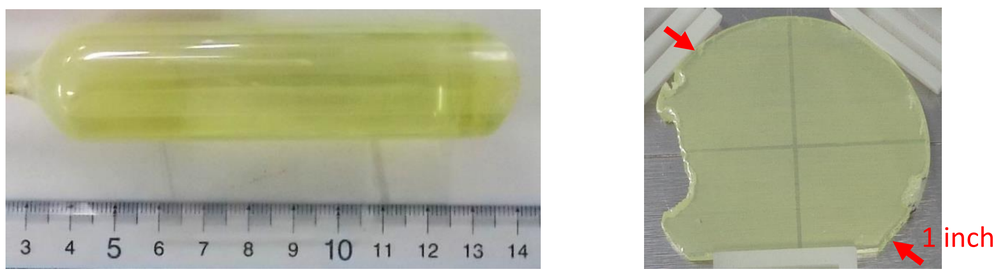


Fig. 5. TlBr crystal (ϕ1 inch) grown by the Bridgman method and a wafer (1.966 mm thick) for crystal evaluation.

XRD

Fig. 6. XRD: Smart Lab SE (Rigaku Co.)

■X-ray : Cu Kα
■Voltage: 40kV
■Current: 50mA

Pole figure measurement

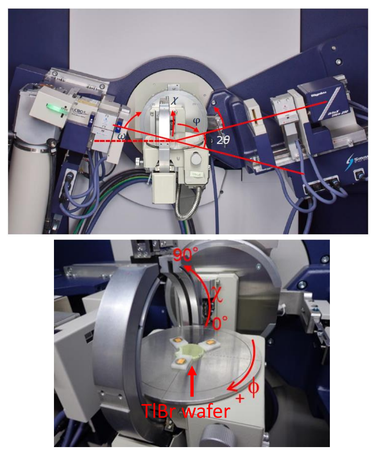


Fig. 7. χϕ attachment for pole figure measurement.

■Range : α=15° ～45°
78° ～90°
β=0～360°
■Scan step(α,β): 1°
■Scan speed (β): 300° /min
■Divergence slit : 0.4mm
■Receive slit : 20mm
■2θ: 31.74° TlBr(110)

Rocking curve measurement

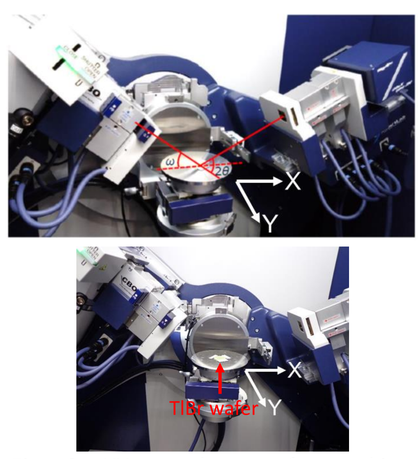


Fig. 8. XY attachment for rocking curve measurement.

■Range : ω=36.5° ～44.5°
■Scan step(ω): 0.04°
■Scan speed (ω): 15° /min
■Divergence slit : 1mm
■Receive slit : 1mm
■2θ: 66.28° TlBr(220)

Results

Pole figure measurement

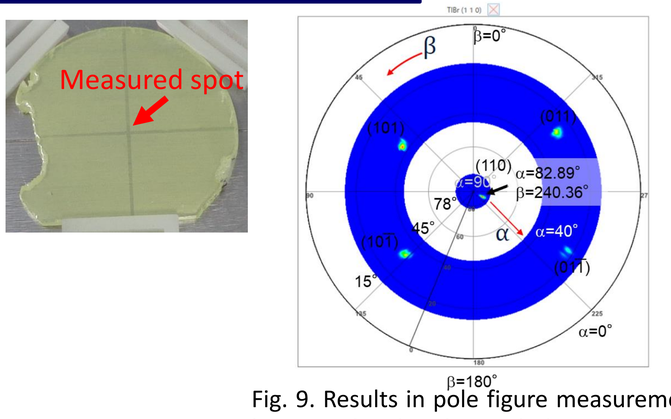


Fig. 9. Results in pole figure measurement of a center of TlBr wafer and estimated gap between (110) and growth direction.

Rocking curves

Sample setting

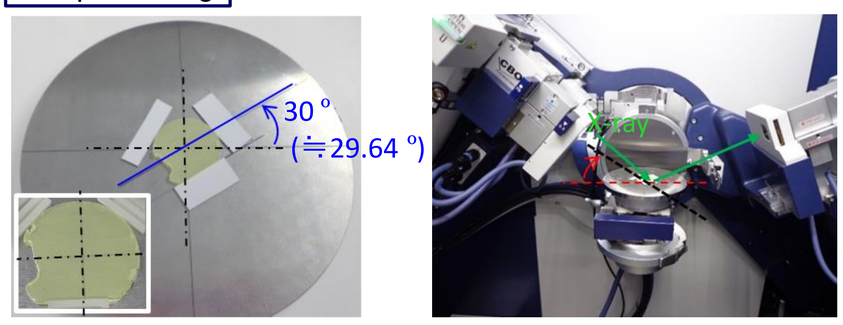


Fig. 10. Position of TlBr wafer position for rocking curve measurement adjusted by using results on pole figure measurements (α=7.11° , β=240.64°) .

Rocking curves

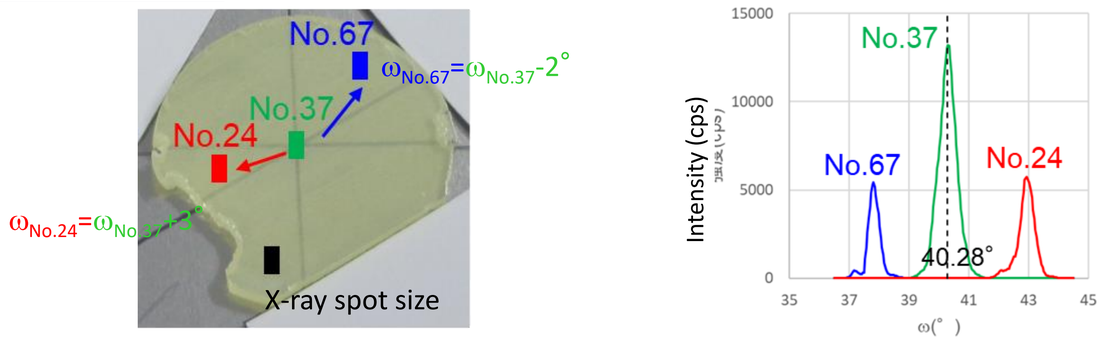


Fig. 11. Diffract peak position at each areas and estimated angle of (220) planes relative to (220) plane at center of the TlBr wafer.

(220) Rocking curves of 1 inch TlBr wafer

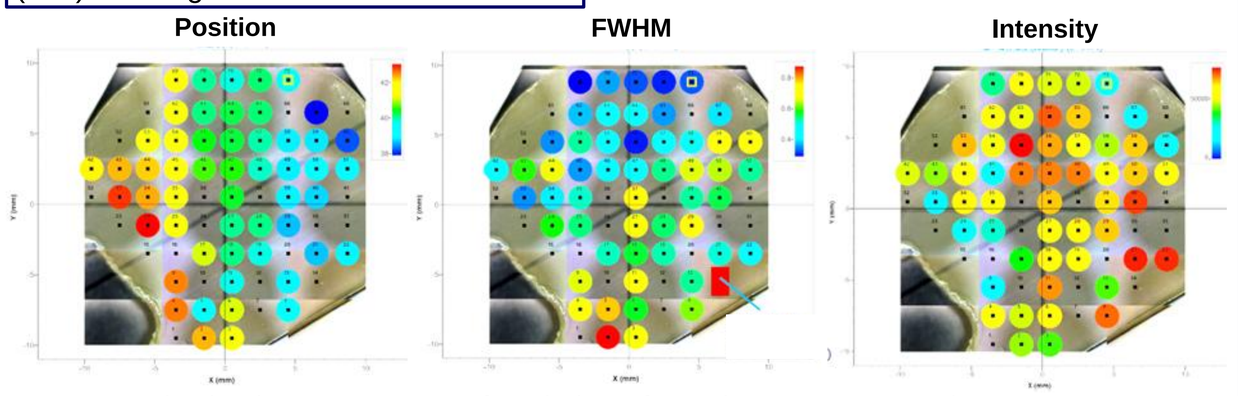


Fig. 12. (200) rocking curve mapping of 1 inch TlBr wafer: peak position, FWHM and intensity.

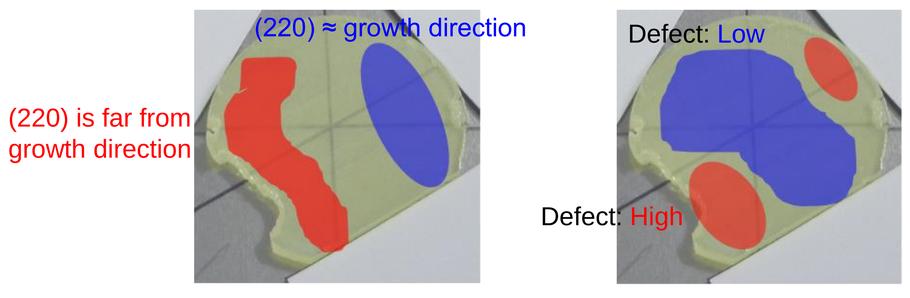


Fig. 13. Crystallographic properties of TlBr wafer estimated from results on rocking curve measurements.

Conclusions

○Pole figure measurement and rocking curve measurements were carried out using XRD and crystallinity of 1 inch TlBr wafer was evaluated.

○This study demonstrated that the crystallographic properties of TlBr wafer can be evaluated by combining the both measurements using XRD.

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