Orientation Cutting of TlBr Crystals via Pole Figure Measurements for Gamma-Ray Detector Fabrication

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Introduction

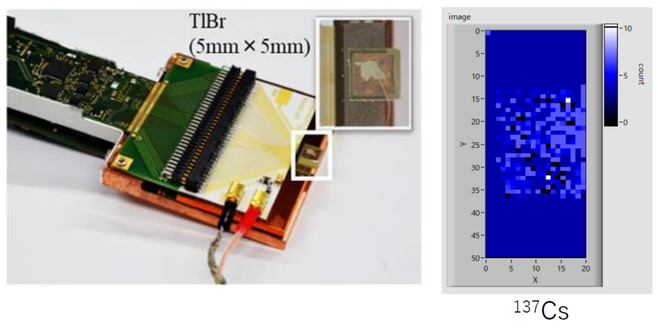
Thallium Bromide (TlBr) semiconductor

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

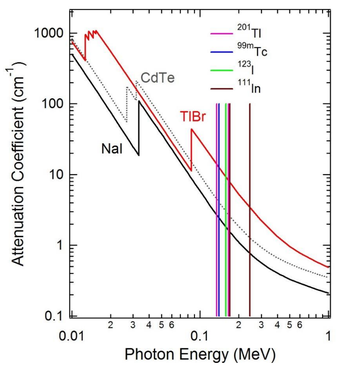


Fig. 2. Linear attenuation coefficient for TlBr and typical detector materials (NaI, CdTe), and gamma-rays energy used in SPECT diagnosis.
*1: GE Healthcare

Challenges in TlBr detector fabrication

Dependence of detector performance on TlBr crystal orientation remains unresolved.
In this study, we aimed to establish a technique for slicing TlBr wafers with specified crystallographic orientations from ingots, using pole figure measurements, and to evaluate detector performance for each orientation.

■Experiment 1: Crystallographic characterization by pole figure measurements
■Experiment 2: Slicing TlBr wafers with (100), (111), and (110) orientations.

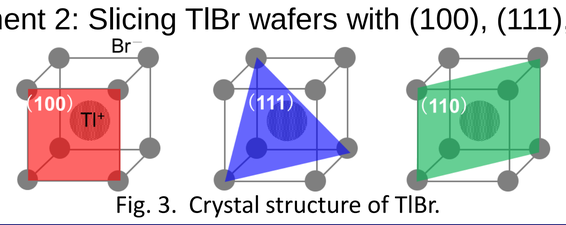


Fig. 3. Crystal structure of TlBr.

Exp.1:Pole figure measurements

TlBr crystal

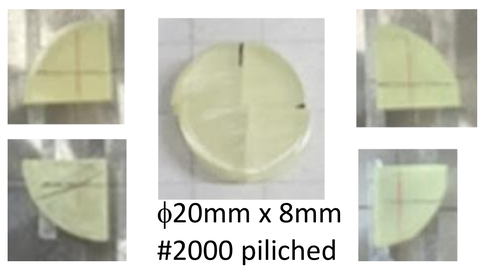


Fig. 4. TlBr crystal (ϕ 20mm x8 mm thick) for pole figure measurements.

Experimental procedure

Pole figure measurements
↓
The misorientation angle between the crystal normal and the intended orientation (Δα=90° -α)

Δα<~40° → Slicing along the tilt direction of lattice plane (hkl) → #2000 polishing → Pole figure measurements for sliced wafers

Δα>~40° → Pre-slicing nearly parallel to the plane (hkl) → Pole figure measurements

(100) pole-figure measurements for a starting wafer

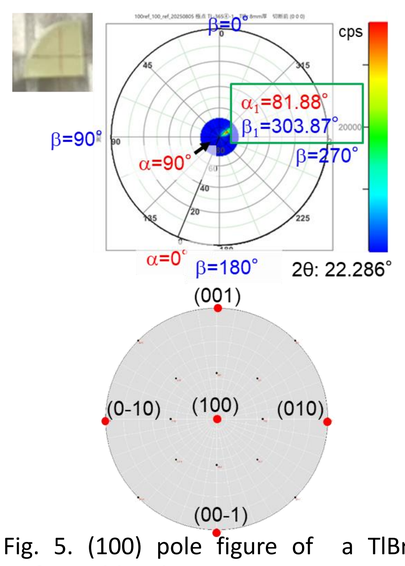


Fig. 5. (100) pole figure of a TlBr wafer and (100) Laue pattern.

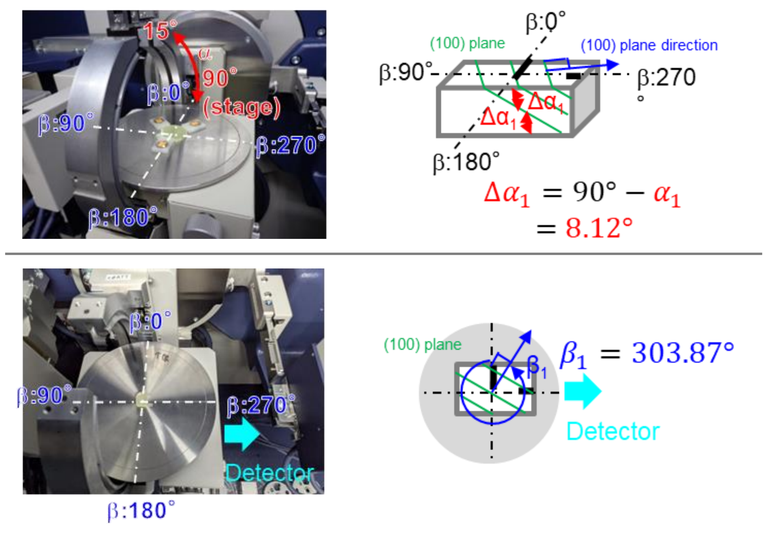
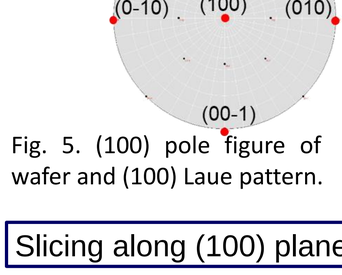


Fig. 6. The tilt direction and angle of the (100) plane.

Slicing along (100) plane



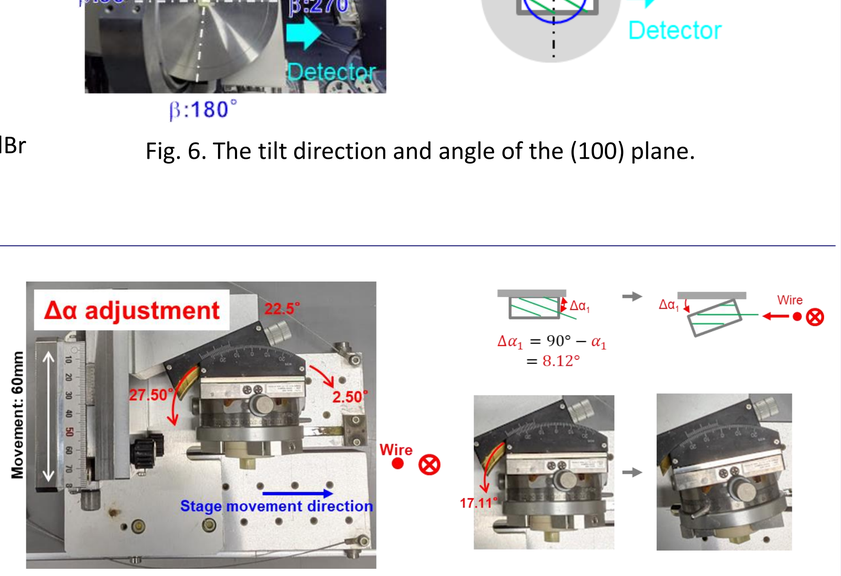
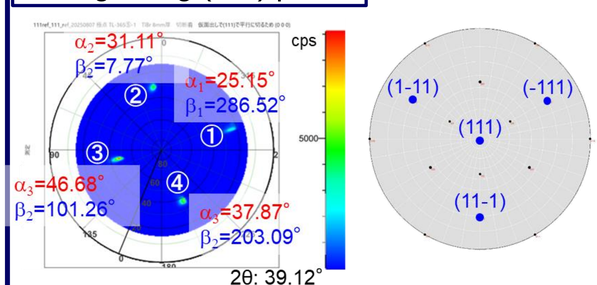


Fig. 7. Diamond wire saw used in this study and the method for adjusting Δα and Δβ angle along the (100) plane.

Slicing along (111) plane



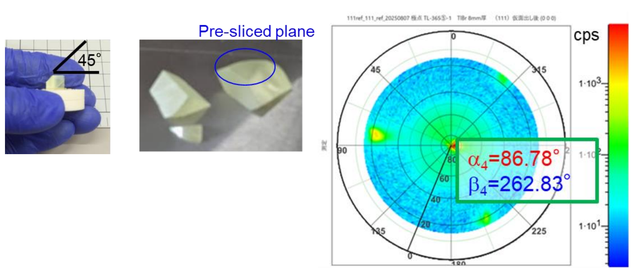


Fig. 9. (111) pole figure of a TlBr wafer, pre-sliced a wafer and (111) Laue pattern.

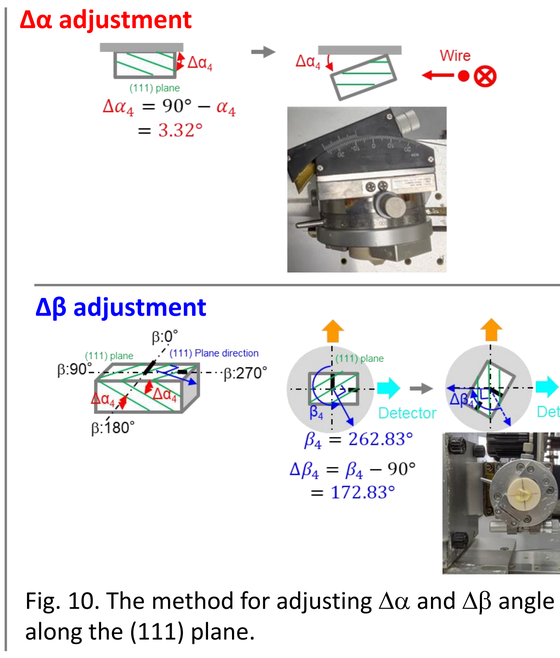


Fig. 10. The method for adjusting Δα and Δβ angle along the (111) plane.

Slicing along (110) plane

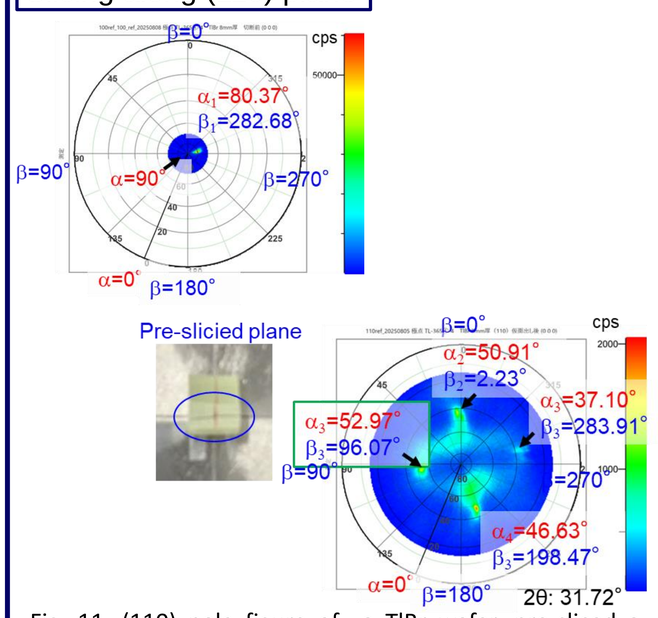


Fig. 11. (110) pole figure of a TlBr wafer, pre-sliced a wafer and (110) Laue pattern.

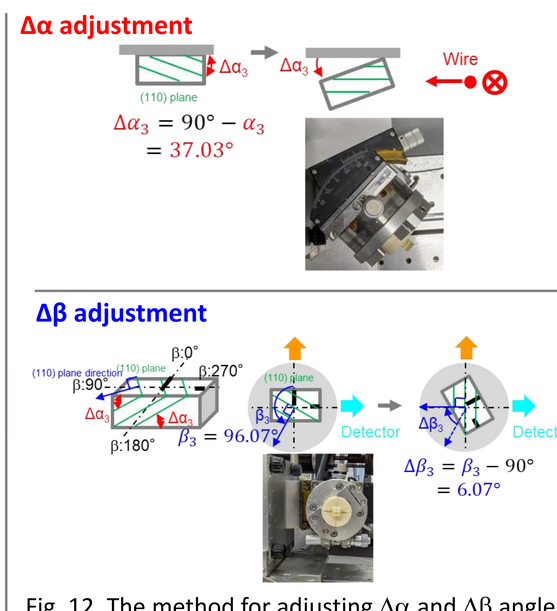


Fig. 12. The method for adjusting Δα and Δβ angle along the (110) plane.

Results on orientation cutting

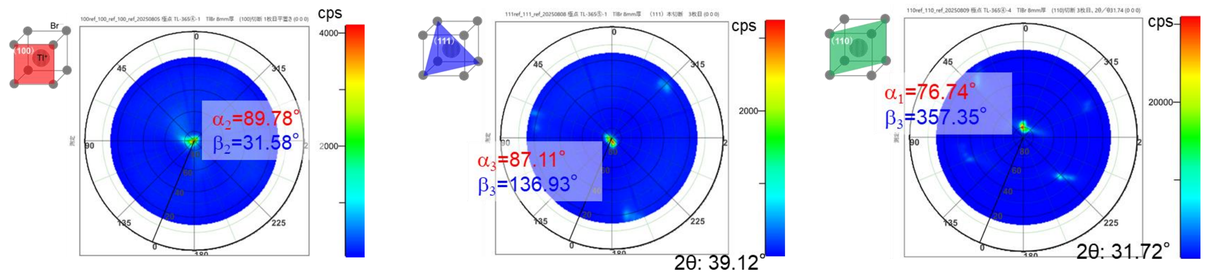


Fig. 12. Pole-figure measurement after the (100), (111) and (110) slicing.

Conclusions

○By using pole-figure measurements and the respective plane orientations, we successfully cut three TlBr wafers with (100), (111) and (110) orientations from a single ingot.
○The deviation from the target orientation is considered to be caused by wire deflection during cutting of the tilted plane.

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