Thallium bromide crystals formed by the hot press mold technique for flat panel gamma-ray detectors

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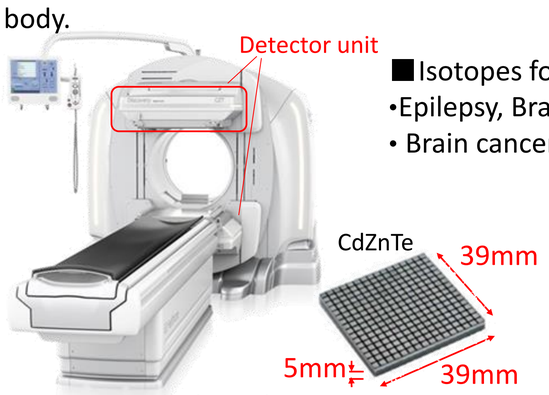
Introduction

SPECT(Single photon emission CT)

SPECT is an attractive nuclear medical device using gamma-rays emitting from drags accompanying isotopes and is helpful for diagnosis of brain diseases and cardiac diseases. In order to obtain isotope distribution showing physiology, gamma-ray detectors with multi-pixel electrodes are used for acquiring gamma-ray energy spectra of induced isotope in patient body.



■Isotopes for SPECT:
•Epilepsy, Brain infarction and Dementia (^{123}I)
• Brain cancer (^{201m}Tc)

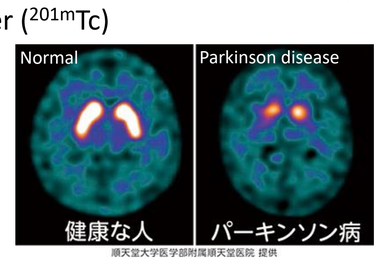


Fig.1. SPECT and CdZnTe detector (GE Discovery NM/CT670CZT)

Fig.2. Brain diagnosis images.

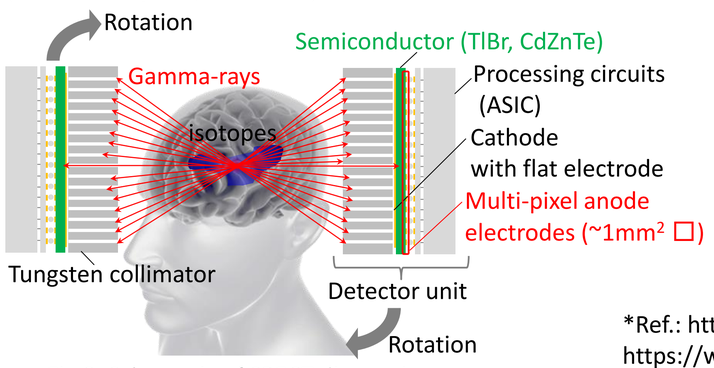


Fig.3. Schematic of SPECT diagnosis.

*Ref.: https://www.crystran.co.uk/
https://www.surfacenet.de/
https://monozukuri.sqcd-aid.com/

Advantage of TlBr for SPECT

Due to high atomic number and high density, TlBr has higher absorption than CdZnTe or NaI for high energy gamma-rays from the isotopes used in SPECT.

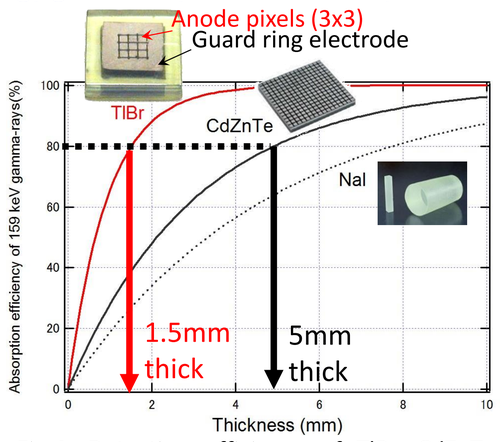


Fig.4. Detection efficiency of TlBr, CdZnTe and NaI for gamma-rays (^{123}I, 159 keV) used in SPECT diagnosis.

Hardness for TlBr crystals

TlBr is seems to be plastic nature and easy to change their shapes by low pressure.

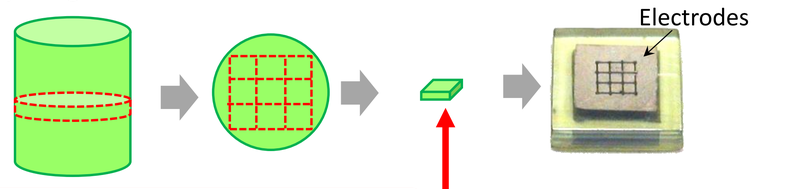
Table 1. Material hardness for TlBr, CdTe and common examples.

Material	*Knoop hardness (kg/mm²)	Examples
TlBr	**12**	Nail – Lead
CdTe	54	
Quarltz	820	

Detector fabrication procedure

Previous procedure

【Crystal growth】 【Cutting】 【Polishing】 【Electrode formation】



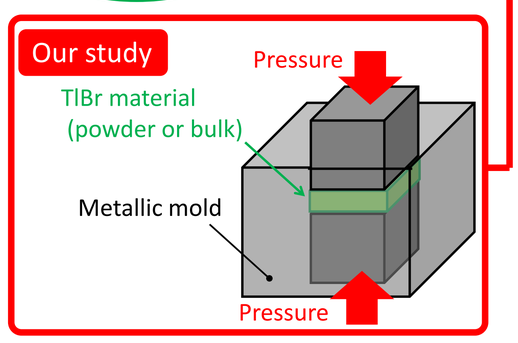


Fig.5. Fabrication procedure for typical semiconductor detectors and new fabrication method performed in our laboratory.

- TlBr crystal ingots are necessary for flat detector production in the typical semiconductor device procedure.
- TlBr bulk crystals with flat panel shape may be easily formed by the press mold technique.

Challenge

TlBr gamma-ray detectors have been fabricated from TlBr bulk materials made by the press mold technique, and their crystallinity and device characterization were evaluated.

Press mold technique

TlBr powder
↓
Zone refining method
↓
Forming ingots using purified TlBr
↓
Cutting(15mmϕ x 4.5mm)
↓
Chemical etching
↓
Press mold (450~500 ℃, 50kN, ~1Pa)

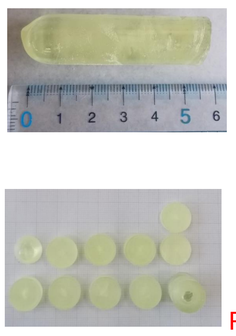


Fig.6. Experiment procedure.

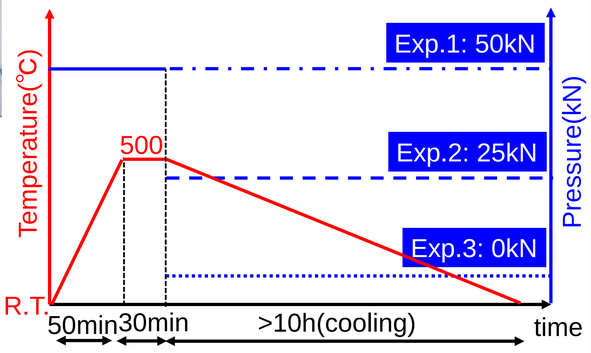
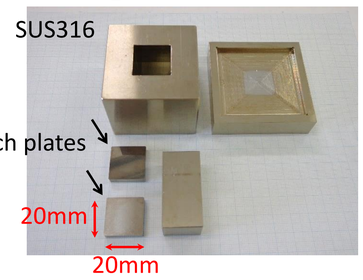
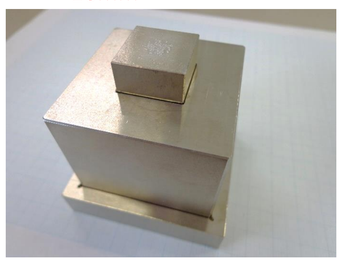
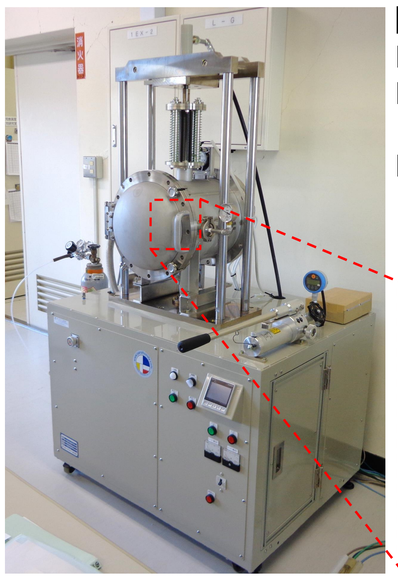


Fig.7. Experiment condition.

【Metal molds】







【SPEC】
■Press power: 50 kN
■Atmosphere: vacuum
Ar, N_2
■Furnace: max 600℃

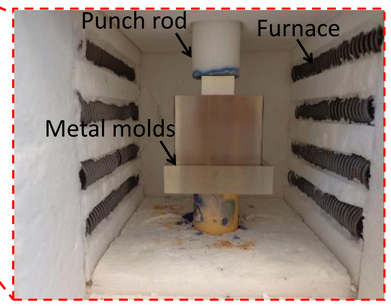


Fig.8. Overview of metal molds and press machine used in this study.

TlBr crystals formed by the press mold technique

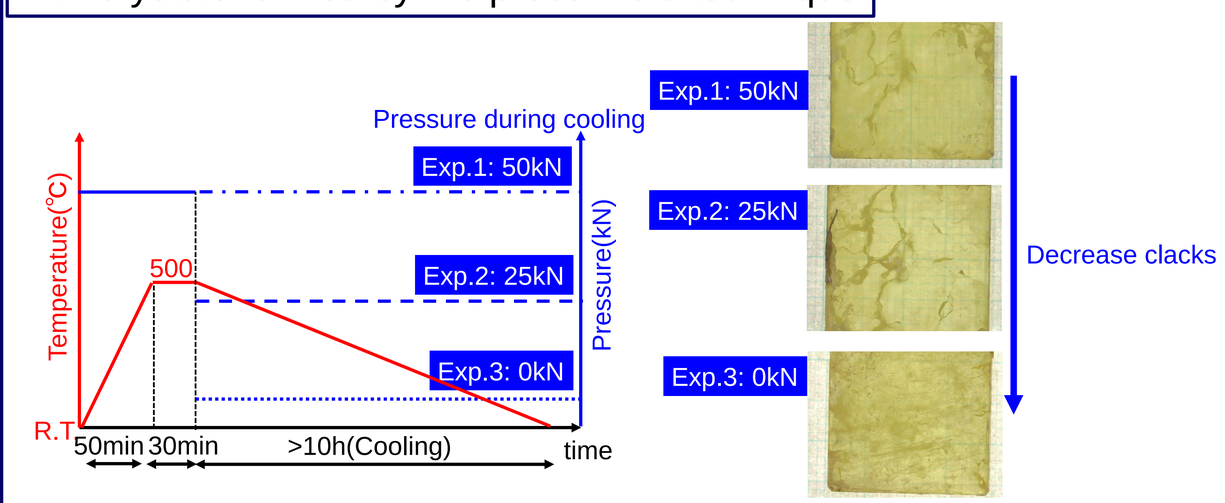


Fig.9. A photograph of molded TlBr (20 mm x 20 mm x 2 mm) and clacks observed in TlBr crystals.

Evaluations

X-ray diffraction and EBSD

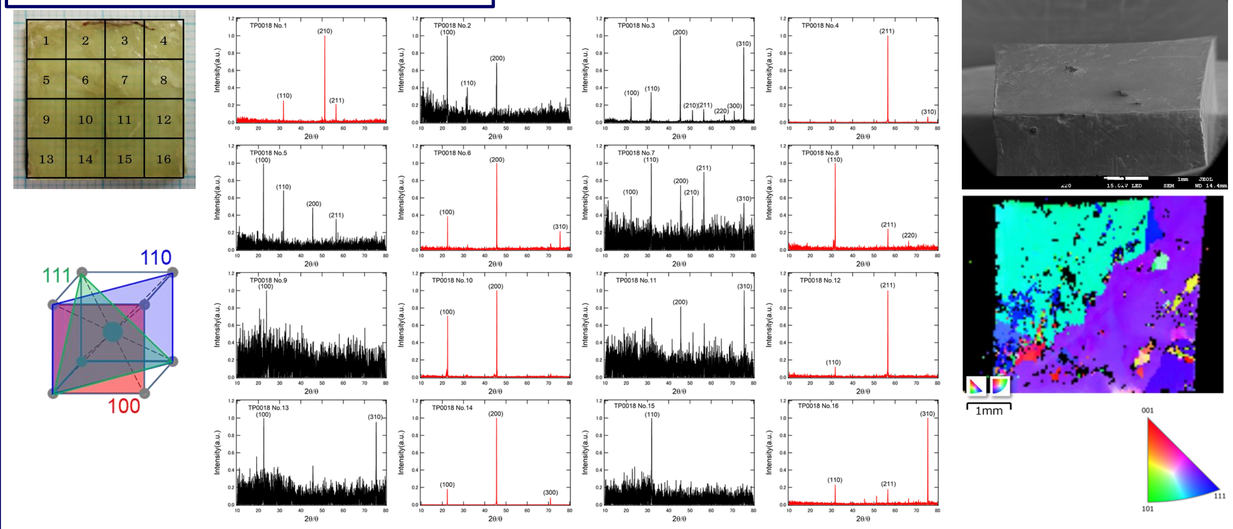
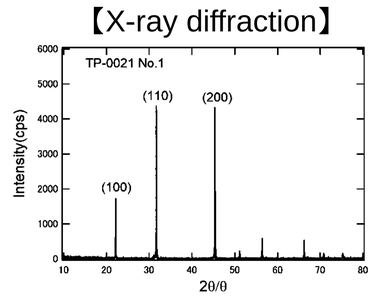


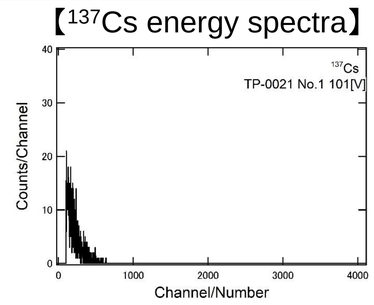
Fig. 10. X-ray diffraction patterns and electron back scatter diffraction (EBSD) mapping obtained from each TlBr crystals (5 mm x 5mm) in the press molded TlBr crystals.

Crystallinity and gamma-ray (^{137}Cs) response characteristics

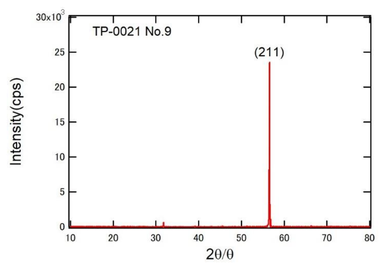
【X-ray diffraction】 【^{137}Cs energy spectra】

Polycrystal TlBr





Oriented TlBr



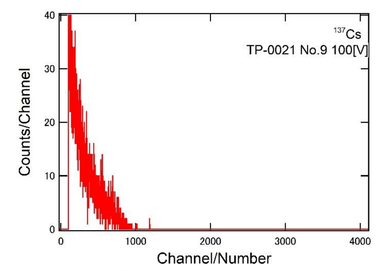


Fig. 11. X-ray diffraction patterns obtained from TlBr crystals (5 mm x 5 mm x 2mm) cut from polycrystal domain and oriented domain in the press molded TlBr.

Fig. 12. ^{137}Cs gamma-ray energy spectra at the same electric fields obtained from TlBr detectors fabricated from oriented domain in the press molded TlBr.

Conclusions

○Cracks in the press molded TlBr suppressed by the decreasing the pressure after the mold temperature.

○Press molded TlBr contained multiple orientation and some domain seems to be single orientation. However, their crystallinity shown in this TlBr are not enough to realize gamma-ray spectrometers.

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