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Investigation of Charge Transport Properties of CdZnTe Detectors with Synchrotron X-ray Radiation

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Introduction

Various internal defects, such as Te inclusions, twin boundaries, dislocation, etc., are prevalent in as-grown CdZnTe (CZT) crystals, which affect the charge transport properties of CZT crystals and, therefore, worsen the performance of CZT detectors. In order to develop high quality CZT detectors, it is imperative to clarify the effects of internal defects on the charge transport properties of CZT. Simple flood illumination with nuclear radiation source cannot reveal the nature of highly localized defects in CZT. Therefore, at Brookhaven's National Synchrotron Light Source (NSLS), we have developed a unique testing system for micro-scale defect investigation of CZT, which employs an X-ray beam collimated with the spatial resolution as small as 3x3 μm^2, a microscopic size comparable to the scale of common defects in CZT. This powerful tool enables us to investigate the effect of internal defects on charge transport properties of CZT in detail.

Experiment

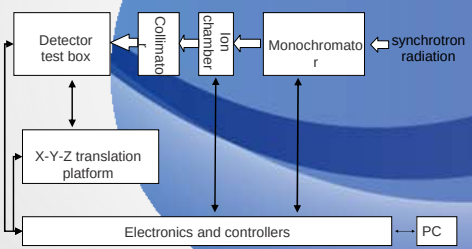
CZT detector Preparation

- CZT crystals mechanically polished with Al_2O_3 suspension
- 5% bromine in methanol (Br–MeOH) for removing the mechanically-damaged layer
- Electroless deposition for Au-CZT contact preparation

X-Ray Mapping System At Brookhaven's National Synchrotron Light Source (NSLS)

System layout

Schematic Diagram



Results and discussion

Te inclusions and charge trapping properties of CZT

IR transmission image. (2.0mm ×1.5mm) The IR light was focused on the surface.

Electron collection X-ray map (2.0mm ×1.5mm) 23keV, 120V

Hole collection X-ray map (2.0mm ×1.5mm) 23keV, -220V

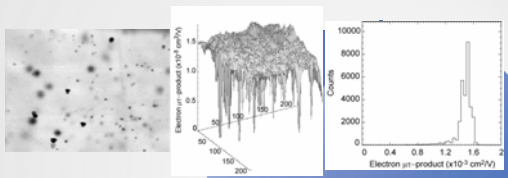
- Charge trapping regions in X-ray response maps correspond precisely to the locations of Te inclusions in the IR transmission image
- Electron collection: Electrons go through the whole wafer due to their high mu-tau-product. Distinct charge trapping regions coincide with Te inclusions ~100 μm below the surfaces of CZT wafer. "Fuzzy" charge trapping regions represent inclusions deeper in the bulk.
- Hole collection: Holes travel in short distances due to their low mu-tau-product. Consequently only Te inclusions near surface are revealed by holes

Twin boundaries and charge trapping properties of CZT

(a) optical photograph (1.25mm ×0.5mm)
(b) hole collection X-ray mapping (1.25mm ×0.5mm): 28keV, -200V
(c) electron collection X-ray mapping (1.25mm ×0.5mm): 28keV, 100V

- These images illustrate charge trapping due to twin boundaries.
- Holes, in comparison to electrons, reveal much clearer trapping defects related to twin boundaries

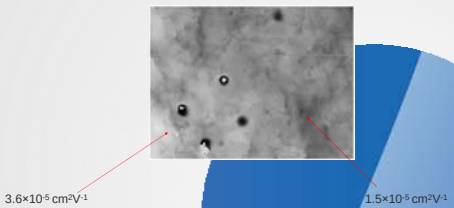
Electron mu-tau-product evaluation



μτ map (2D) μτ map (3D) μτ distribution

The average mu-tau-product of electrons is at the level of 10^{-3} cm^2/V

Hole mu-tau map



The average mu-tau-product of holes for the entire area is 2.0×10^{-5} cm^2V^{-1}

Conclusion

- Te inclusions and twin boundaries are related to the trapping of electrons and holes.
- Hole collection X-ray mapping reveals clearer trapping defects related to twin boundaries
- The electron mu-tau-product of measured wafer is at the level of 10^{-3} cm^2/V
- The hole mu-tau-product of the measured wafer is at the level of 10^{-5} cm^2/V

Ongoing work

Clarifying the effects of dislocations on the charge transport properties of CZT

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