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Characterization of Detector-Grade CdTeSe Crystals

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Characterization of Detector-Grade $CdTe_{0.9}Se_{0.1}$ Crystals

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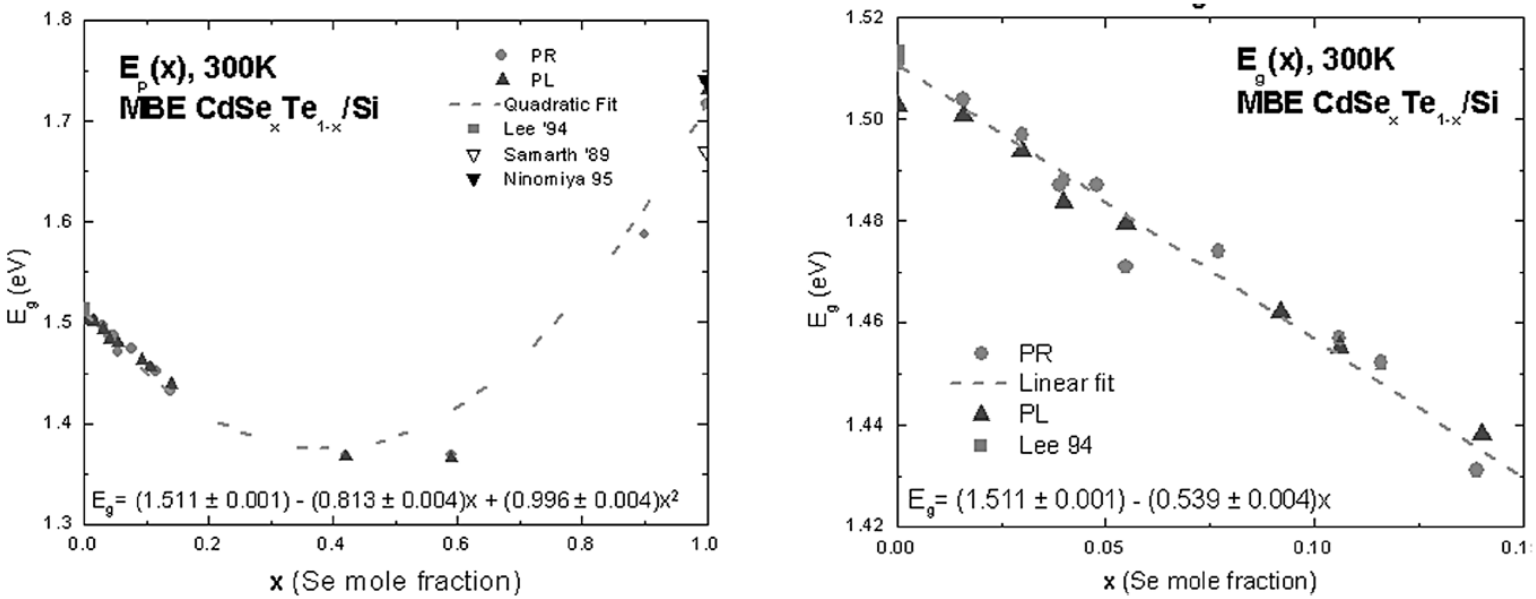
Introduction

- $CdTe_{0.9}Se_{0.1}$ (CTS) is expected to be an excellent candidate for gamma-ray detectors
- Density is ~ 5.8 gm/cc (nearly the same as CZT and CdTe).
- Band gap is little less than CdTe, and the effective mass of the electron is less than CdTe. Thus, a higher electron mobility and $\mu\tau$ product are expected for $CdTe_{0.9}Se_{0.1}$. Hence, enhanced charge transport properties are possible.
- The segregation coefficient of Se in the CdTe host is nearly unity, ensuring the compositional uniformity throughout the whole ingot, both in the axial and radial directions resulting in reduced cost of production.

Band Gap Versus Composition

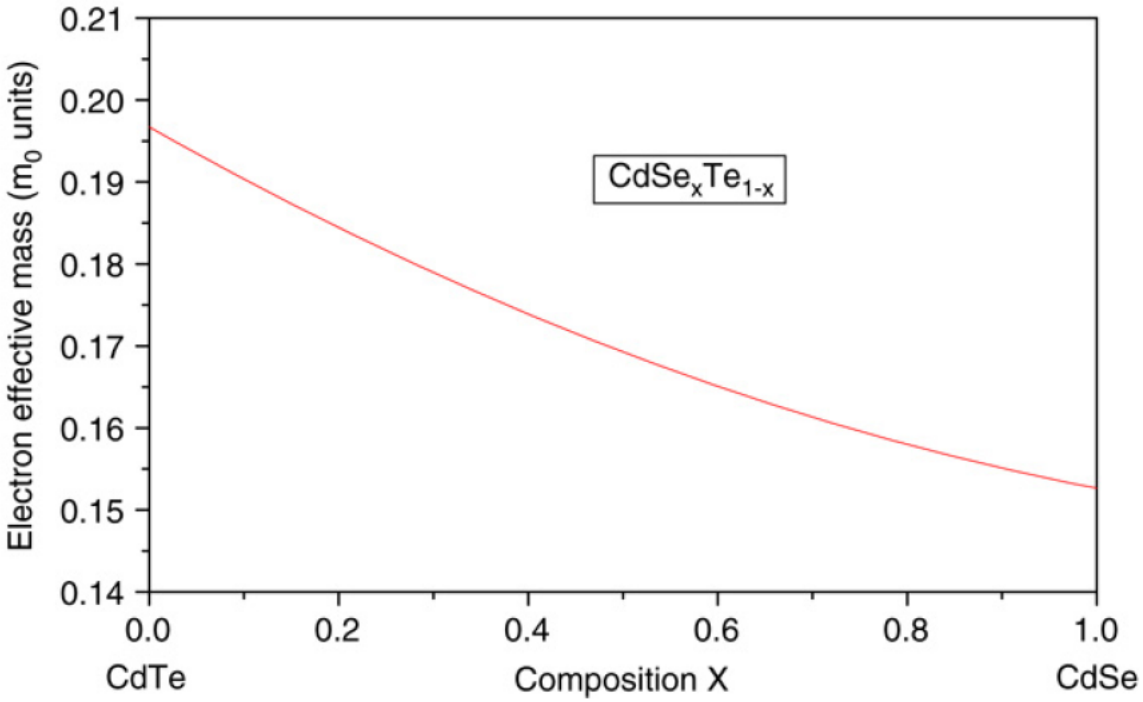


a **b**

$CdSe_xTe_{1-x}$ band gap value as a function of x. a) x= 0 to 1 and b) = 0 to 0.15

G. Brill et al., J Electronic Materials 34 (2005) 655.

Electron Effective Mass Versus Composition



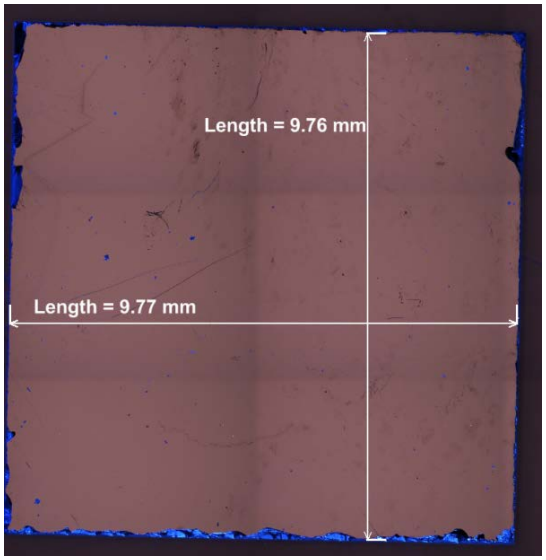
Electron effective mass for $CdSe_xTe_{1-x}$ as a function of x

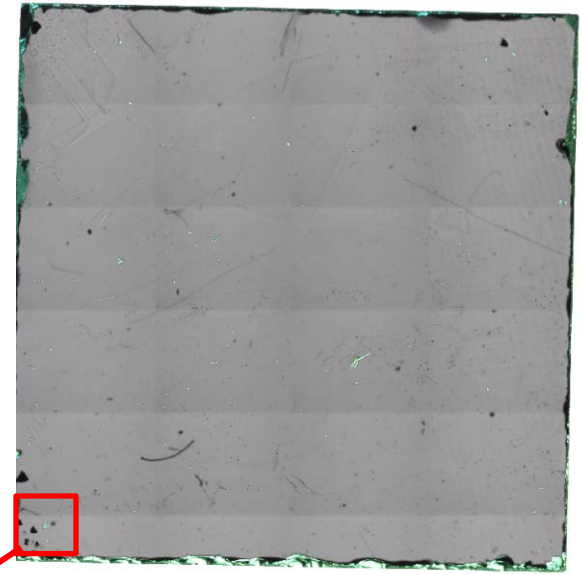
L. Hannachi et al., Superlattices and Microstructure 44 (2008) 794.

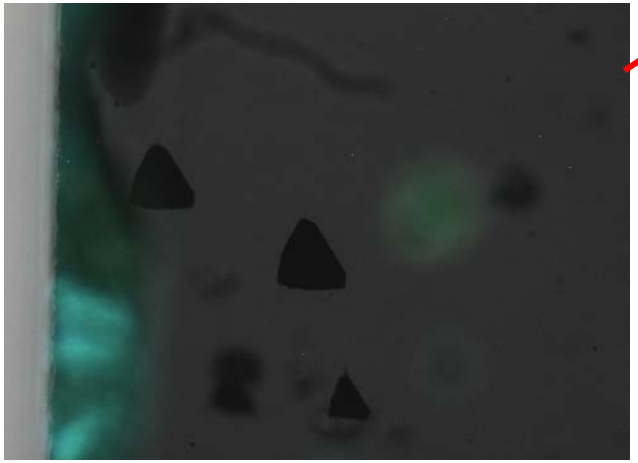
Characterization of $CdTe_{0.9}Se_{0.1}$

- Cadmium Telluride Selenide crystals ($CdSe_xTe_{1-x}$ or CTS) were grown with nominal concentration of 10% Se (x =0.1).
- Indium was used as dopant.
- Crystals were cut and polished for characterization.
- The crystals were characterized by X-ray topography, IR microscopy, compositional uniformity by X-ray fluorescence mapping, PL, high resolution X-ray response mapping, I-V, and charge-transport characterization.
- Detector fabrication and investigations of the device performance.

IR Imaging of $CdTe_{0.9}Se_{0.1}$

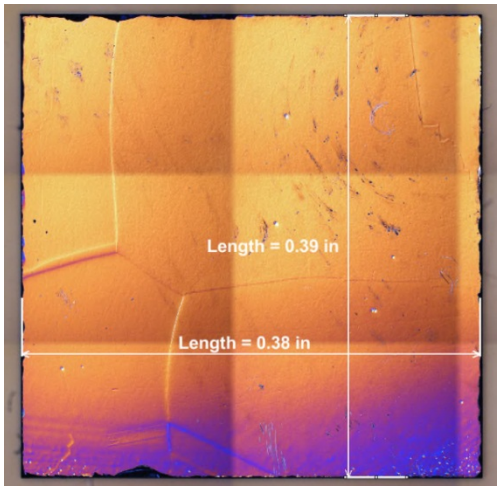


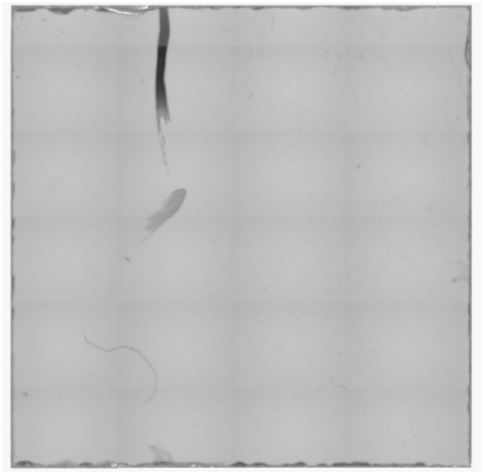


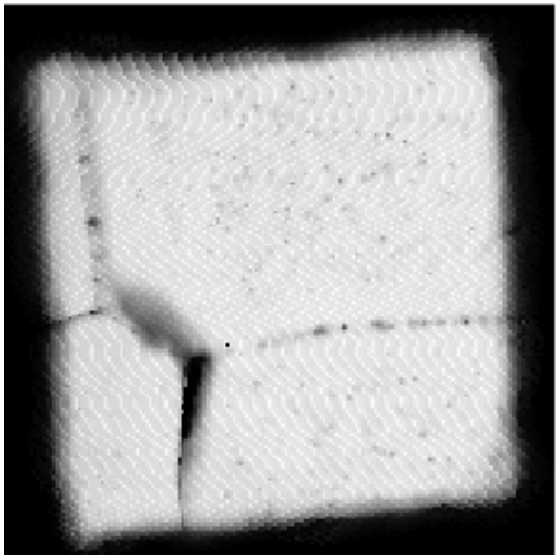


Photograph of $CdTe_{0.9}Se_{0.1}$ sample and IR transmission image of dimension 10x10x5 mm^3

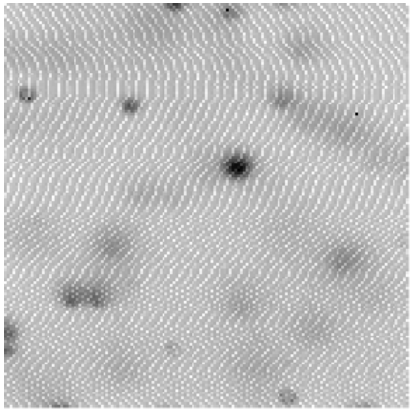
X-Ray Response Mapping and Topography



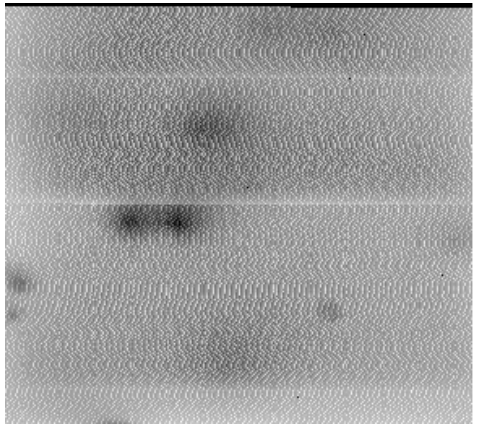




10 x 10 mm^2 area; V = 15V; 50 µm step



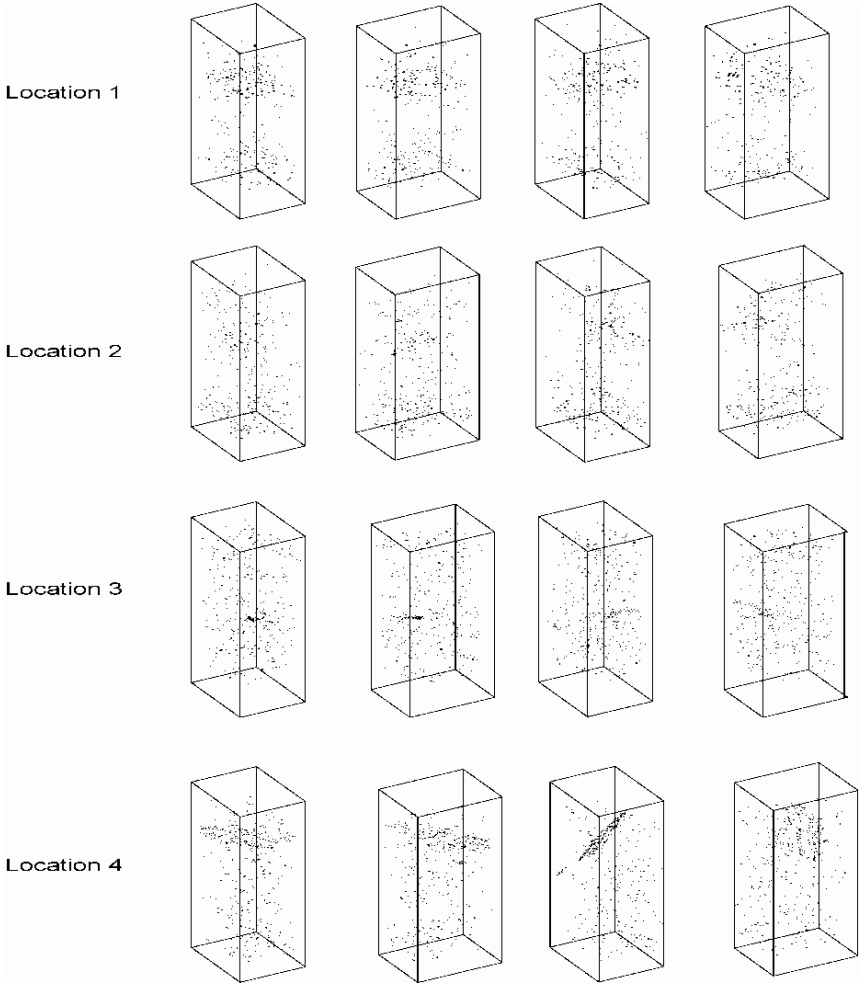
1.5 x 1.5 mm^2 area; V = 15V; 10 µm step



0.9 x 0.9 mm^2 area; V = 15V; 3 µm step

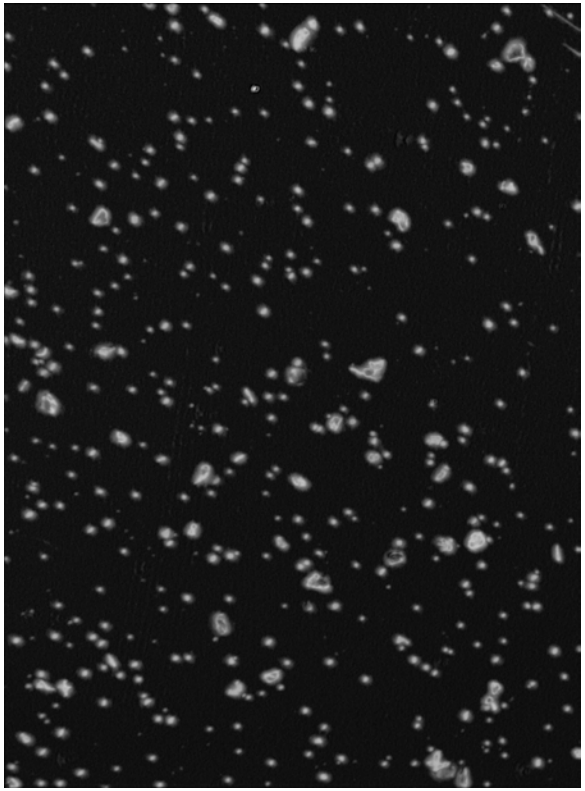
X-ray response mapping of $CdTe_{0.9}Se_{0.1}$ sample, dimension 10x10x5 mm^3

3D Distribution of Secondary Phases

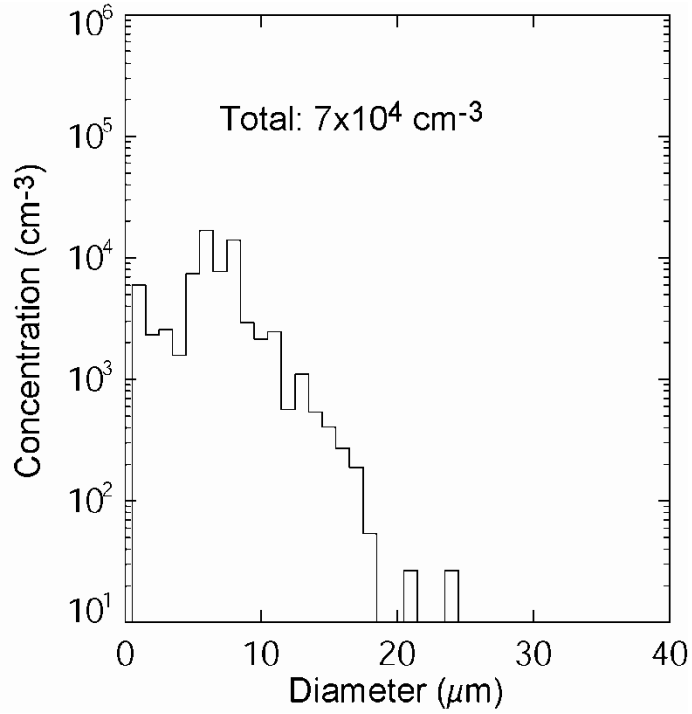


3D maps of Te inclusions reconstructed for 4 locations. The volumetric regions dimension are 1.5x2x 5 mm^3.

Size and Distribution of Secondary Phases

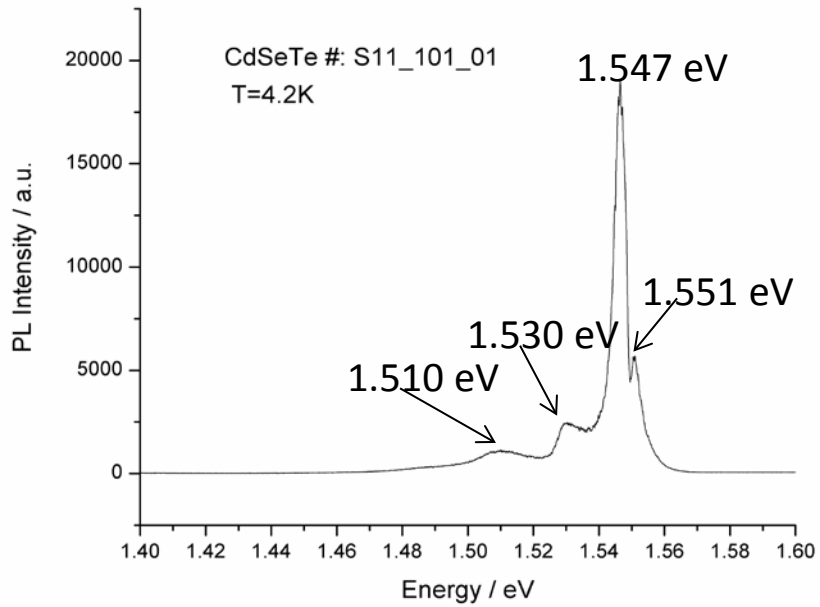


All Te inclusions in a 1.5x2x5 mm^3 volumetric region are projected to a single 1.5x2 mm^2 plane



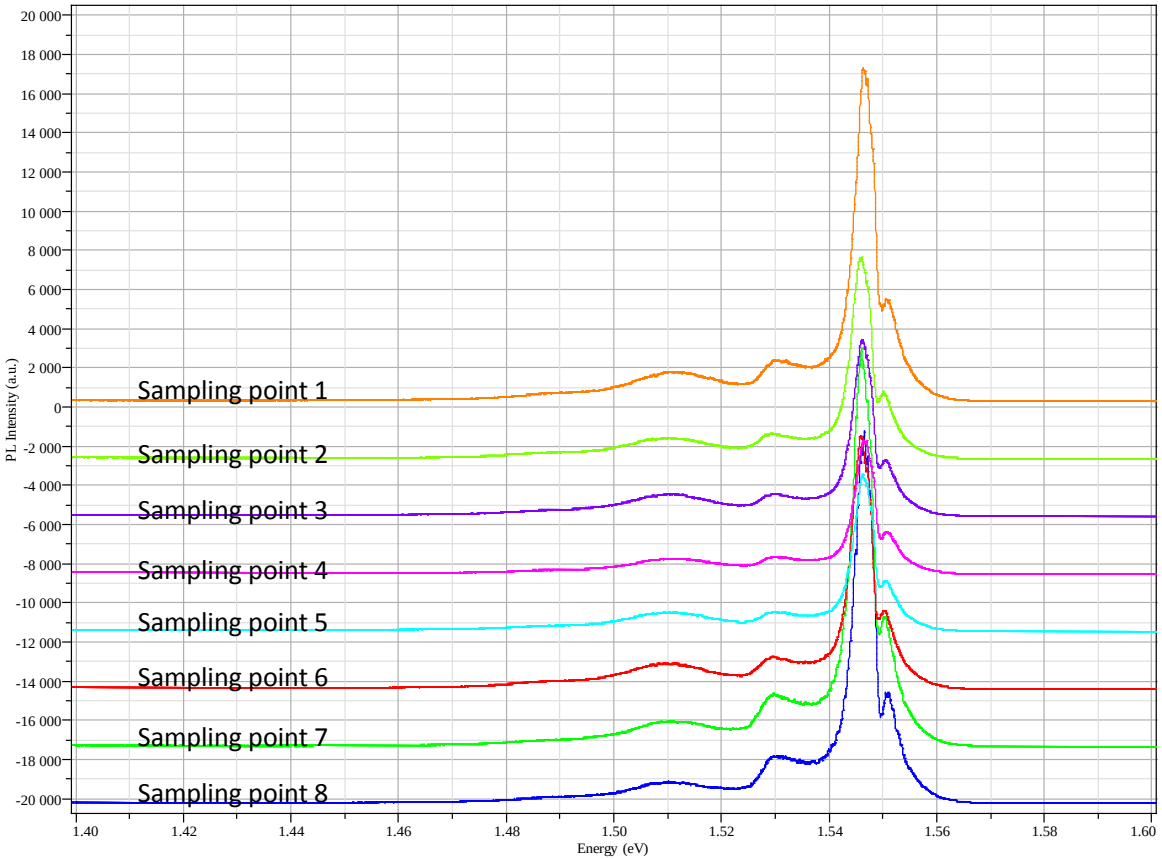
Distribution of the Te inclusions averaged over 4 locations

Low-Temperature PL



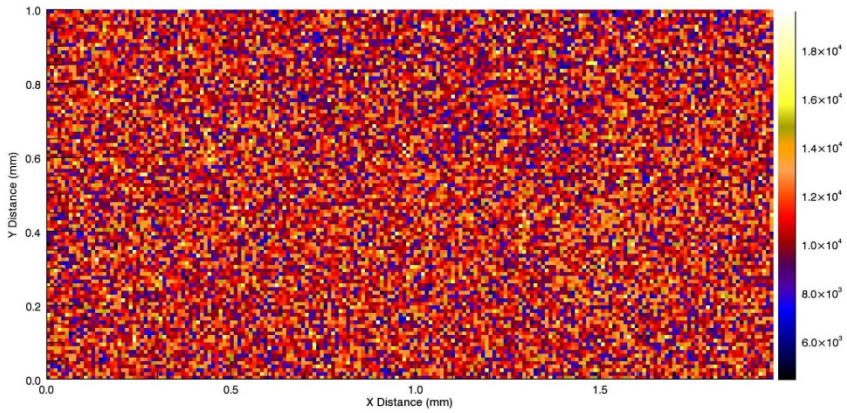
PL spectrum of a $CdTe_{0.9}Se_{0.1}$ sample at 4.2 K

PL Mapping

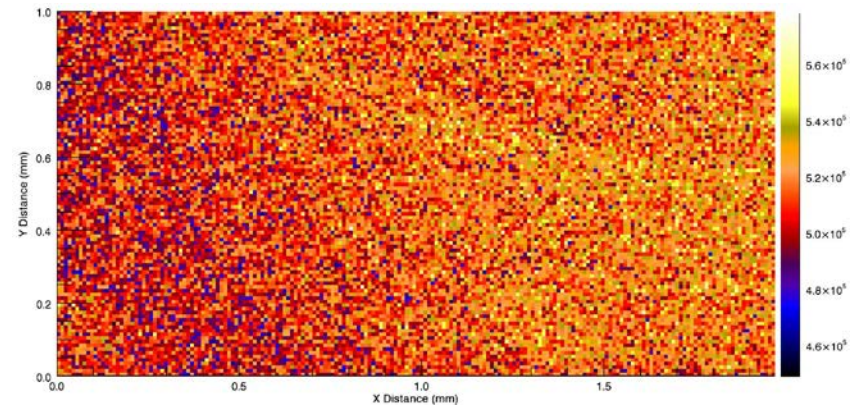


PL spectra from different sampling points across the surface

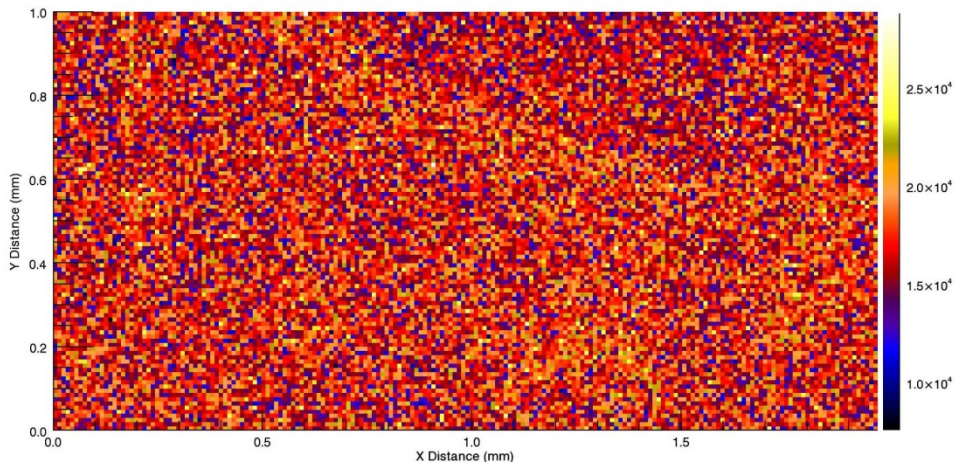
X-ray Fluorescence Mapping



Mapping of Cd La1 line

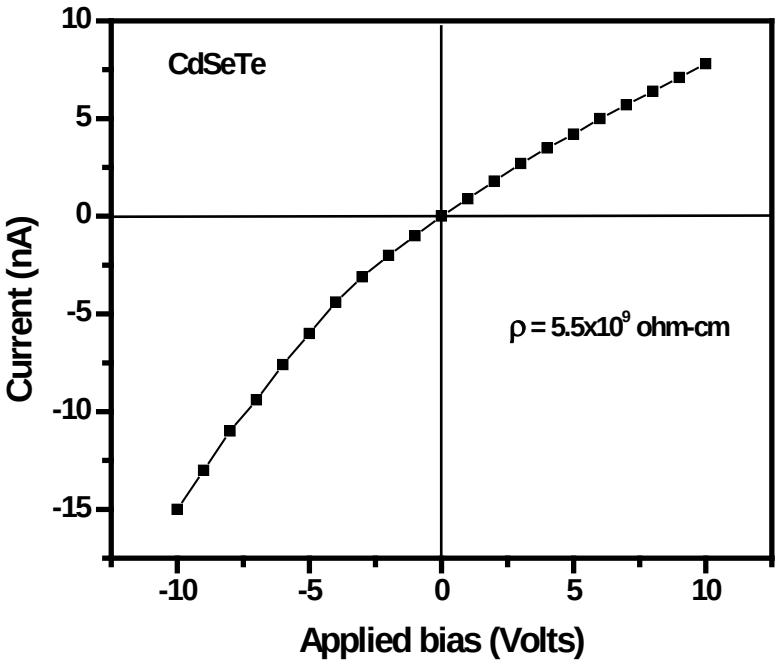


Mapping of Se Kα line

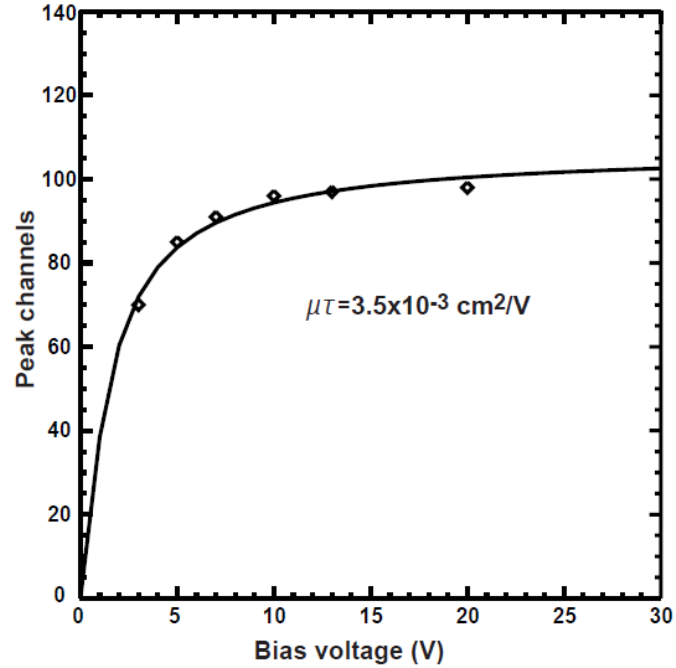


Mapping of Te La1 line

Resistivity and Charge-Transport Properties

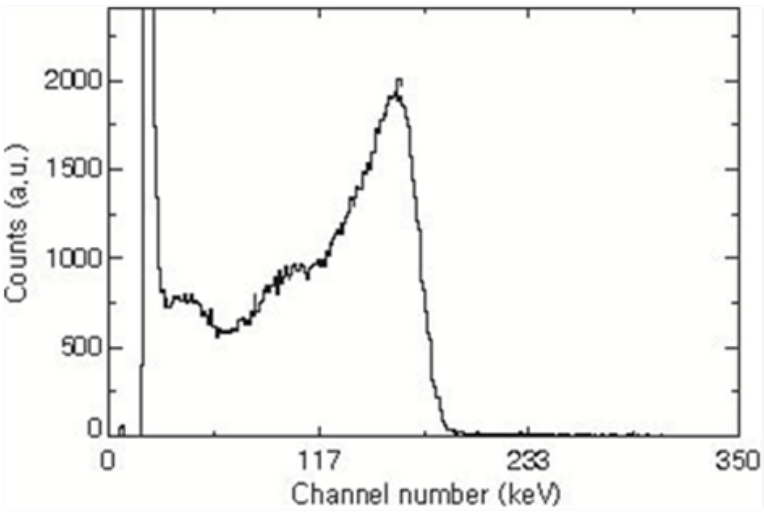


I-V curve at room temperature

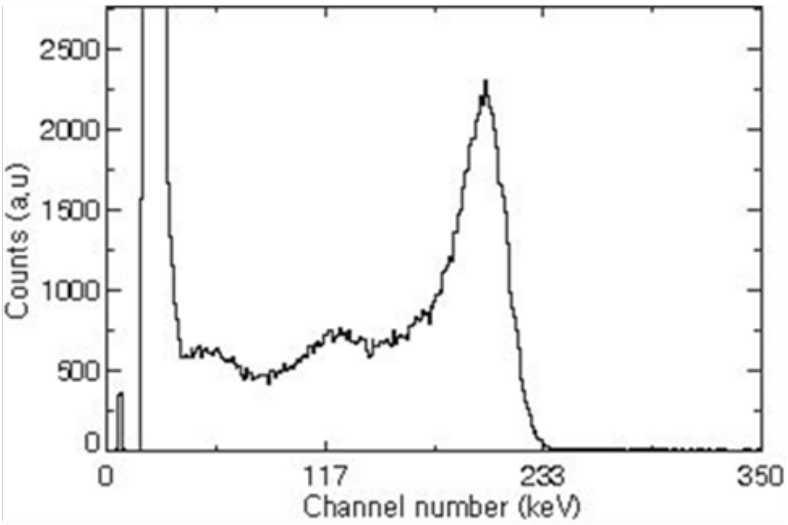


Charge collection vs voltage

Detector Performance at RT



(a)



(b)

Room-temperature $CdTe_{0.9}Se_{0.1}$ detector response for ^{241}Am under applied bias: a) 5 V and b) 25 V. The energy resolution at 25V obtained was ~12% at 59.6 keV. Sample dimension: 10x10x1 mm^3 . The lower bias voltages were used due to the lower electrical resistivity and the sample's associated thermal noise. A higher resistivity will allow a higher voltage bias and much better spectra for CTS crystals.

Summary

- **Our initial evaluations of $CdTe_{0.9}Se_{0.1}$ are promising.**

- **IR transmission imaging showed less Te inclusions compared to conventional CZT with average concentration of the secondary phase of ~ 7x $10^4/cm^3$ compared to ~ 1x $10^5/cm^3$ for conventional CZT material.**

- **Fairly good macro and micro compositional uniformity.**

- **Fairly high resistivity at room temperature of ~ 6x 10^9 ohm-cm with very good $\mu\tau_e$ value of 3.5x $10^{-3}cm^2/V$ was obtained.**

- **High charge collection was achieved at only 25 volts applied across 1-mm thick sample.**

- **Study on surface passivation is underway to decrease surface leakage current in order to apply higher voltage.**

- **Efforts to increase the bulk resistivity of the grown samples are in progress.**