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The correlation of detector performance with 1.1-eV traps in Se-added CdTe compounds

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Introduction

- 1.1-eV deep defect level is commonly observed in CdTe compounds with optical (mainly PL) and electrical (I-DLTS, PICTS) defect analyses.

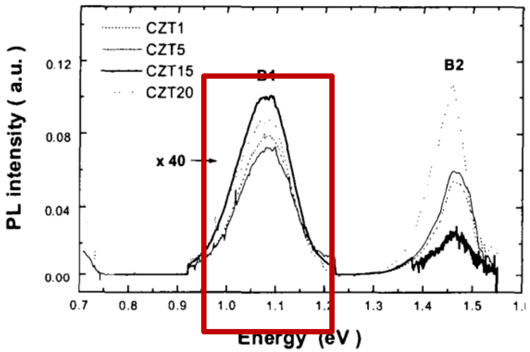


Figure 2 : Deep photoluminescence bands spectra of the HPB

HPB CdZnTe

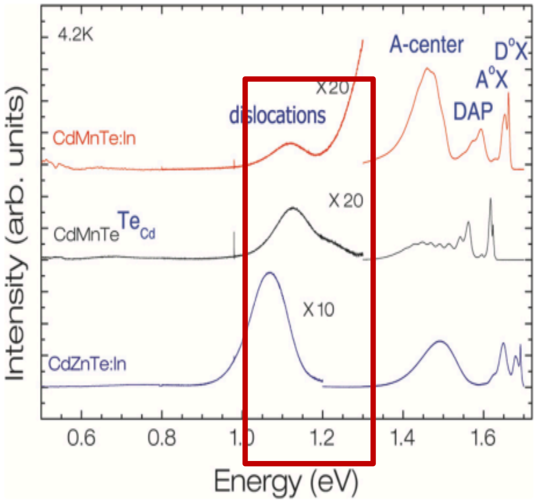


FIG. 2. (Color online) PL spectra of CMT, CMT:In, and CZT:In crystals between 0.5- and 1.7-eV. Indium-doped CMT and CZT crystals exhibit very strong A-center peaks and donor-bound exciton (D^oX) peaks, which are typical properties of doped materials.

Bridgman CdMnTe, CdMnTe:In, CdZnTe:In

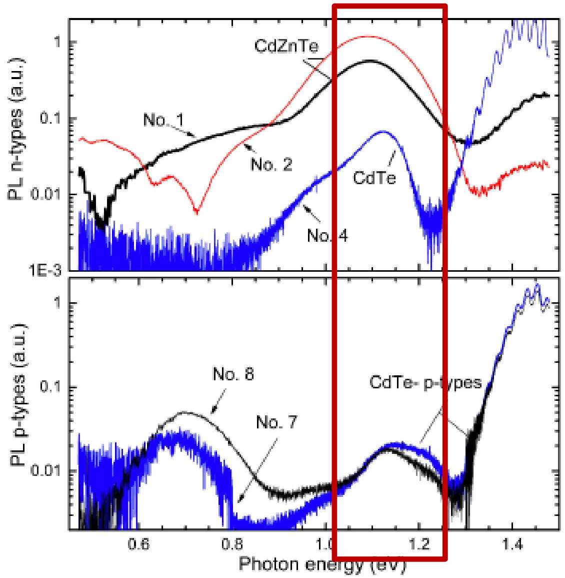


Figure 6. PL spectra representing DLs transitions in CdZnTe and CdTe samples. Upper and bottom panels plot the *n*-type and *p*-type samples respectively. The affiliation of each curve is labeled by a number from table 1.

Bridgman CdTe, CdZnTe

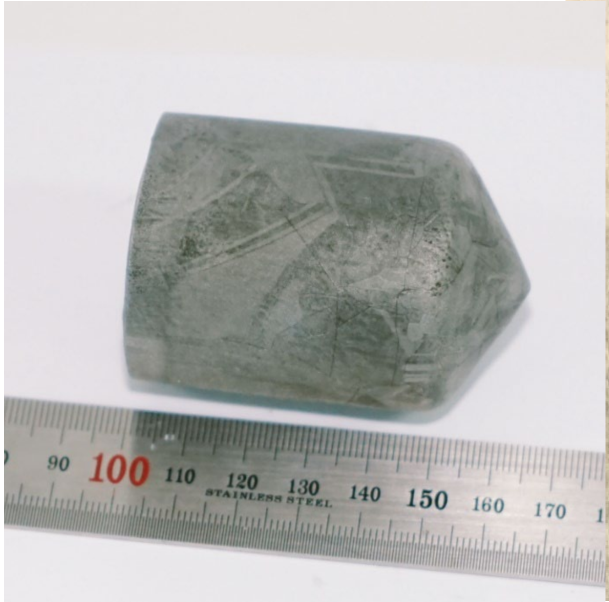
Introduction

- The origin of the 1.1-eV defect level was attributed to a Te vacancy related level. However, it is consistently observed in Te-rich CdTe compounds and annealed CdTe compounds in a Te overpressure.
- Recently, it was considered as a Te secondary phase induced dislocation and deep hole trap (E_c-1.1 eV). However, its origin is still controversial.
- 2% of Se added to CdTe compounds leads to an improved detector performance in spite of a slightly degraded electron mobility-lifetime product. In addition, the hole mobility-lifetime product was improved by adding Se.

Preparation of 2%-Se added CdTe compounds

● Growth of 2% of Se-added CdTe and CdZnTe

- 1- and 2-inch diameter ingots were grown by the Bridgman method with a mixture of CdTe, ZnTe, CdSe, and Te.
- Growth temperature: 1110-1130 ^{o}C
- Growth rate: 2 mm/hour
- Indium doping



Cu migration experiment

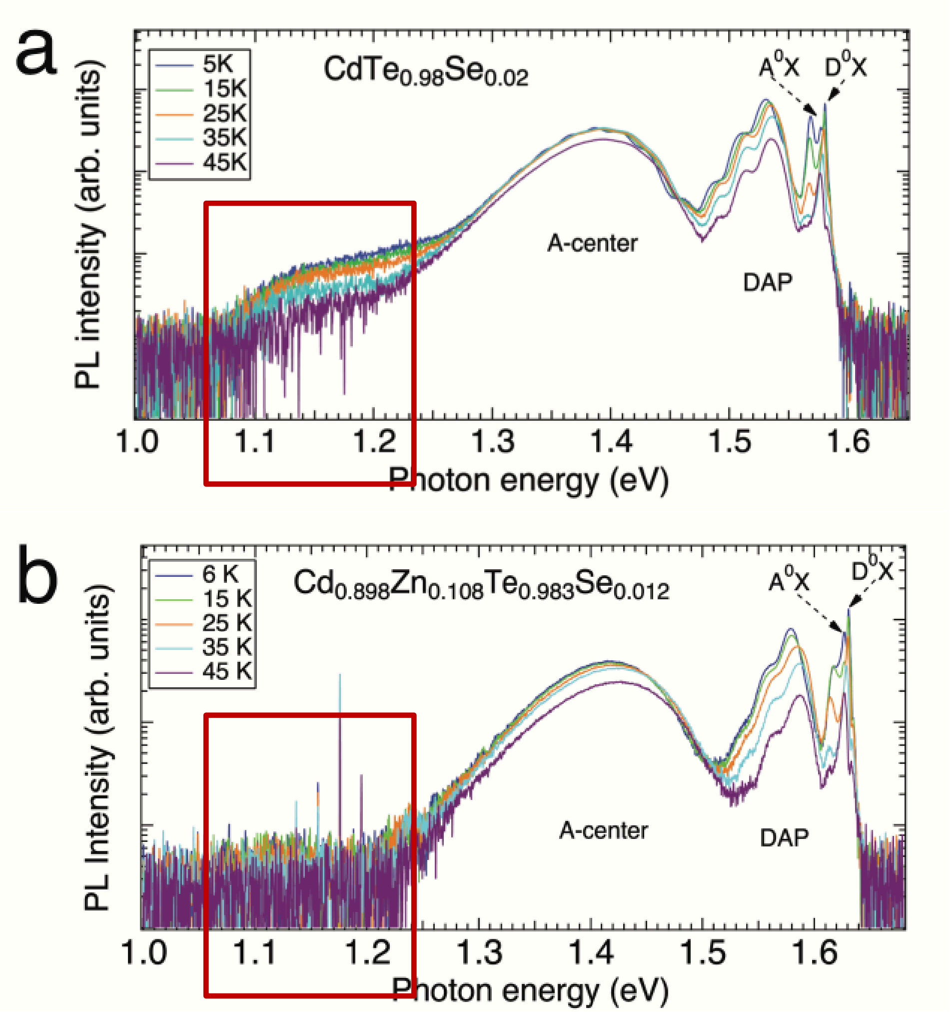
● **Cu is fast diffuser in CdTe compounds and detrimental to the electrical properties.**

- 100-nm thick Cu layer was deposited on CdZnTe and CdZnTeSe sample surfaces.
- Both samples are annealed at 800 ℃ for 8 hours in Te ambient overpressure.
- Then they were quenched to room temperature to avoid additional movement of the Cu during the cooling process.

- Diffused Cu atoms might occupy the native defect sites in CdTe compounds.

Results and Discussion

● Photoluminescence (PL) measurement

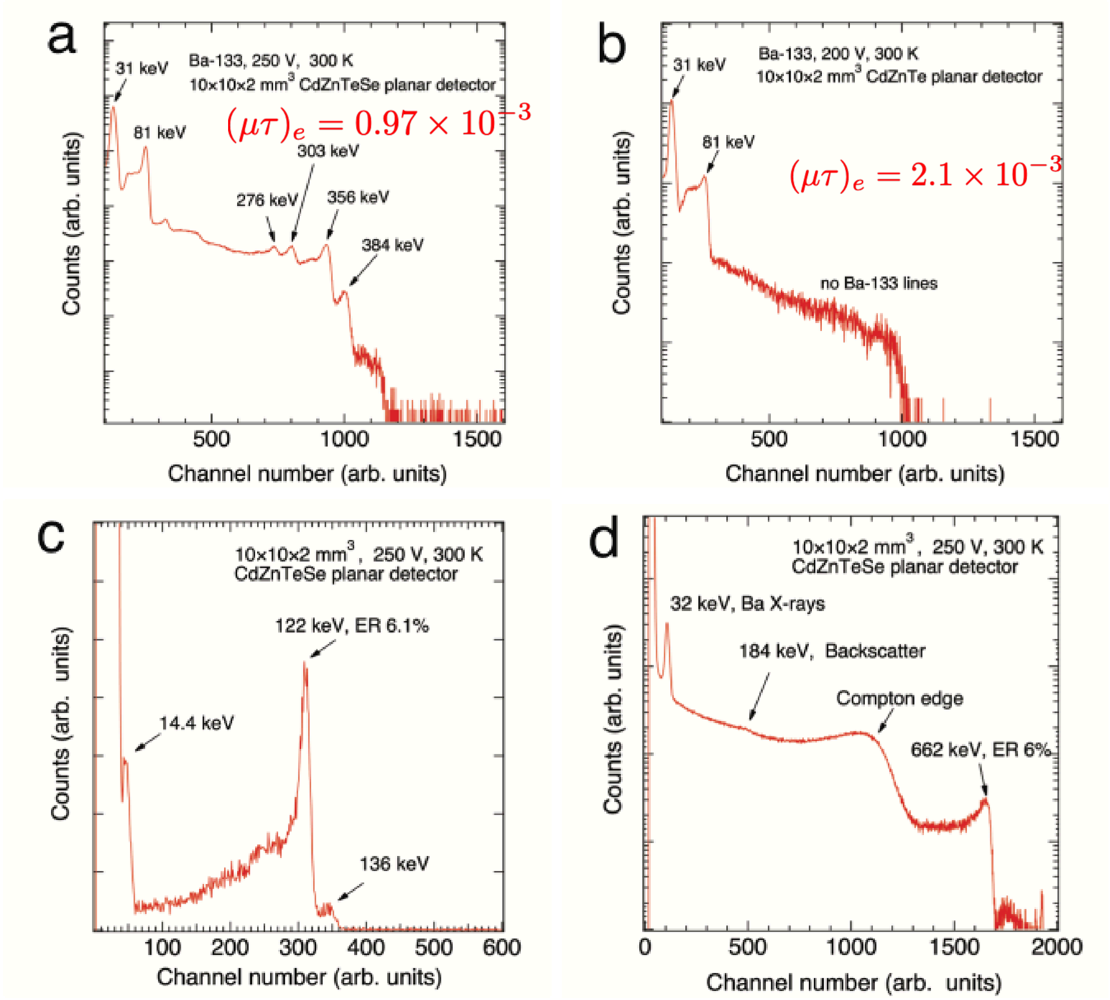


- PL spectra between 5K and 45 K for CdTeSe and CdZnTeSe samples.

- 1.1-eV level peak disappeared in both Se-added samples.

Results and Discussion

● Pulse height spectra taken with CdZnTe and CdZnTeSe



- Pulse height spectra of a) Ba-133, c) Co-57, and d) Cs-137 taken with a 2-mm thick CdZnTeSe detector.

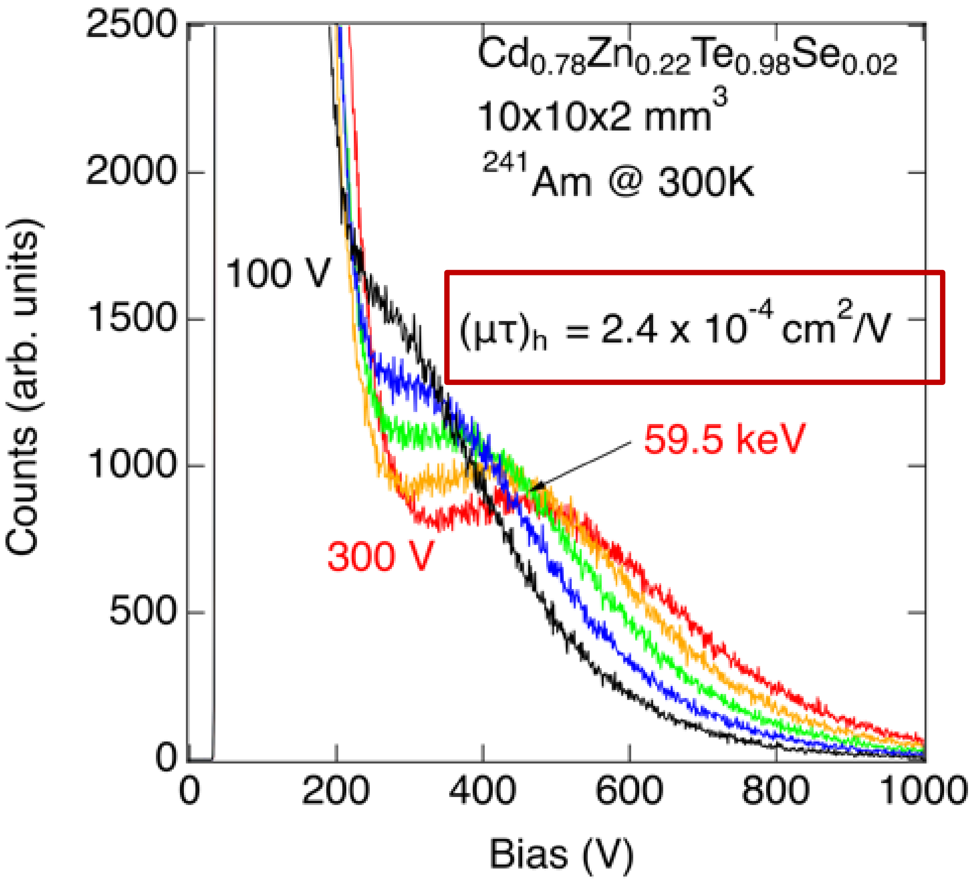
- b) Pulse height spectra of Ba-133 taken with a 2-mm thick CdZnTe detector.

- The mobility-lifetime of electrons for the CdZnTe and CdZnTeSe detector is 2.1 $\times 10^{-3}$ and 0.97 $\times 10^{-3}$ cm^2/V, respectively.

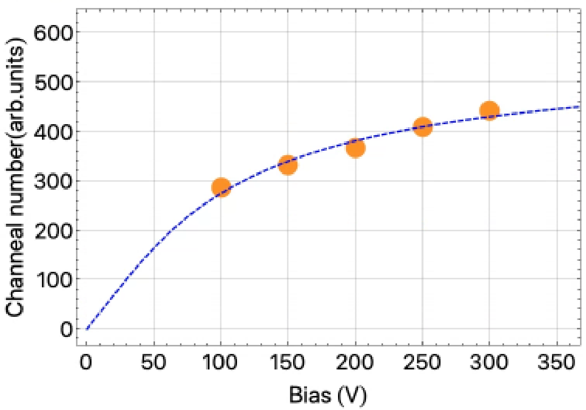
- The mobility-lifetime of holes for CdZnTe can't obtained due to the noisy pulse height spectra.

Results and Discussion

- **Measurement of hole mobility-lifetime product of CdZnTeSe detector.**

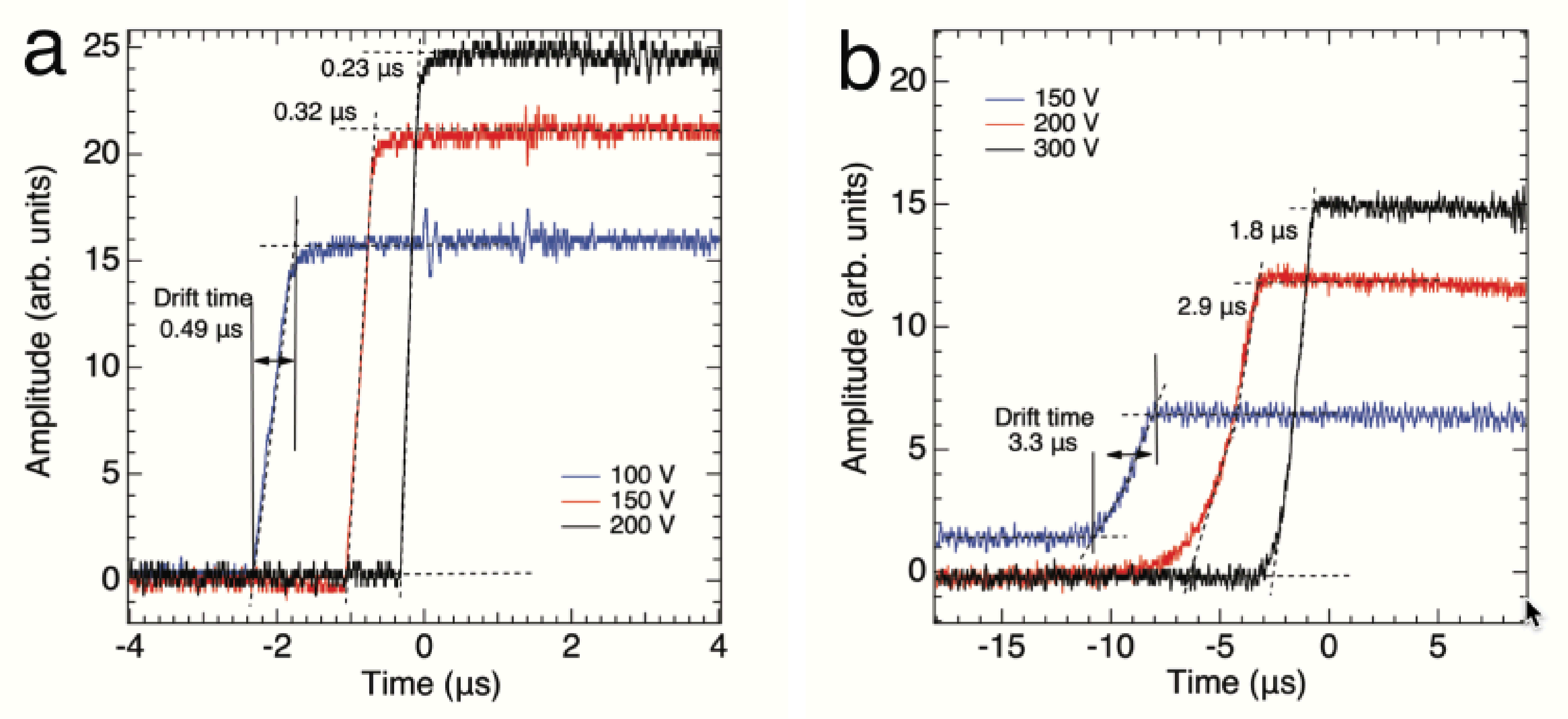


- Pulse height spectra of Am-241 taken a 2-mm thick CdZnTeSe detector in hole-collection mode.
- Hole mobility-lifetime product obtained by Hecht equation fitting with peak channel vs. bias.



Results and Discussion

- **The calculation of electron and hole mobility from the mean drift velocity vs. the electric field**



- The drift time of a) electrons and b) holes depends on the electric field. The mobility of the electron and hole obtained from the mean drift velocity vs. the electric field is 828 and 75 cm^2/V-s, respectively.

Results and Discussion

- **Analysis of carrier mobility and lifetime in CdZnTeSe detector**

carrier	Mobility-lifetime product (cm^2/V)	Mobility (cm^2/Vs)	Lifetime (μsec)
Electron	9.7×10^{-4}	828	1.17
Hole	2.4×10^{-4}	75	3.20

Results and Discussion

- **Why is the pulse height spectra of CdZnTeSe detector better than CdZnTe given the lower electron mobility-lifetime product?**
- **Charge collection efficiency**

$$\eta = \frac{\lambda_e}{d}\left[1 - \exp\left(-\frac{d-z}{\lambda_e}\right)\right] + \frac{b\lambda_e}{d}\left[1 - \exp\left(-\frac{z}{b\lambda_e}\right)\right]$$

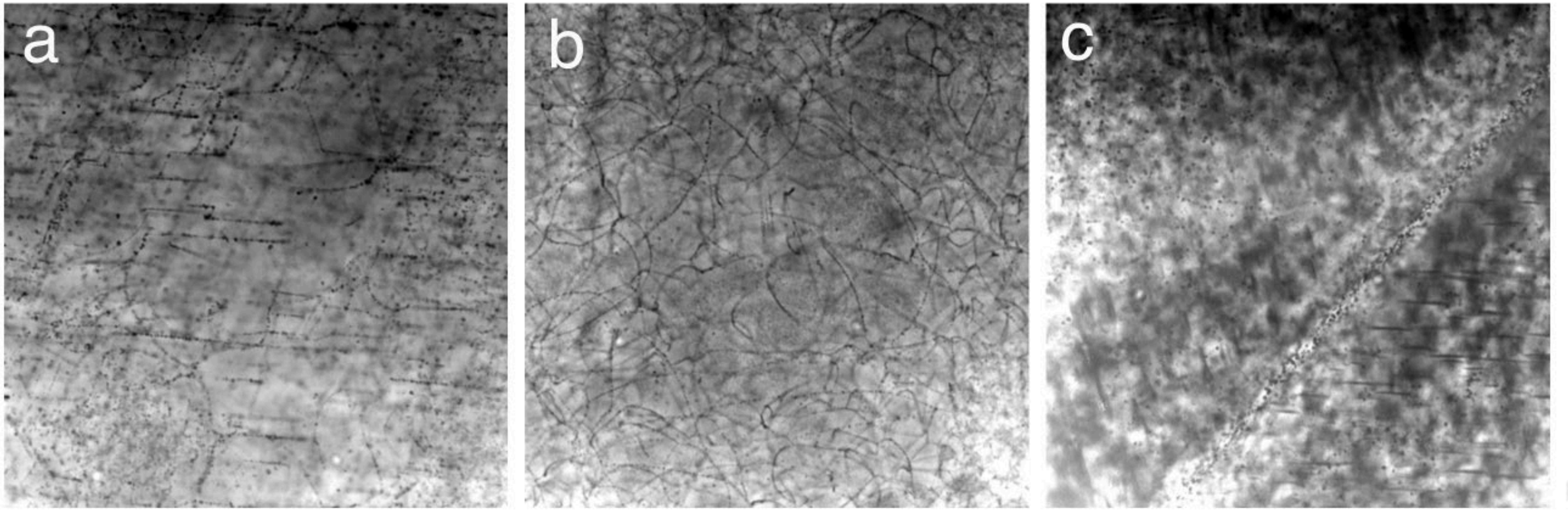
$$\lambda_e = \mu_e \tau_e E, \quad b = (\mu\tau)_e/(\mu\tau)_h$$

$$\frac{d\eta}{db} = \frac{\lambda_e}{d} - \left(\frac{\lambda_e}{d} + \frac{z}{bd}\right)\exp\left(-\frac{z}{b\lambda_e}\right) \quad \text{for constant z.}$$

- For the same value of $(\mu\tau)_e$, detectors with a higher value of b exhibit better charge collection efficiency, which gives better energy resolution.

Results and Discussion

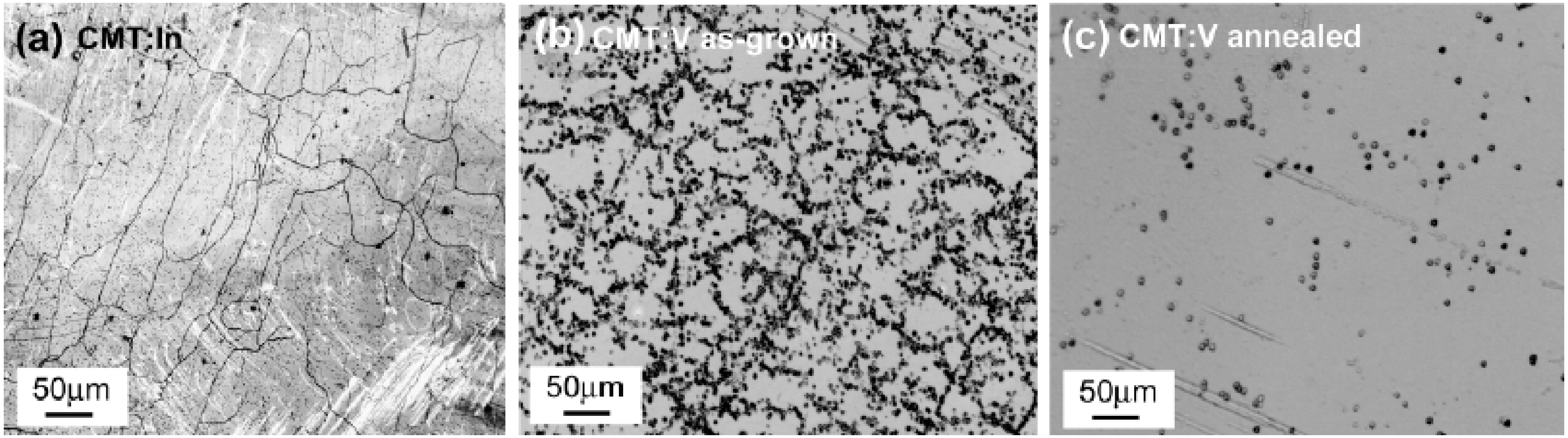
- **Evaluation of the dislocation density in CdZnTe and CdZnTeSe using a Cu migration experiment in a Te ambient condition.**

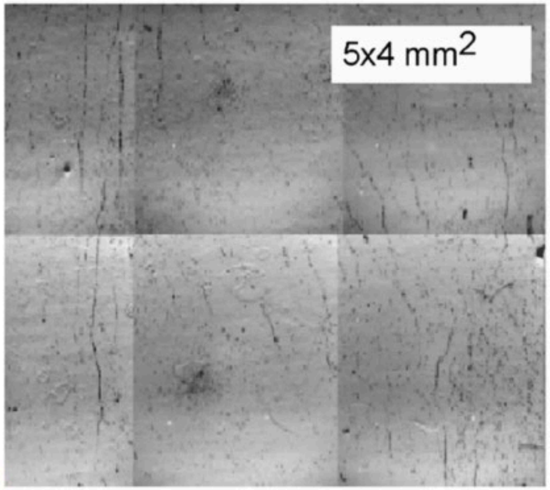


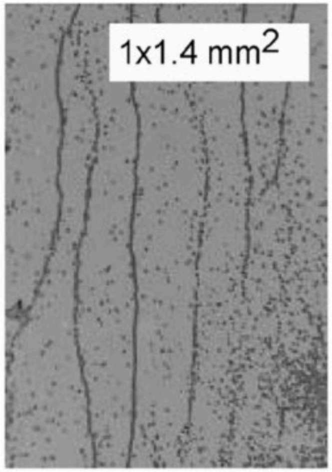
IR image of Cu-migrated (a) CZTS, (b) CZT, and (c) grain boundary of CZT taken at a 1-mm depth from the surface. The area of the IR images is 4×4 mm^2. There is no remarkable difference in CdZnTe and CdZnTeSe.

Results and Discussion

- **Cu decorated patterns are similar to the linear dislocations formed after chemical etching.**







Summary

- A larger hole lifetime in Se-added CdTe compounds is attributed the disappearance of the 1.1-eV hole trap.
- Thus, the addition of Se is responsible for the disappearance of the 1.1-eV defect level, although the detailed mechanism is not clear at this moment.
- There is no remarkable difference in the density of dislocations and their network in CdZnTe and CdZnTeSe (Se=2%).
- An understanding of the 1.1-eV deep level and its connection as an important hole trap in limiting $\mu\tau$ for holes is emerging.
- We provided another tool to visualize the shape of the dislocation distribution in CdTe compounds.

Thank you for your attention!!