Comparative study of (Cd,Mn)Te and (Cd,Mn)(Te,Se) Bridgman-grown crystals – Structural characteristics and gamma radiation response

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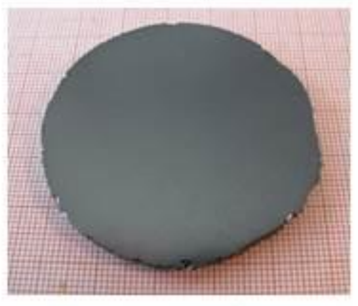
Introduction

Aim: Comparative study of two Bridgman-grown crystals: (Cd,Mn)Te and (Cd,Mn)(Te,Se) for room-temperature X- and gamma-ray detectors.

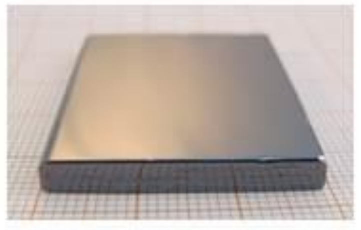
- We grow doped $Cd_{0.95}Mn_{0.05}Te$, $Cd_{0.95}Mn_{0.05}Te_{0.98}Se_{0.02}$, $Cd_{0.93}Mn_{0.07}Te_{0.98}Se_{0.02}$ crystals using the low-pressure Bridgman method. The crystals are **2 or 3 inches in diameter**.
- **Mn**-alloying vs. **Zn**-alloying of CdTe
  - (Cd,Mn)Te crystals: reduced segregation effects, larger grains.
- Addition of **Se**:
  - Inhibits the development of sub-grain boundary network
  - Reduces the density of Te inclusions

Starting point – monocrystalline samples, high resistivity, high mobility-lifetime product

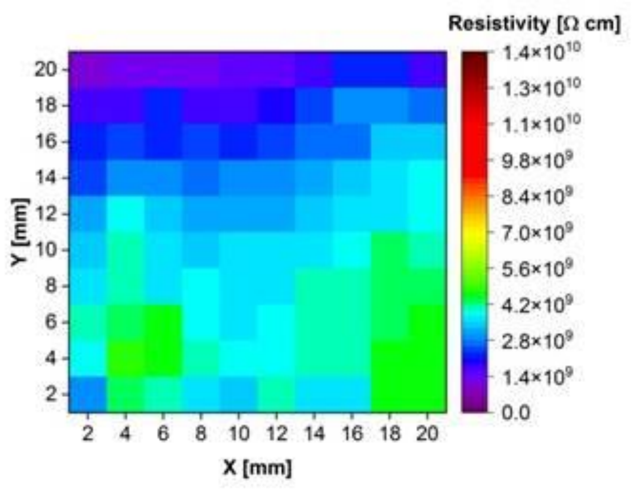
20×20 mm² single crystal (Cd,Mn)Te sample:



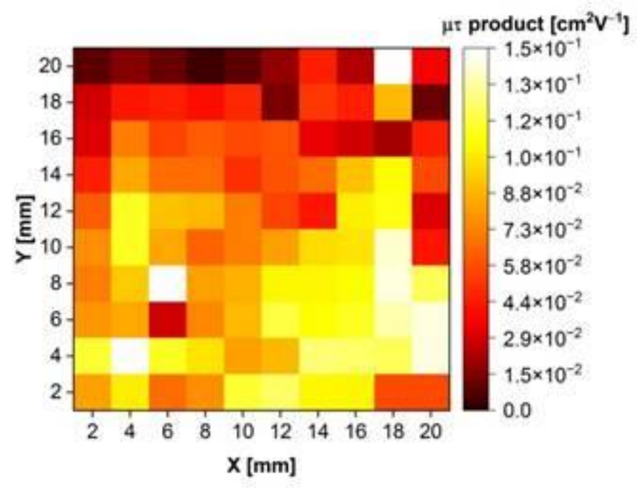
A 2-inch diameter (Cd,Mn)Te single-crystal sample.



A (111)-oriented (Cd,Mn)Te single-crystal sample of a specified shape for a detector.



mean ρ: **3.28×10⁹** Ω cm

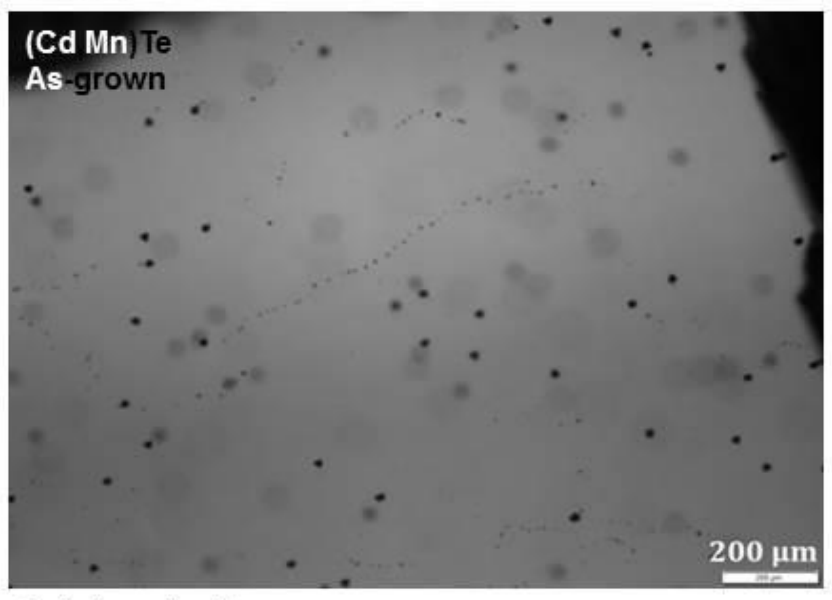


mean μτ: **7.31×10⁻²** cm²V⁻¹

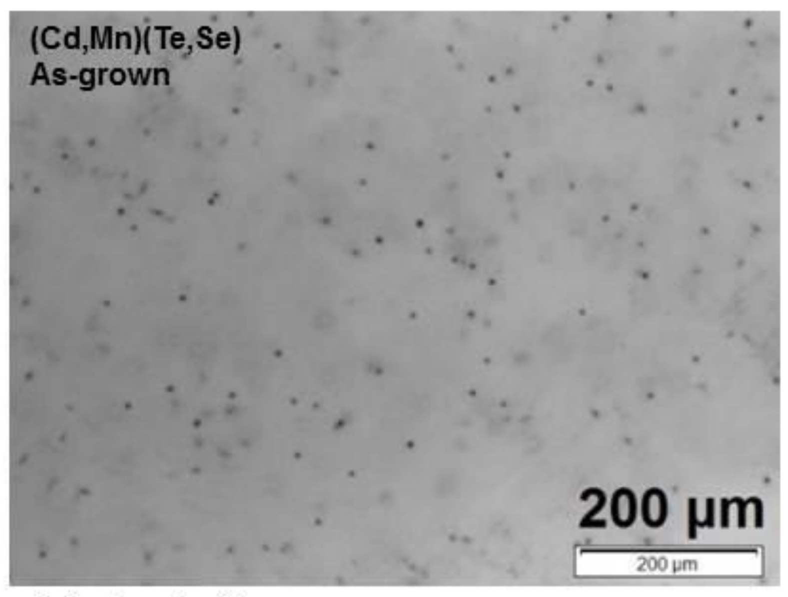
We map the values of resistivity and mobility-lifetime product in crystal plates using the EU-ρ-μτ-SCAN apparatus, which operates on the principle of **time-dependent charge measurement**.

Microstructure observed using infrared microscopy

Inclusion size 1-5 μm



Inclusion density 8×10⁴ cm⁻³

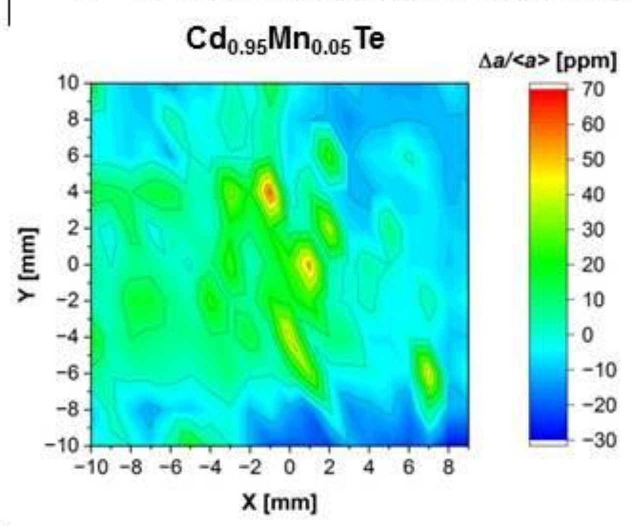


Inclusion density 2×10⁵ cm⁻³

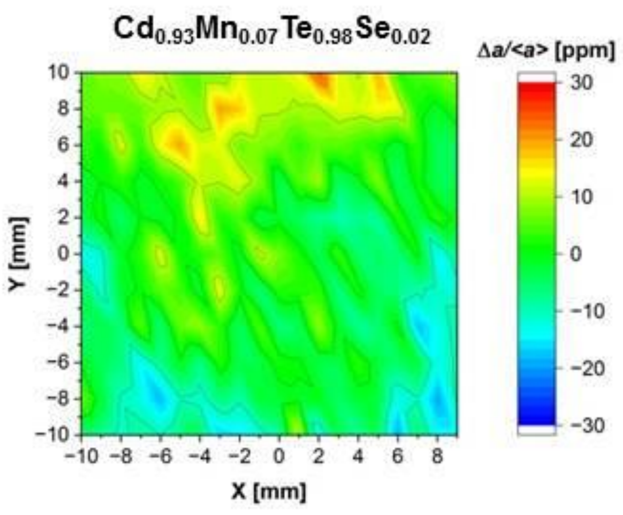
Lattice constant

$$\frac{\Delta a}{\langle a\rangle} = \frac{a - \langle a\rangle}{\langle a\rangle} \cdot 10^6 \quad [ppm]$$

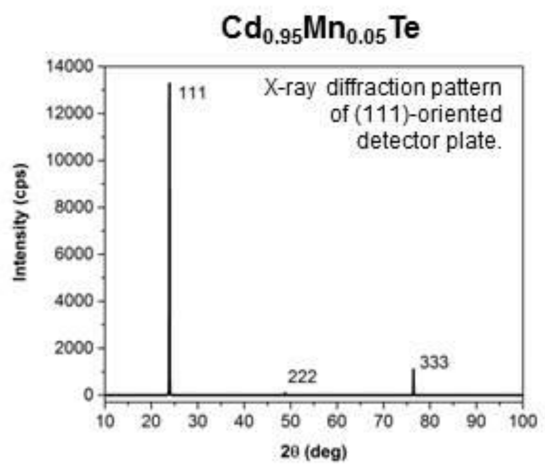
a – local value of lattice constant,
<a> – the arithmetic mean value of all local values a determined at different locations along the sample



$\bar{a}$ = 6.4766 Å (±0.0001)

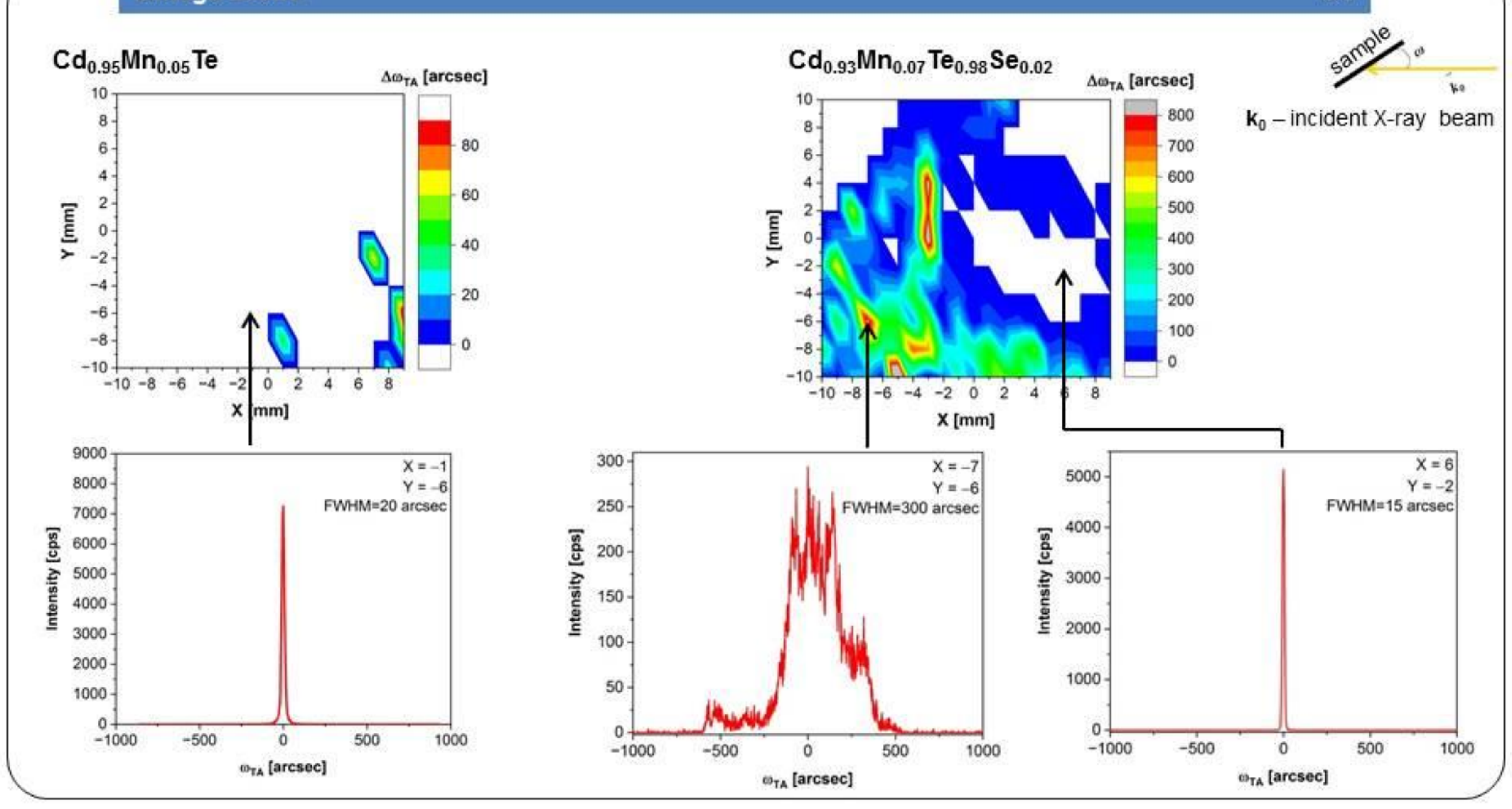


$\bar{a}$ = 6.4641 Å (±0.0001)



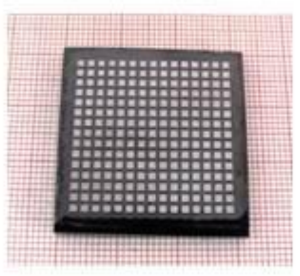
Both crystals exhibit a high level of uniformity in terms of lattice constant distribution. The deviations from the average lattice constant are very small, on the order of ppm.

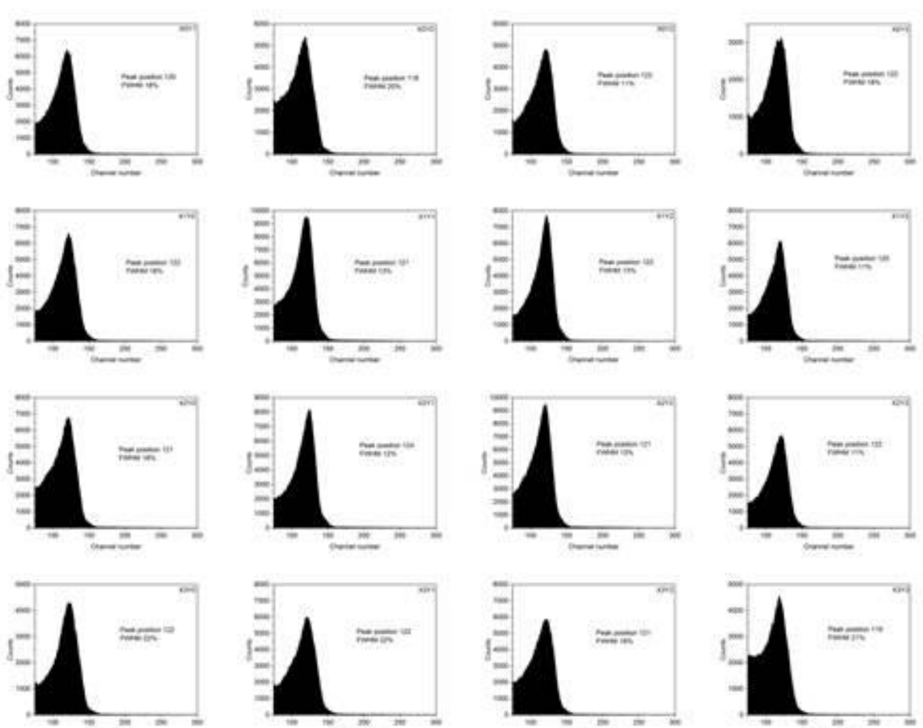
Omega scans



Detector response, T=300 K, Co-57 source $Cd_{0.95}Mn_{0.05}Te$

Peak position 122 keV
Energy resolution 14-22%





Conclusions

- Our **(Cd,Mn)(Te,Se)** detectors exhibited poor responses to X- and gamma-rays. Additionally, **the significant contribution of block-like structure** in selenium-containing crystal samples, accompanied by notably larger misorientation angles between these blocks compared to (Cd,Mn)Te, may contribute to the bad performance.
- **(Cd,Mn)Te** shows a great promise as a material for X-ray and gamma-ray detectors with an energy resolution FWHM 14-22%. (Cd,Mn)Te crystals exhibited nearly perfect monocrystalline structure, with block-like features observed in only 2% of the 18×20 mm² area.

This work was partially funded by The Polish National Centre for Research and Development through grant No. TECHMATSTRATEG1/346720/8/NCBR/2017.

The National Centre for Research and Development

The authors would like to thank **Stanisław Jabłoński, Adam Marciniak, Paweł Skupiński** and **Marek Zubrzycki** for their technical support.