CdTeSe Crystals for Gamma-Ray Detectors

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CdTeSe Crystals for Gamma-Ray Detectors

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• CdTeSe (CTS) is expected to be an excellent candidate for gamma-ray detectors
• Density is \( \sim 5.8 \, \text{gm/cc} \) (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 CdTeSe. 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.


Project Goal and Deliverables

• Growth of detector-grade CTS by THM technique for room-temperature radiation detector applications.
• Motivation for pursuing the growth by THM technique. Advantages include:
  i) Low-temperature growth
  ii) Less chance of incorporation of impurities from the crucible during growth
  iii) Less/no chance of ampoule explosion
  iv) Enhanced purity of the ingot
  v) Less defects due to the lower growth temperature
• Growth of as-grown detector grade CdTeSe (CTS).
• Growth of large ingots with uniform composition throughout the whole ingot, hence drastic reduction of production cost.
• Characterization of the grown ingots through X-ray topography, IR microscopy, compositional uniformity by X-ray fluorescence mapping, photoluminescence (PL), high resolution X-ray response mapping, I-V, and charge-transport characterization.
• Detector fabrication and investigations of the device performance.
• Cadmium Telluride Selenide crystals (CTS) were grown using the THM.

• Indium was used as the dopant.

• Crystals were cut and polished for characterization.

• Detectors were fabricated and tested.
IR Imaging of CdTe$_{0.9}$Se$_{0.1}$

Photograph of CdTe$_{0.9}$Se$_{0.1}$ sample

IR transmission image

Photograph of CdTe$_{0.9}$Se$_{0.1}$ sample and IR transmission image of dimension 10x10x5 mm$^3$

Unclassified
X-Ray Response Mapping and Topography

X-ray response mapping of CdTe\textsubscript{0.9}Se\textsubscript{0.1} sample, dimension 10x10x5 mm\textsuperscript{3}

- 10 x 10 mm\textsuperscript{2} area; V = 15V; 50 µm step
- 1.5 x 1.5 mm\textsuperscript{2} area; V = 15V; 10 µm step
- 0.9 x 0.9 mm\textsuperscript{2} area; V = 15V; 3 µm step

1.5 x 1.5 mm\textsuperscript{2} area; V = 15V; 10 µm step

10 x 10 mm\textsuperscript{2} area; V = 15V; 50 µm step

Unclassified
3D maps of inclusions reconstructed for 4 locations. The volume dimensions are 1.1x1.5x 5 mm³.
All inclusions within a 1.1x1.5x5 mm³ projected on a single 1.5x2 mm² plane

Distribution of the inclusions averaged over 4 locations

Total: $7 \times 10^4$ cm⁻³
Low-Temperature PL

PL spectrum of a CTS sample at 4.2 K

T=4.2K

1.547 eV

1.530 eV

1.510 eV

1.551 eV
Uniformity of composition

4.2K PL spectra from different sampling points across the surface show uniform Se content.
X-ray Fluorescence Mapping

Mapping of Cd La1 line

Mapping of Se Kα line

Mapping of Te La1 line
I-V at room temperature

Charge collection efficiency vs. voltage
Room-temperature detector response for $^{241}\text{Am}$ under applied bias: a) 5 V and b) 25 V. Sample dimension: 10x10x1 mm$^3$. 
Ongoing Experiments

• Growth of two ingots is in progress (finished by the end of April 2013).

• Fabrication of detectors including surface passivation for enhanced applied bias and detector performance.
Technical Challenges

• Increase the resistivity and $\mu\tau$ by optimization of the dopant concentration and growth process
• Growth of large ingots with uniform composition throughout the whole ingot
• Reduce the size and concentration of secondary phases

Future Work

• Growth of one- and two-inch diameter ingots of CTS.
• Characterization of the as-grown ingots.
• Fabrication of large detectors ($>1\, \text{cm}^3$) with enhanced charge-transport properties.

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