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Development of Room-temperature CdMnTe Gamma-ray Detectors

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Project Overview

CdMnTe materials have wide bandgap, high resistivity, fair electron-transport properties, and good compositional uniformity. All these features make CdMnTe a good candidate for low-cost, high-resolution room-temperature gamma-ray detector.

Using several techniques available at BNL, we are characterizing CdMnTe as a material for gamma-ray detectors. The consequent improvements in growth, fabrication, and manufacturing techniques for CdMnTe potentially yield a suitable material for sensing devices with lower production costs.

Success of this research has the possibility of generating high impact to nuclear nonproliferation with the goal of offering inexpensive highly sensitive gamma spectrometers.

Research Team:
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Sub-contractors:
L. Li, Yinnel Tech, Inc., South Bend, IN
A. Mycielski, Institute of Physics PAS, Warsaw, Poland
Other Universities:
A. Burger, Fisk University, TN
Budget:
$480k (FY08), $485k (FY09), and $490k (FY10)

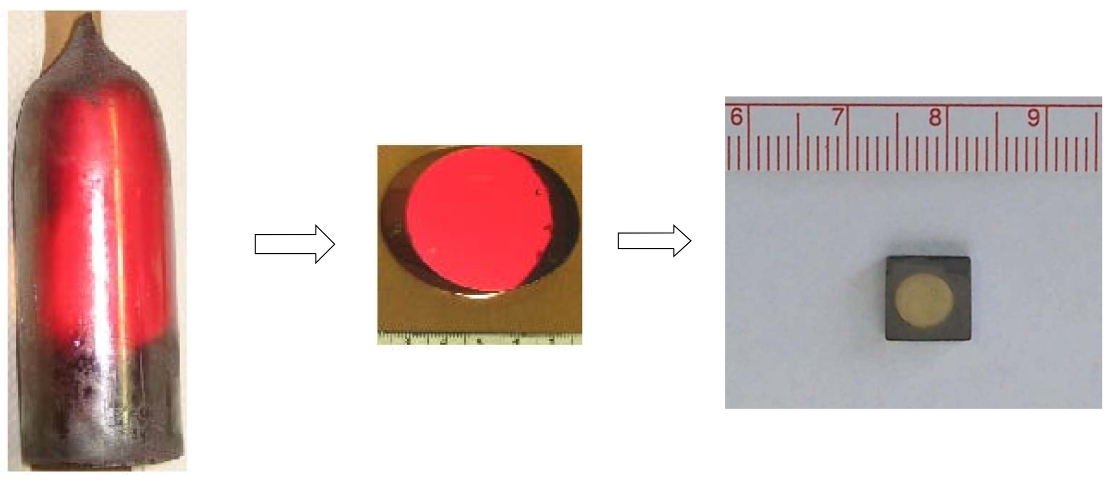
Relevant to NA-22 Mission

The yield of this project will be a technique to grow and fabricate novel CdMnTe radiation detectors with low-cost, high energy-resolution, and ambient-temperature operation. Potentially, CdMnTe offers the same advantages of compactness and simplicity of operation as CdZnTe, and, in addition, it overcomes the limitation of crystal quality and low production yield. Together with highly integrated electronics circuit, CdMnTe detectors can be used in large area/volume radiation detection systems as well as highly compact portable/hand-held radiation detection devices. Such systems/devices are widely used in nonproliferation applications, e.g. radiation-field surveys, treaty verification, and nonproliferation accounting.

Research Approaches

- We collaborate with CdMnTe growing vendors on:
  - * Crystal growth;
  - * Post-growth thermal processing.
- We establish in-house techniques to characterize CdMnTe materials and test detectors:
  - * Detector fabrication (polishing, etching, coating, etc.);
  - * Customized systems (IR, I-V, Spectroscopy, etc.);
  - * Unique technique at NSLS.
- We feedback the test results to crystal growing vendors and work together to improve / modify the growing process.

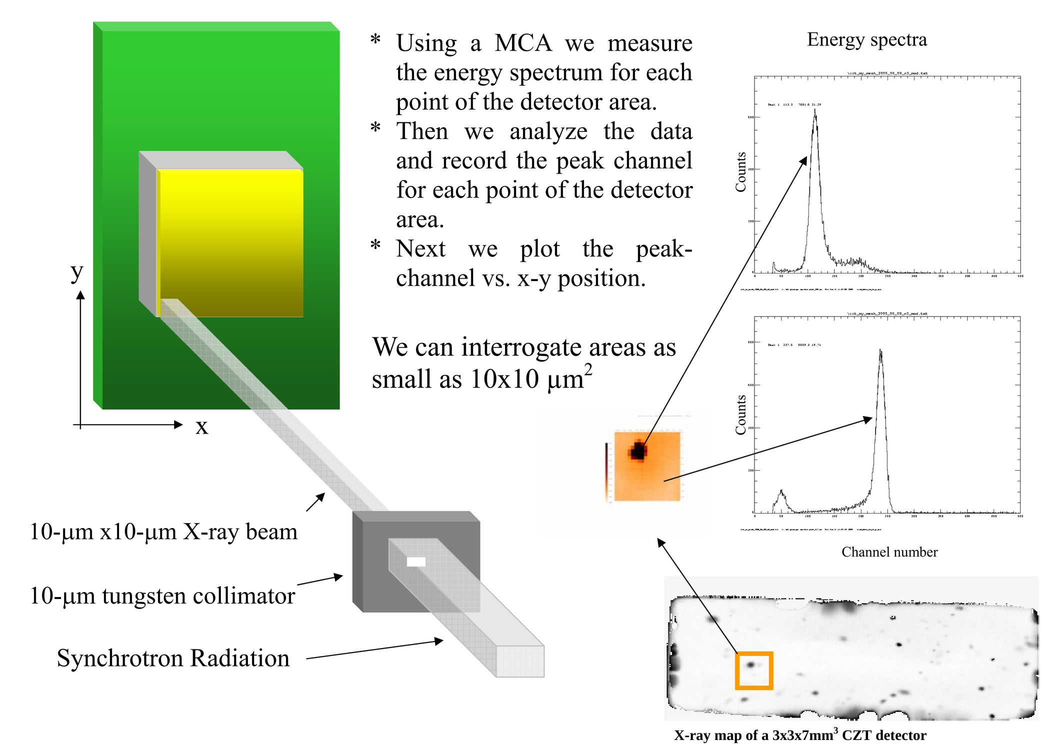
Detector Fabrication



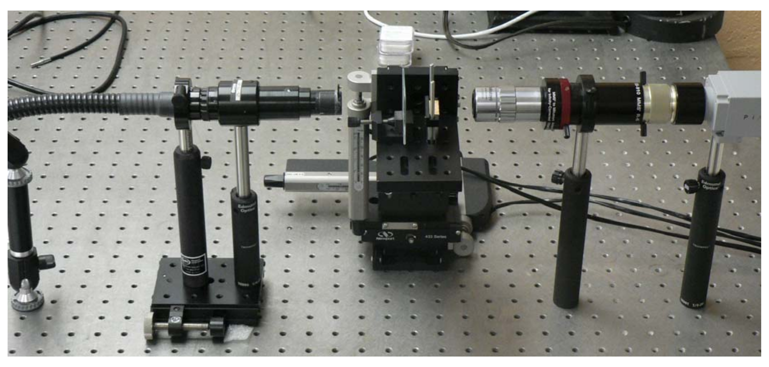
- Crystal growing vendors:
  - * Yinnel Tech, Inc., South Bend, IN;
  - * Institute of Physics, PAS, Poland.
- We are also establishing in-house capability for CdZnTe crystal growth. (See poster on "Novel Method for Growing Te-inclusion-Free CZT")

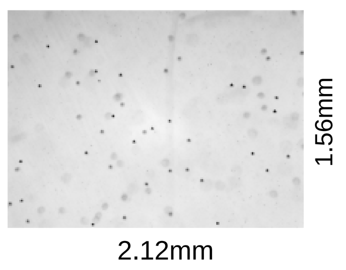
Facilities and Techniques

High spatial resolution X-ray mapping



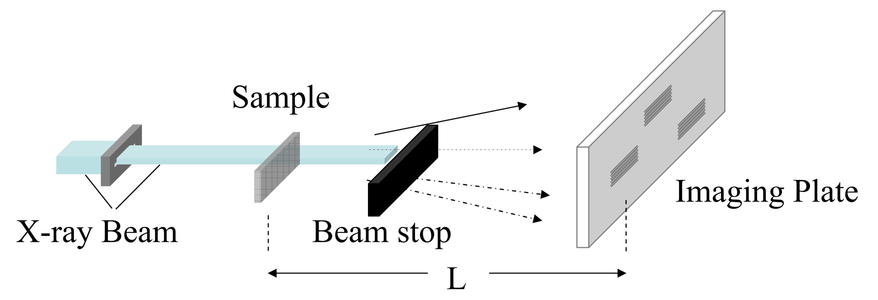
IR (Infrared) imaging





- 3-D IR scanning
  - * Field-of-View: 10.6x7.8 mm^2
  - * Image size: 3000x2208 pixels
  - * Pixel size: 3.5 µm

White beam x-ray diffraction topography



EPD (Etch Pits Density) measurements

- Revealing the microstructure and defects in the crystals;
- Etching solutions:
  - * E-solution (HNO_3:H_2O:$K_2Cr_2O_7$ + $AgNO_3$)
  - * Nakagawa (H_2O:H_2O_2:HF)

I-V measurements

- Polishing (Bromine in Methanol)
- Surface passivation
- Electroless ohmic contact

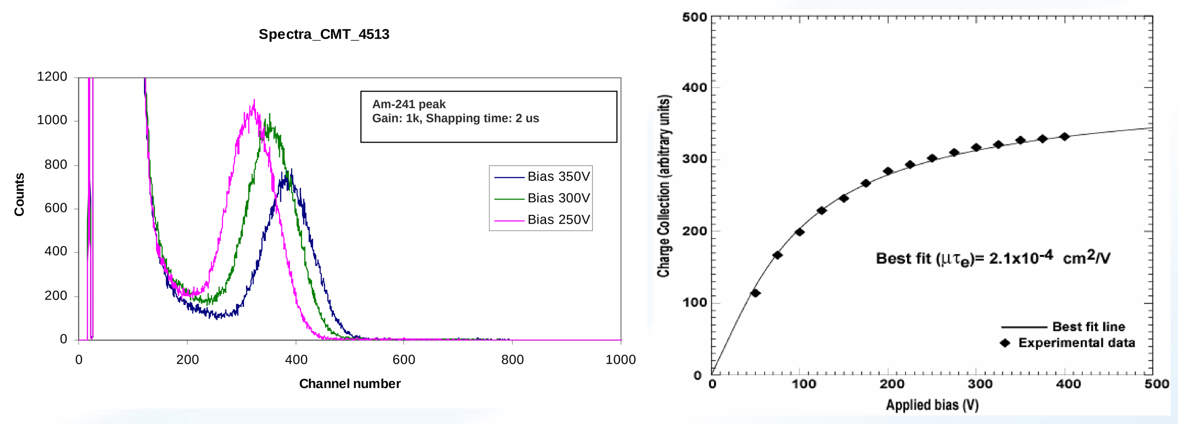
Spectroscopy system

- Sealed gamma-ray source
- Low-noise hybrid preamplifier
- NIM modules for signal processing
- Multiple Channel Analyzer in computer

Progress to Date

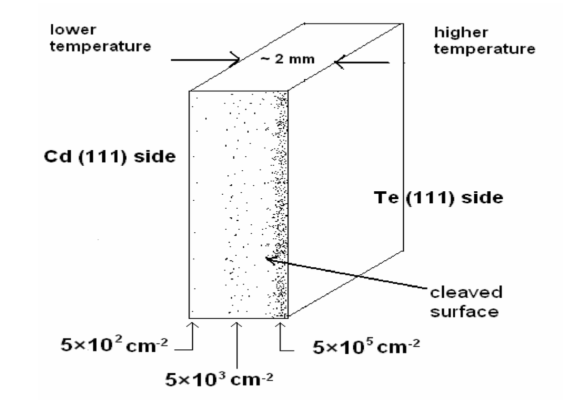
Example of good samples - No.4513: $Cd_{0.94}Mn_{0.06}Te$:V

- Our first CdMnTe detector (Vanadium = $5x10^{16}$ cm^{-3}).
- 9x8.5x1.8 mm^3 with active area 28.3 mm^2.
- Resistivity: $3.2x10^{10}$ Ω·cm.
- Material response to incident gammas observed.
- $\mu\tau_e \approx 2.1x10^{-4}$ cm^2/V.
- Good starting point for crystal growth.



Effects of annealing on material properties

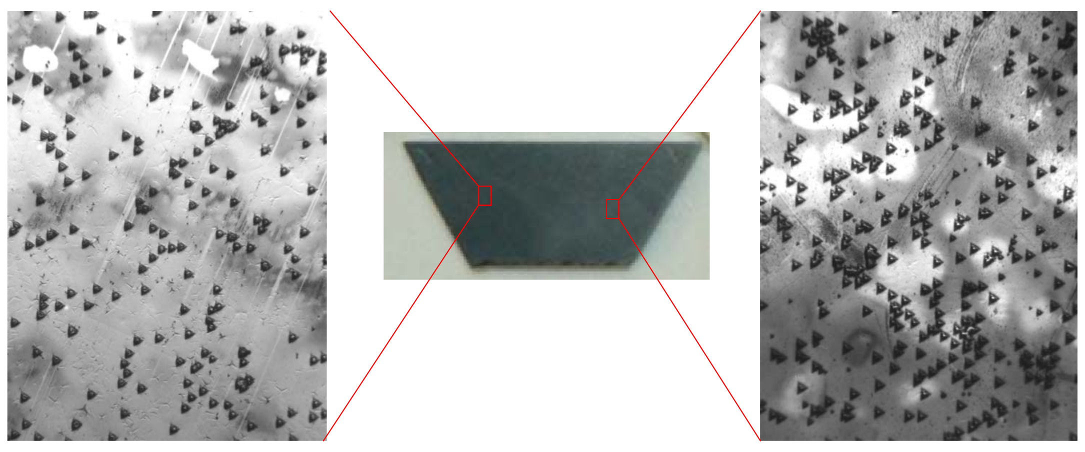
- Annealing in a gradient temperature found to reduce the Te precipitates and inclusions.
- Annealing in constant temperature with Cd overpressure reduce V_{Cd} (acceptors) thus increasing the resistivity.



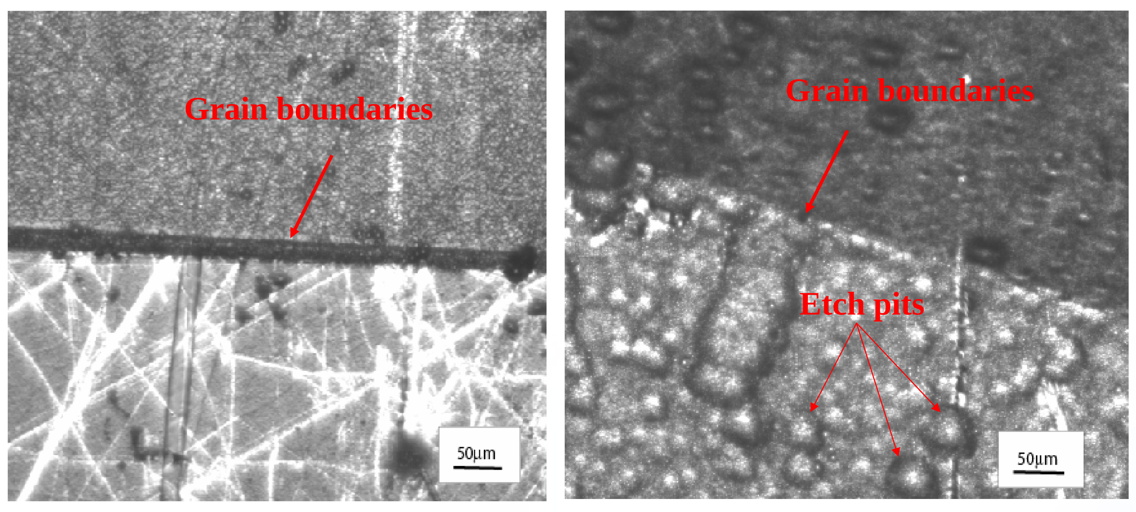
The sample after 4-day annealing in Cd vapour in a temperature gradient of 10 K/cm.

Dislocation density and its effect on µτ product

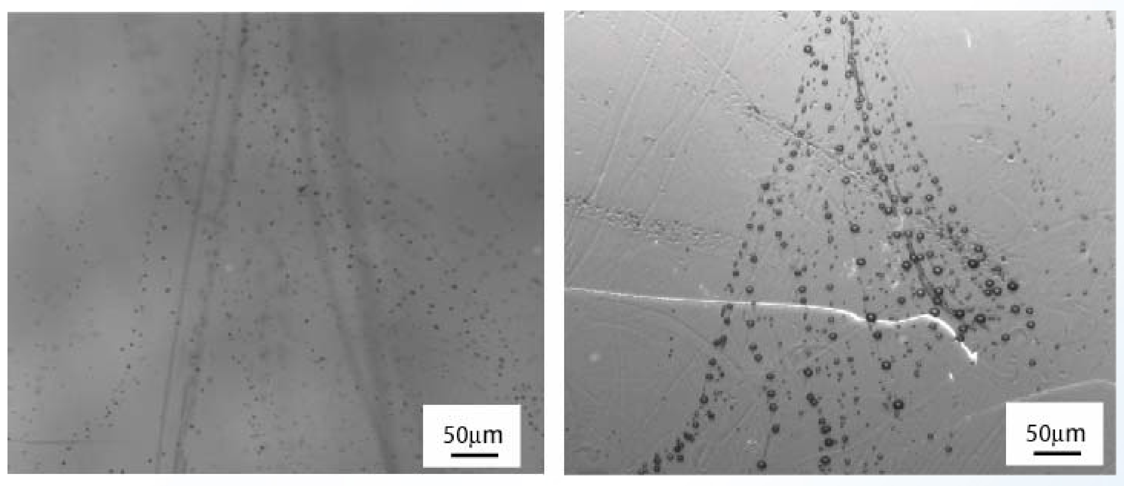
- Dislocation density is low in the central areas of crystals, while high close to the surface (ampoule wall)
- Dislocations may affect charge collection.



EPD measurements



IR imaging



10x IR images of as-grown CMT crystal. Te inclusions can be seen with certain patterns.

10x image of etch pits of the same area of the crystal. Correlation can be found. (Etched by Nakagawa solution)

Conclusions

- * CdMnTe is very promising as a material for gamma-ray detection.
- * BNL has unique and comprehensive techniques for characterization of CdMnTe material and fabrication and test of CdMnTe detectors.
- * BNL works closely with crystal growing vendors to improve CdMnTe growing process.
- * We fabricated the first CdMnTe detector.
- * Development of room-temperature CdMnTe gamma-ray detectors will benefit nuclear nonproliferation applications.

Acknowledgments

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