CORRELATION BETWEEN QUALITY OF CZT CRYSTALS AND SPECTROMETRIC PERFOMANCE OF HEMISPERICAL RADIATION DETECTORS

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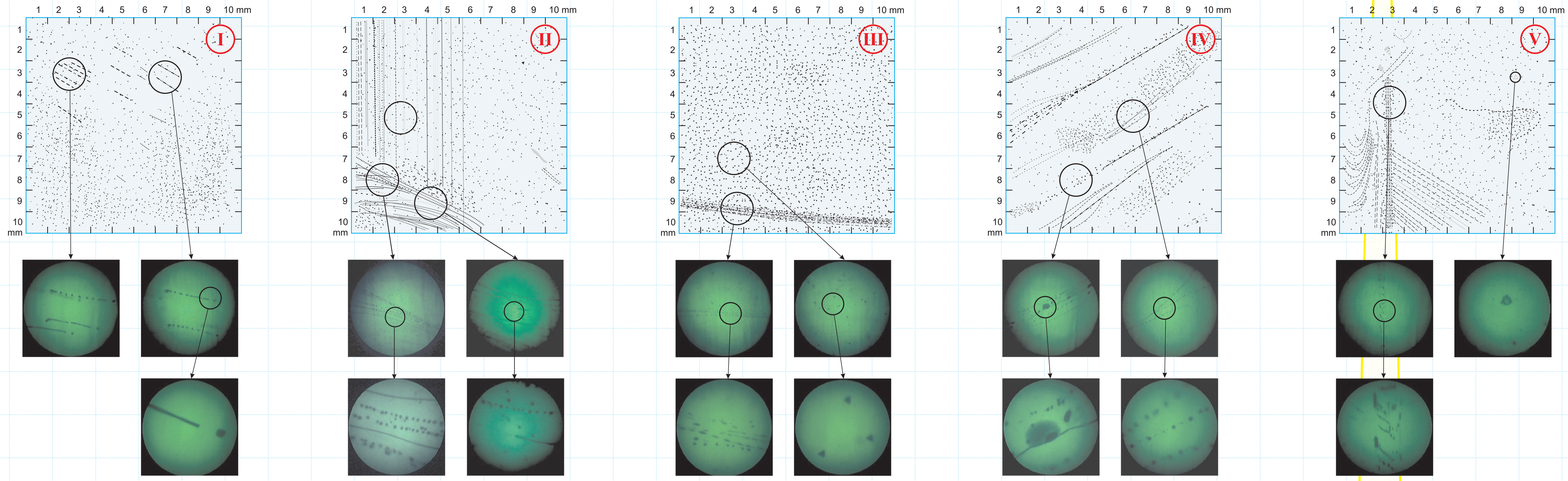
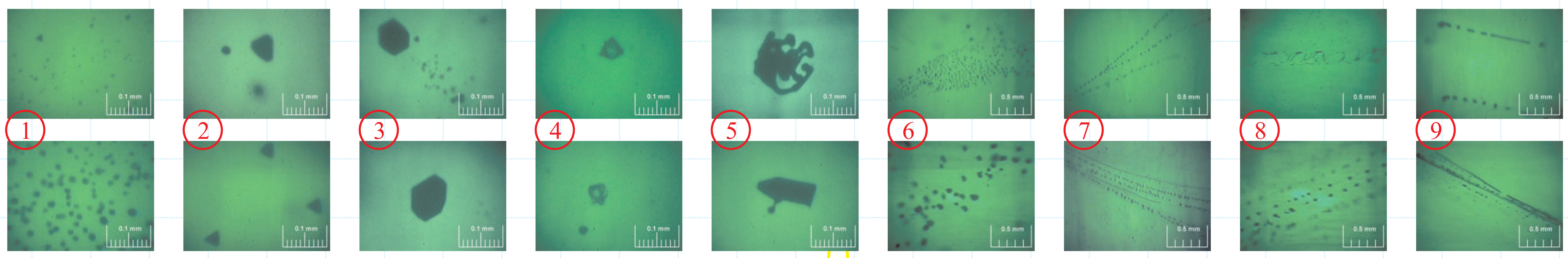
The work presents analysis of the correlation existing between the spectrometric performance of commercially produced hemispherical detectors of volume 500 mm^3 and the quality of starting CdZnTe material. More then 100 detectors made from CdZnTe crystals grown by eV PRODUCTS, Saint-Gobain and Yinnel Tech were studied. For the incoming inspection of the material an infrared (IR) transmission microscope was used. The presence of structural defects such as grain boundaries, twins, inclusions, cavities was checked and their shapes, sizes and spatial distributions were examined; the values of $(\mu\tau)_e$ were measured. The hemispherical detectors were made by a technology elaborated at the RITEC. Spectrometric performance of the detectors was verified by measuring the energy resolution and the peak-to-Compton ratio at the 662 keV line.

Examples of IR mapping and micrograph of above uniform (III) and non-uniform structural defects spatial distribution (I), (II), (IV), (V)



Characteristic types of obtained structural defects



1. Uniform distributed small size (<20 μm) inclusions of regular and irregular shapes.
2. Average size (20-40 μm) inclusions of regular triangular or/and hexagonal shapes and irregular shapes.
3. Large (>50 μm) inclusions of regular shapes.
4. Cavities or pores.
5. Large inclusions (>50 μm) of irregular shapes.
6. Aggregations of inclusions.
7. Branching linear clusters of inclusions.
8. Rectilinear or plane cellurar or segregated inclusions.
9. Tubular linear rod-like defects such as "pipes" or sticks.

Structural performance

The control using the IR transmission microscope has revealed the presence of variously shaped structural defects in the samples of all producers. The shapes of defects observed by us and their spatial distributions changed considerably from sample to sample.

We have tried to classify the most typical forms of the revealed defects and the variants of their distributions:

- Most typical defects were small inclusions <20 μm uniformly distributed in volume. Such inclusions are present practically in all samples tested.

- The medium-sized inclusions (about 20-40μm) are also met quite often. These inclusions may have both regular geometric shape (triangular and/or hexagonal) and irregular one.

- Some samples exhibit large inclusions (>50 μm). Such inclusions can also be both regularly and irregularly shaped. As a rule, samples with large regularly shaped inclusions possess considerably fewer small inclusions. The irregularly shaped inclusions met quite rarely only in about 4% of all tested samples.

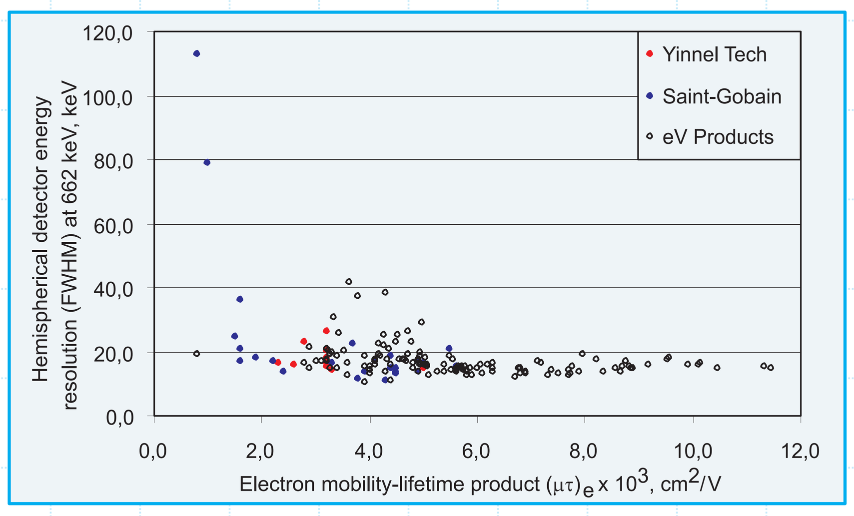
- The revealed inclusions might be either Te enriched inclusions or Te precipitates. As was noted in the paper [1], usually Te enriched inclusions are much larger then Te precipitates with an average diameter in the 1-50 μm range.

- In some samples cavities 30-50 μm in size were observed.

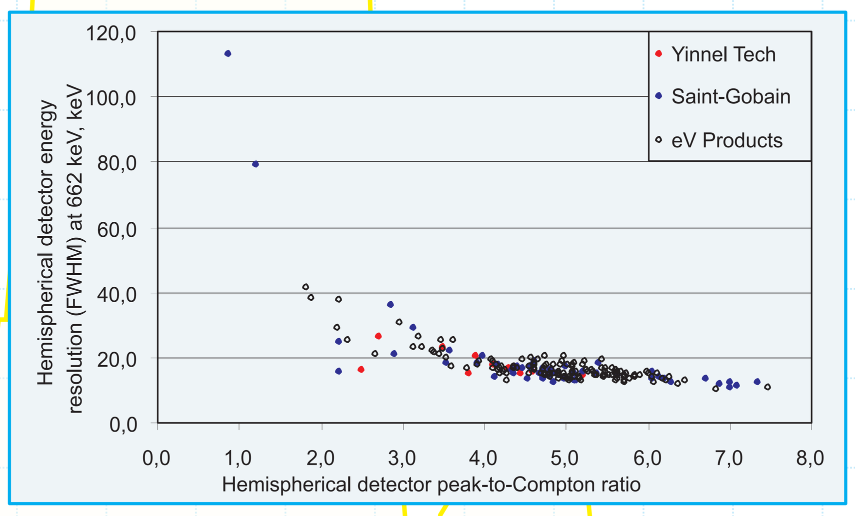
- The spatial distribution of inclusions can strongly vary from sample to sample. They can be uniformly distributed in volume or can create aggregations in the form of clouds in a definite part of a sample. As a separate group can be noted an extended aggregations of defects both linear and plane. In some samples of all the producers known [1] linear tubular defects ("tubes" or sticks) were revealed. In many samples there were met aggregations of inclusions as extended linear branched clusters that can occupy the entire space or its major part. For many samples it is typical to have rectilinear aggregations (cellurar or segregated) defects stretching through the entire sample. Such defects, as a rule, are located along the planes of twinning or grain boundaries [2].

- Many samples have simultaneously a few types of structural defects.

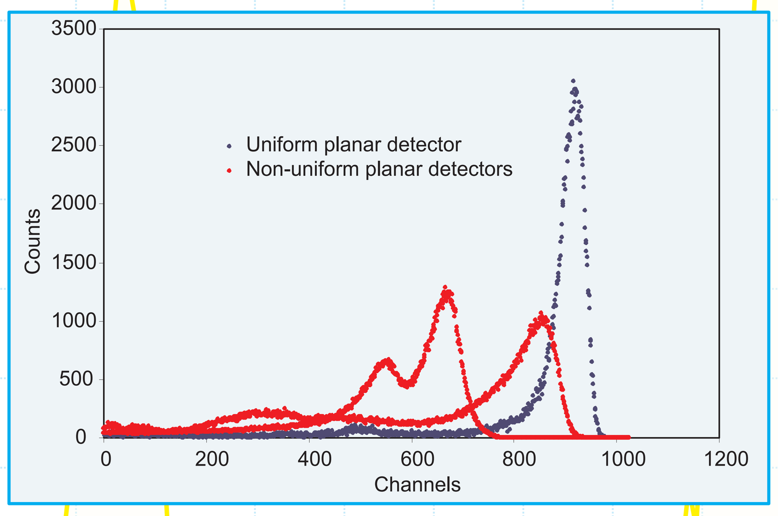
Measured hemispherical gamma-ray detectors energy resolution (FWHM) at 662 keV vs. electron mobility-lifetime product



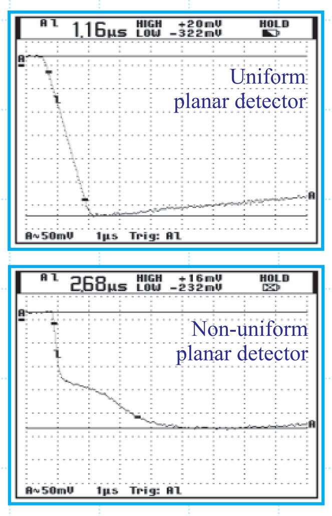
Measured hemispherical gamma-ray detectors energy resolution (FWHM) at 662 keV vs. peak-to-Compton ratio



Shapes of alpha spectra recorded by uniform and by non-uniform planar detectors



Waveforms of induced output charge signal



Hemispherical gamma-ray detectors performance

All hemispherical detectors were made by similar technology. Spectrometric characteristics of the detectors were measured under the same conditions for the 662 keV line of the ^{137}Cs isotope at room temperature. The energy resolution (FWHM) of the ready-made detectors was in the range of 10.5-40 keV, except for several detectors with poorer performance. The peak-Compton ratio was in this case in the limits of 2 - 8.

Was find that the energy resolution in a wide range of $(\mu\tau)_e$ variations does not depend on the value of this parameter, and only at its low values (less than 2*10^{-3} cm^2/V) a deterioration of the detector performance is observed. A definite number of the detectors with poorer performance that were made from the material with $(\mu\tau)_e$ value in a range of (2.5-4.5) *10^{-3} cm^2/V generally can be associated with the presence of defects in the material.

Our measurements have shown the existence of a certain correlation between the performance of detectors and the type of defects, namely:

- The use of a material with large inclusions of irregular shape does not allow for making detectors with good spectrometric characteristics.

- The use of a material with extended tubular defects of the "tube" or stick type does not, as a rule, allow for making the detectors with good spectrometric characteristics.

- The use of a material with aggregations of inclusions in the form of branched linear defects occupying the major part of a crystal considerably reduces the possibility of making high-quality detectors.

- Non-uniform distribution of inclusions worsens the performance of detectors.

- The presence in the central positive electrode region of exits to a detector's surface of defects in the form of pits or hillocks worsens the performance of a detector and decreases the value of its possible working voltage.

- No marked correlation has been observed between the number of uniformly distributed inclusions with a size less than 40 μm and the quality of a detector.

- The use of a material with individual large inclusions of regular geometric shape does allow, as a rule, to make detectors with good spectrometric performance.

References

1. C. Szeles, E. E. Eisler, Current issues of high-presure bridgman growth of semi-insulating CdZnTe", MRS Symp Proc., vol. 487, Warrendale, pp. 3-12, 1998.

2. J. R. Heffelfinger, D. L. Medlin, R. B. James, "Analysis of grain goundaries, twin boundaries and Te precipitates in $Cd_{1-x}Zn_xTe$ grown by high-pressure bridgman method", MRS Symp Proc., vol. 487, Warrendale, pp. 33-38, 1998

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