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Characterization of virtual Frisch grid detectors fabricated from as-grown CdZnTeSe ingots

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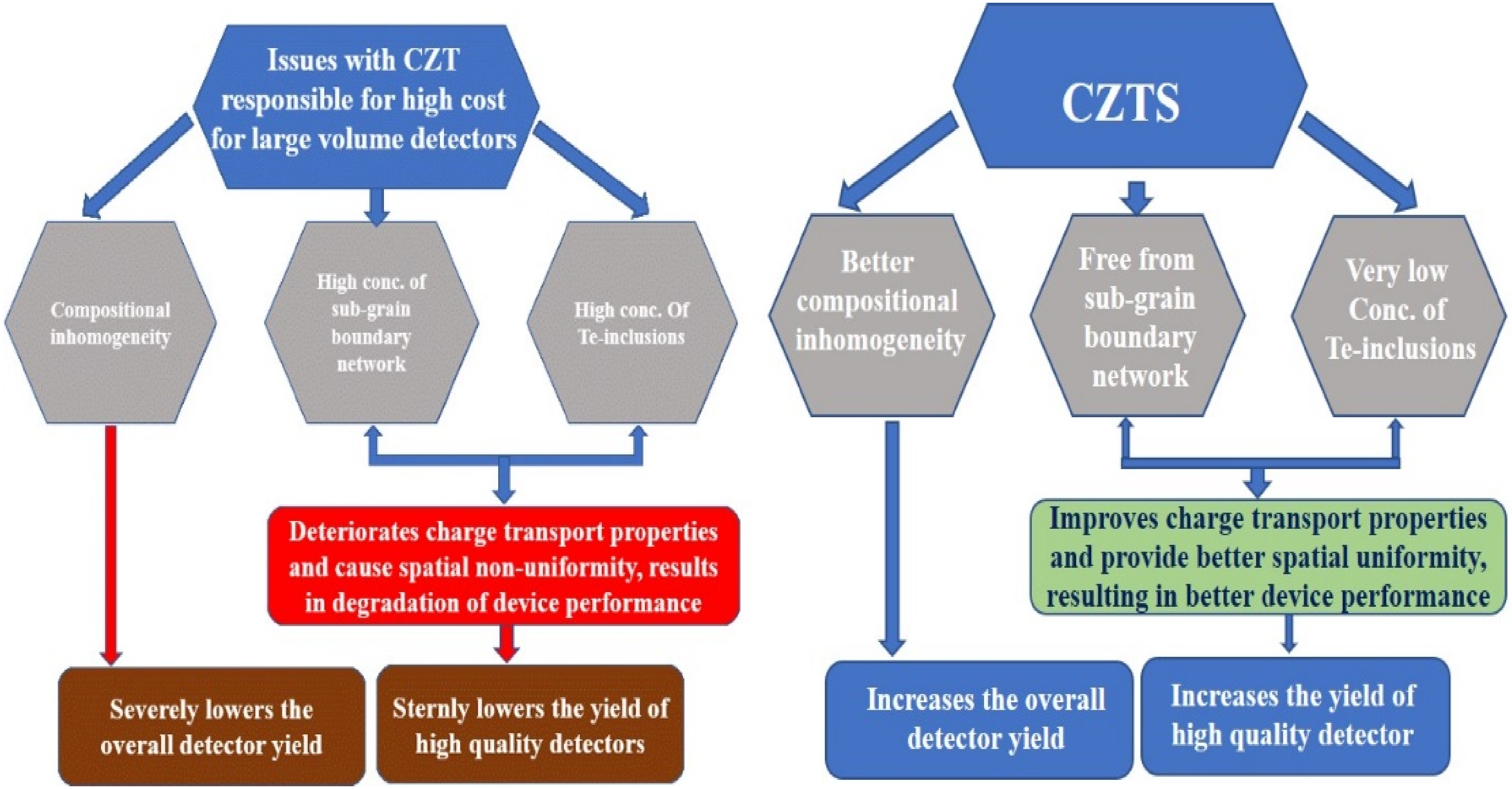
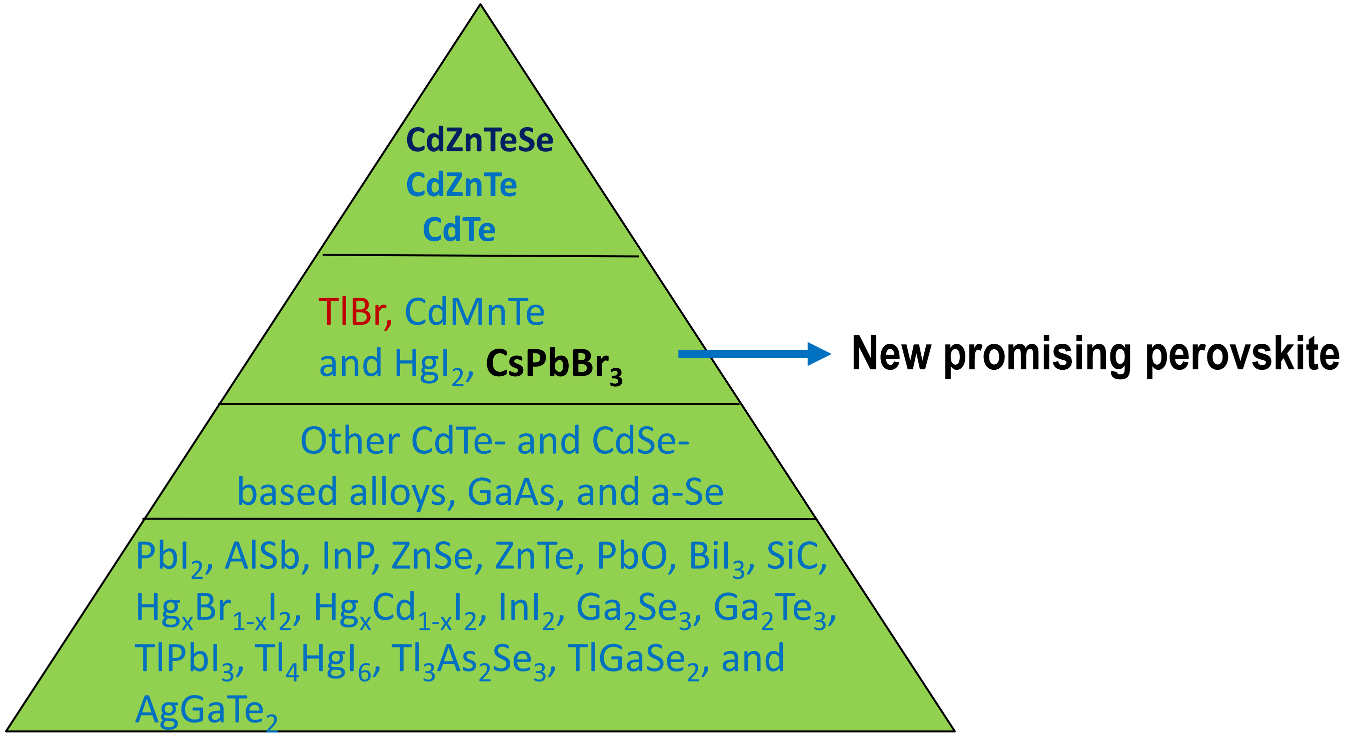
Competitiveness of CdZnTeSe in the present form



Benefits of Se in CdZnTeSe matrix at a glance

- Strong influence in modifying Zn segregation coefficient: better compositional homogeneity (about 90% of the ingot length) for THM-grown ingots.
- Effective solution hardening in arresting sub-grain boundaries and their network (free from sub-grain boundary network).
- Decreased concentrations of Te-inclusions/precipitates.
- Reduced thermal stress.
- Reduced Cd-vacancies.

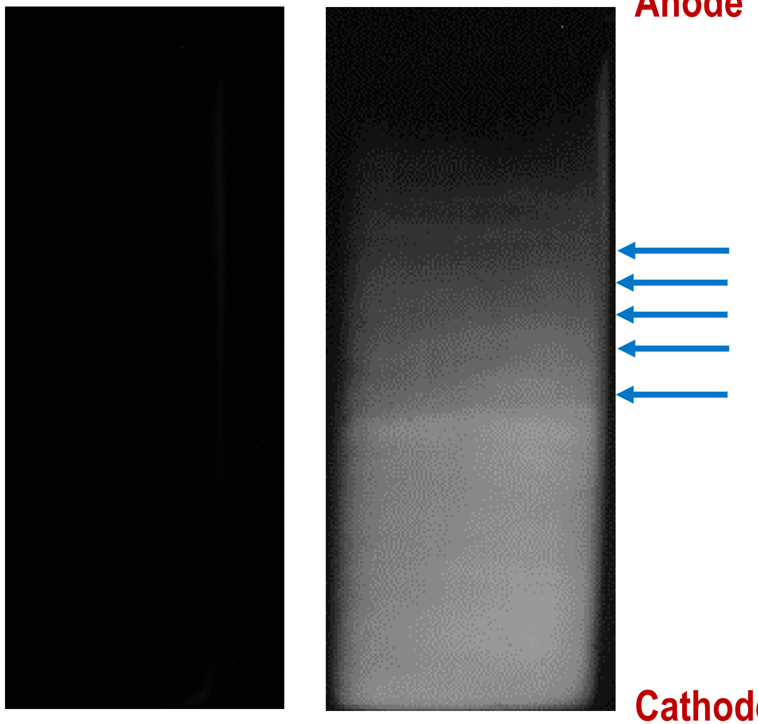
CdZnTeSe perhaps qualifies to be at the top of the pyramid of semiconductor detector family



First, some issues suffered by CdZnTeSe need to be resolved:

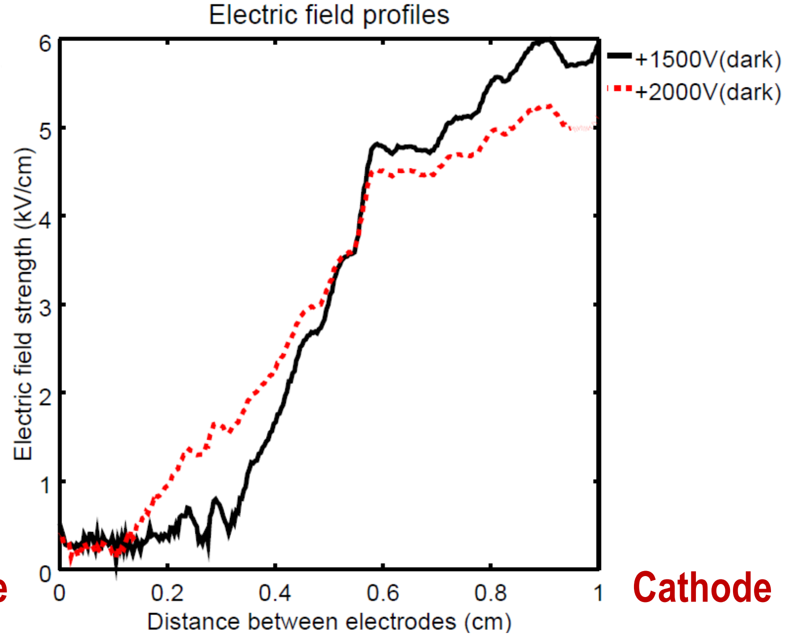
- **High concentrations of performance limiting impurities**
- **Striations**

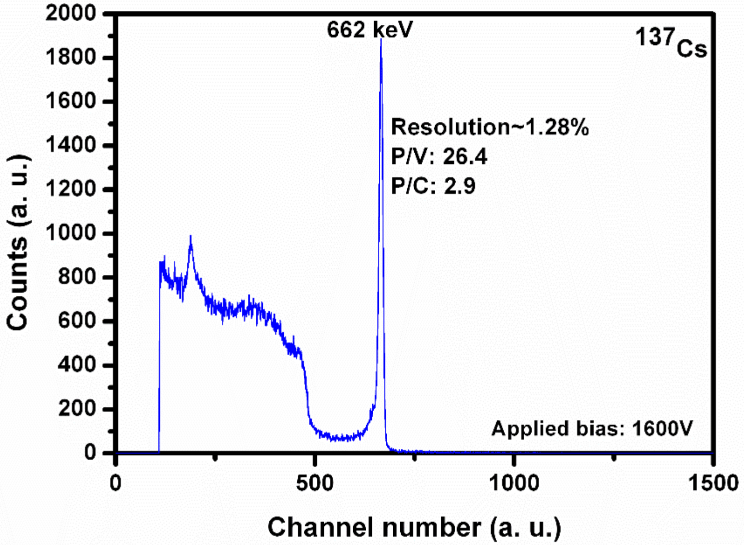
Detector performance: Detector #1



Crossed polarizers 0V Crossed polarizers, +2KV

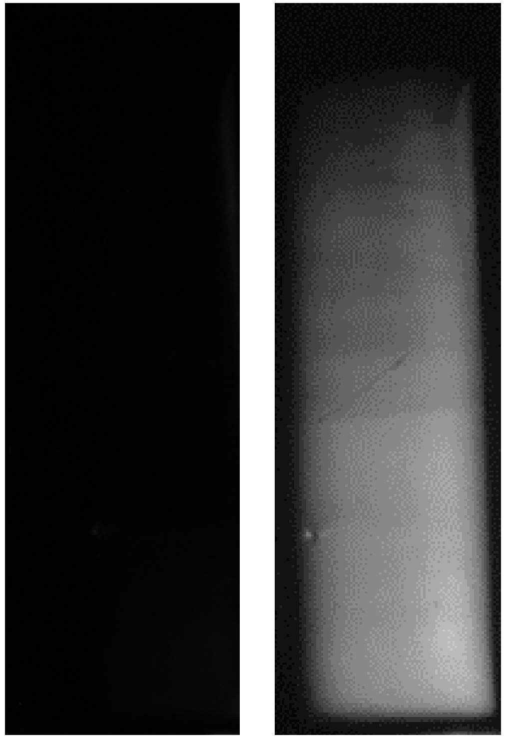
Detector dimensions: 4.4x4.4x10 mm^3





Detector performance: Detector #2

Anode

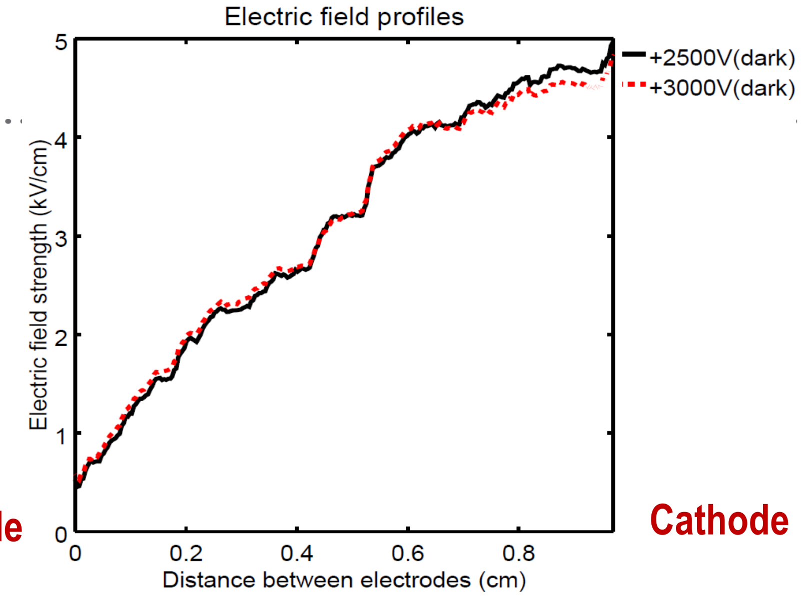


Cathode

Crossed polarizers 0V

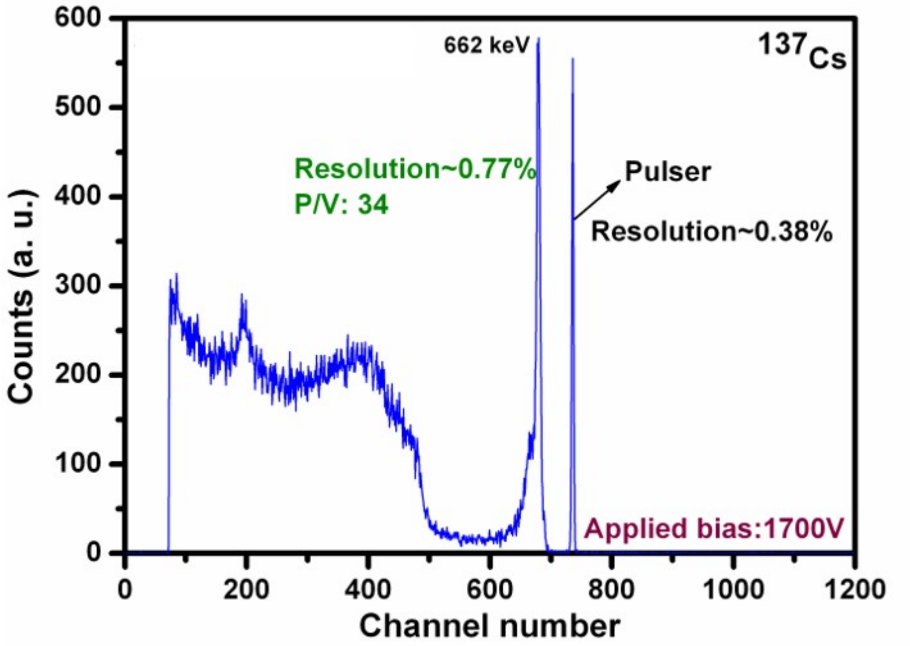
Crossed polarizers, +3KV

Detector dimensions: 3.5x3.5x9.15 mm^3



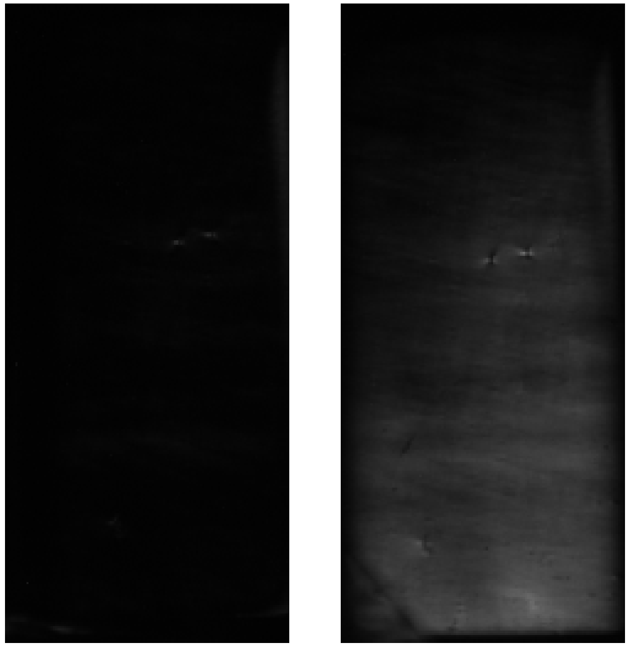
Anode

Cathode



Detector performance: Detector #3

Anode

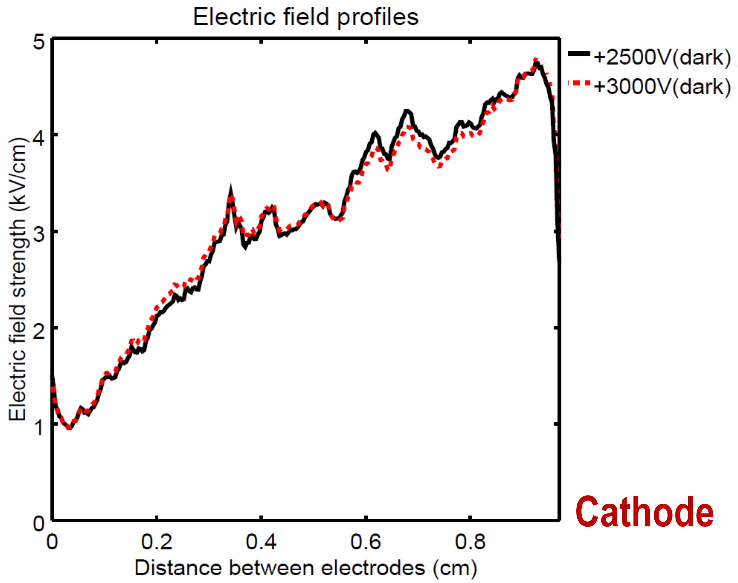


Cathode

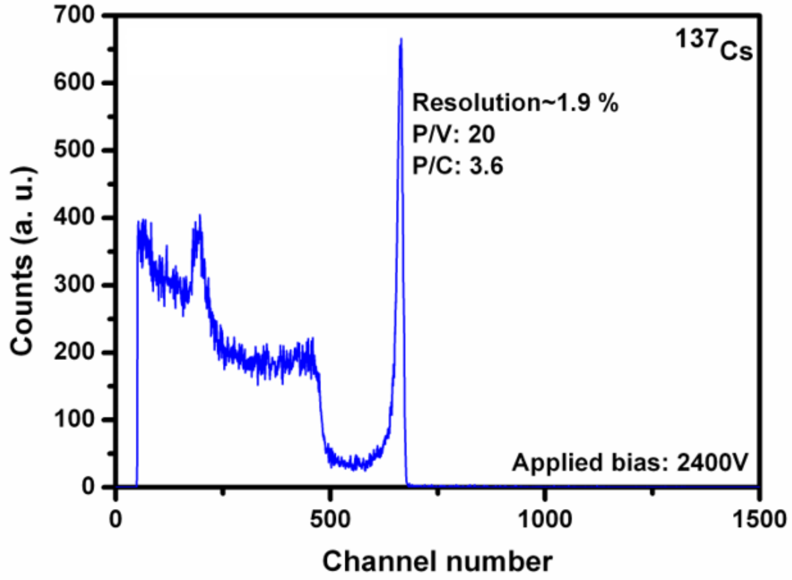
Crossed polarizers 0V

Crossed polarizers, +3KV

Anode



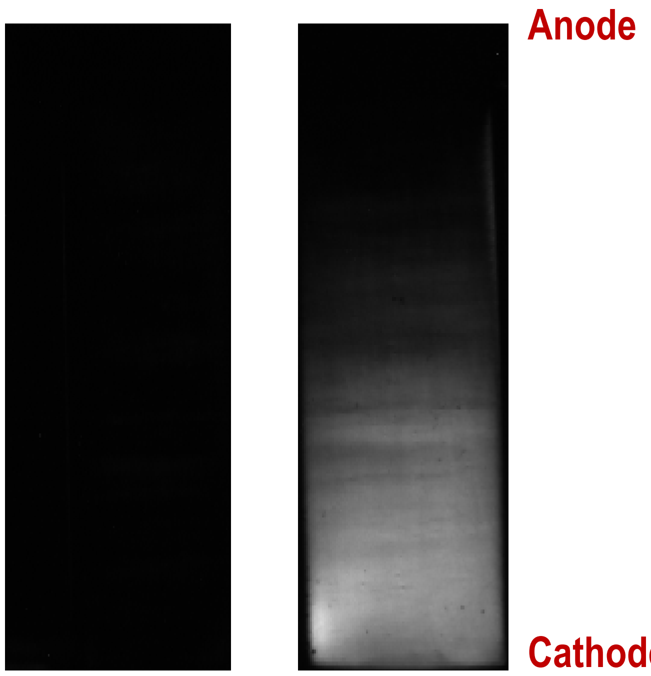
Cathode



Detector dimensions: 4.8x4.9x9.7 mm^3

Cross polarized IR transmission image for this sample depicts the presence of minor residual stress.

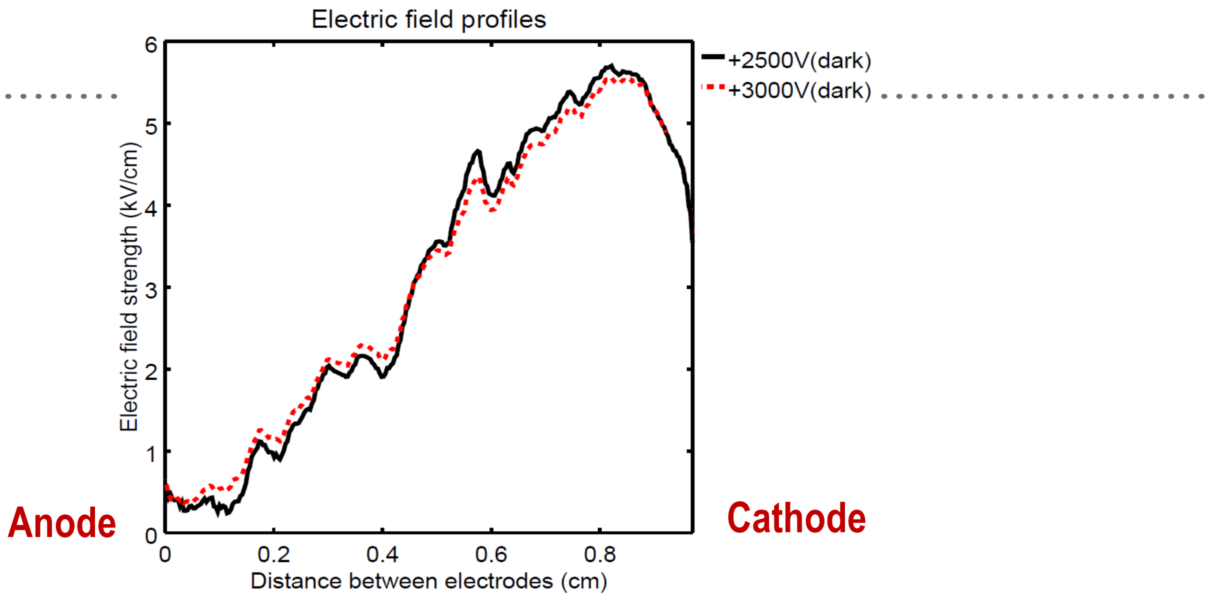
Detector performance: Detector #4

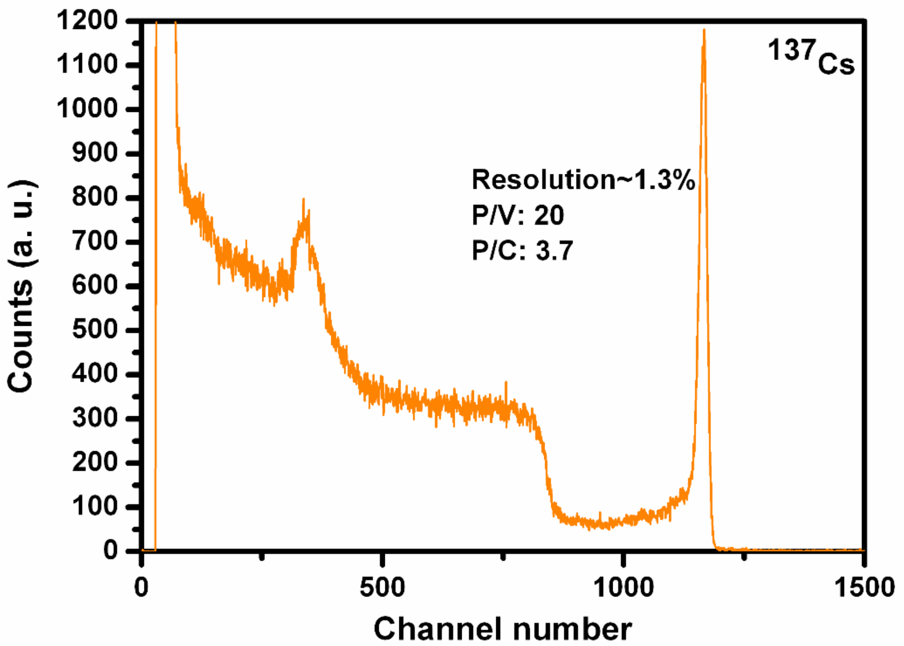


Crossed polarizers 0V

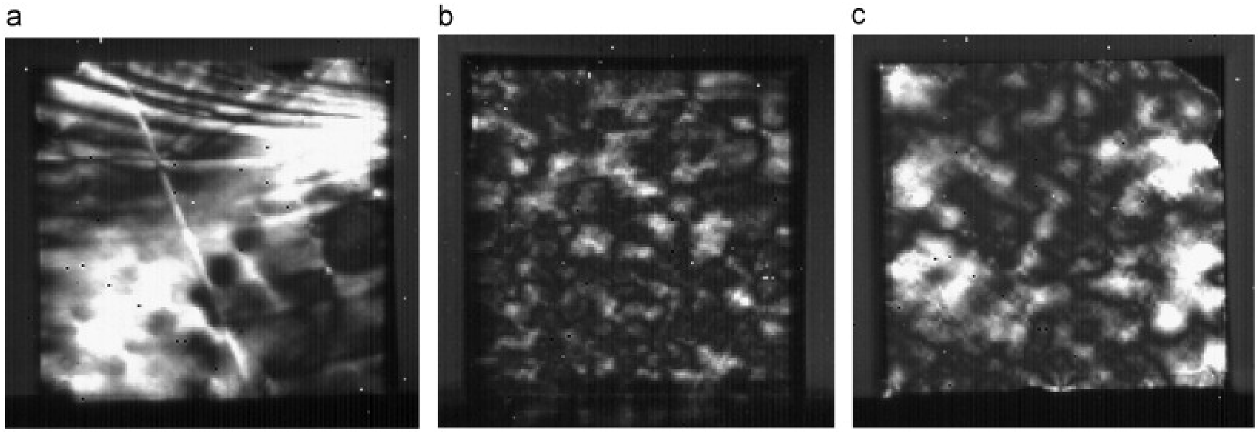
Crossed polarizers, +3KV

Detector dimensions: 3.4x3.6x9.7 mm^3





IR transmission under crossed polarizers



Cross polarized IR transmission images of three different THM-grown CZT samples with 100-mm^2 field of view.
S.A. Awadalla et al., J. Cryst. Growth 312 (2010) 507.

Cross polarized IR transmission image reveals the presence of residual stress in CZT samples.

Most of the CZTS samples did not show the presence of residual thermal stress based on IR transmission images.

Origin of striations ???

Presently the origin of the striations is not clear.

The striations might be due to compositional variations, such as dopant variations or structural imperfections. However, X-ray topography did not reveal structural imperfections.

Striations of dopants might arise due to the high aspect ratio (ingot length to ingot diameter) for melt-grown ingots.

In THM-grown ingots, the aspect ratio can be considered as the ratio of the molten zone length to ingot diameter. Thus, further studies are needed to understand the effects of molten zone length on the THM growth. We believe the issue might be resolved for three-inch diameter THM-grown ingots, as for larger diameters, the ratio of the molten zone to the ingot diameter will be drastically reduced which should decrease the formation of dopant striations.

Impurity analyses of THM grown CZTS

6N purity CZT (raw material)

CZT 1

Element	Concentration [ppb at]
Cr	<3
Fe	34
Ni	<5
Cu	<15
Sn	<45
Pb	<2

CZT 2

Element	Concentration [ppb at]
Cr	<3
Fe	110
Ni	<4
Cu	<8
Sn	<30
Pb	<2

6N purity $Cd_{0.9}Zn_{0.1}Te_{0.98}Se_{0.02}$ grown by THM

Ingot #1

Element	Concentration [ppb at]
Cr	<20
Fe	42
Ni	<4
Cu	22
Sn	<100
Pb	10

Ingot #2

Element	Concentration [ppb at]
Cr	36
Fe	42
Ni	16
Cu	<4
Sn	<100
Pb	11

The impurities present in THM-grown $Cd_{0.9}Zn_{0.1}Te_{0.98}Se_{0.02}$ are 3-8 times higher compared to CZT raw material.

While for commercial THM-grown CZT contain (ppb at):
Cr-ND, Fe-22, Ni-ND, Cu-ND

ND- Not Detected

J.J. McCoy et al., J. Electronic Materials 48, 4226 (2019).

Most of the impurities are expected to originate from the CdSe raw material.

5N Plus has provided us high-purity CdSe, and we expect that could help with the growth of higher purity CZTS.

Can we further improve the detector performance of CZTS?

We strongly believe the detector performance can be further improved:

i) By using high-purity CdSe raw material
ii) Optimizing the growth parameters to reduce the striations in the as-grown ingot. We believe this issue will be resolved for three-inch diameter ingots.

Acknowledgement

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Thank you for your kind attention !