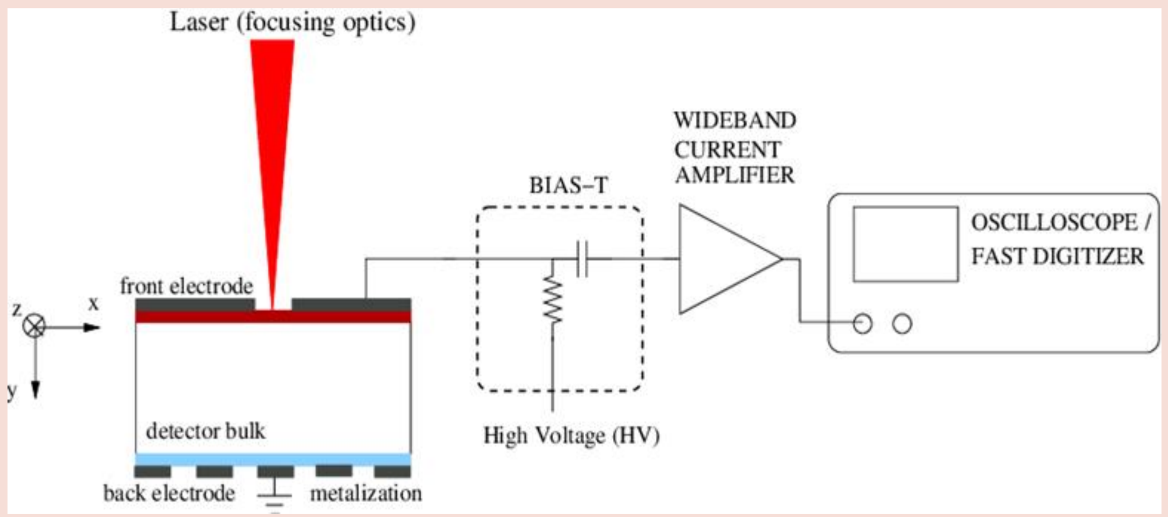
Polarization effect in $Cd_{1-x}Zn_xTe$ and $Cd_{1-x}Mn_xTe$ detectors under various biasing conditions

O. Amzallag[1], L. Chernyak[2], A. Ruzin[1]

1 Faculty of Engineering, School of EE, Tel Aviv University, Tel Aviv 69978, Israel

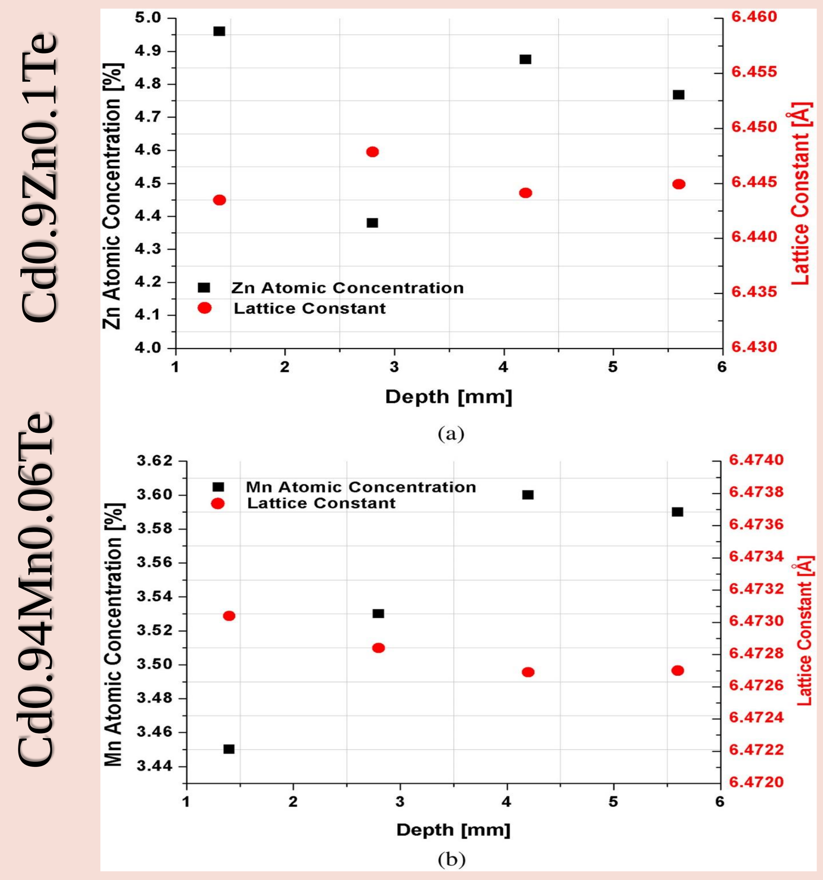
2 Department of Physics, University of Central Florida, P.O. Box 162385, Orlando, USA

Wide bandgap alloys of II-VI group materials are widely used for gamma-photon detection. The more established CdZnTe alloy is recently being challenged by CdMnTe, which shown improved uniformity and wider tunable bandgap. These compounds mostly owe their high resistivity to deep level compensation process (Fermi level "pinning"). Therefore, such compound "semi-insulators" have high densities of traps. In spite of that fact, such detectors exhibit reasonable charge collection. However, when they are exposed to high fluxes, considerable polarization is often observed. The later occurs due to high volume trapping, leading to modification of internal electric field. In this work we present the polarization differences in CdZnTe and CdMnTe devices grown by the same method. The study is performed by reconstruction of electric filed, using improved TCT method.



Transient Current Technique system

A pulse laser illuminates the detector through the front contact and creates charge carriers near it. The charge carriers drift in the presence of a field. Their movement creates induced current in contacts, which is the output of the system. We applied negative voltage to measure electron movement.



The crystals grown by the vertical Bridgman method and provided by GE Healthcare. The approximate dimensions of 20 x 20 x 5 mm^3. Using indium evaporation M-S-M devices with ultra-thin (semitransparent) top contacts were created.

Mechanisms affected by the polarization:

Populating the traps

The reconstructed electric field from the measured current pulses

According to Shockley-Ramo theorem, the relationship between the instantaneous induced current and the electric field is:

$$I_{e,h}(t) = q\vec{v}(\vec{r}(t)) \cdot \vec{E}_w(\vec{r}(t)) = N_{e,h}(t) \cdot e^{\frac{t}{\tau_{eff,e,h}}} \cdot \mu_{e,h} \cdot \vec{E}(\vec{r}(t)) \cdot \vec{E}_w(\vec{r}(t))$$

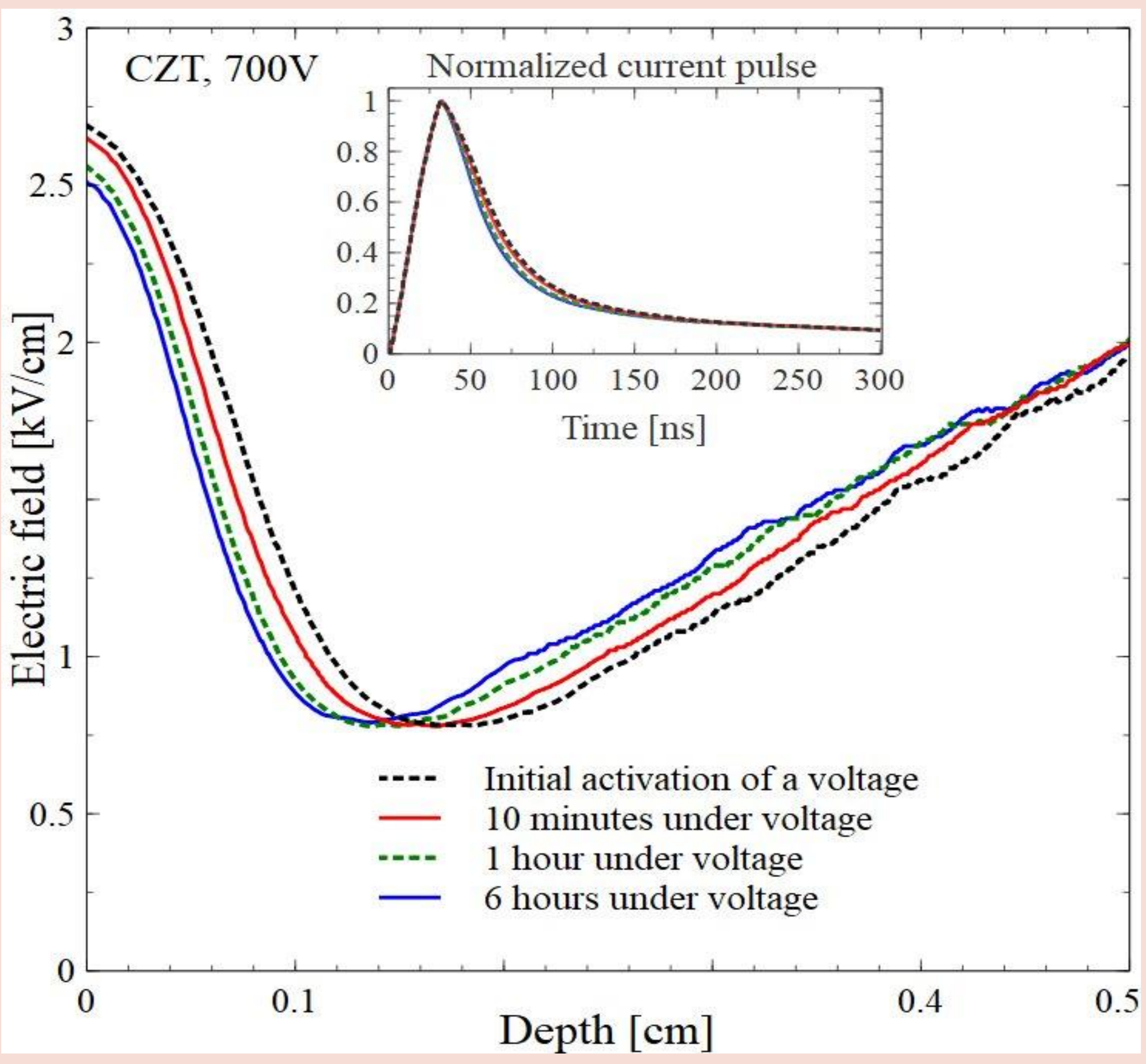
where, $\vec{v}$- charge carrier velocity, $\vec{r}$- location of the charge carrier, μ- mobility, $\vec{E}_w$- the weighting field given by the in the detector.

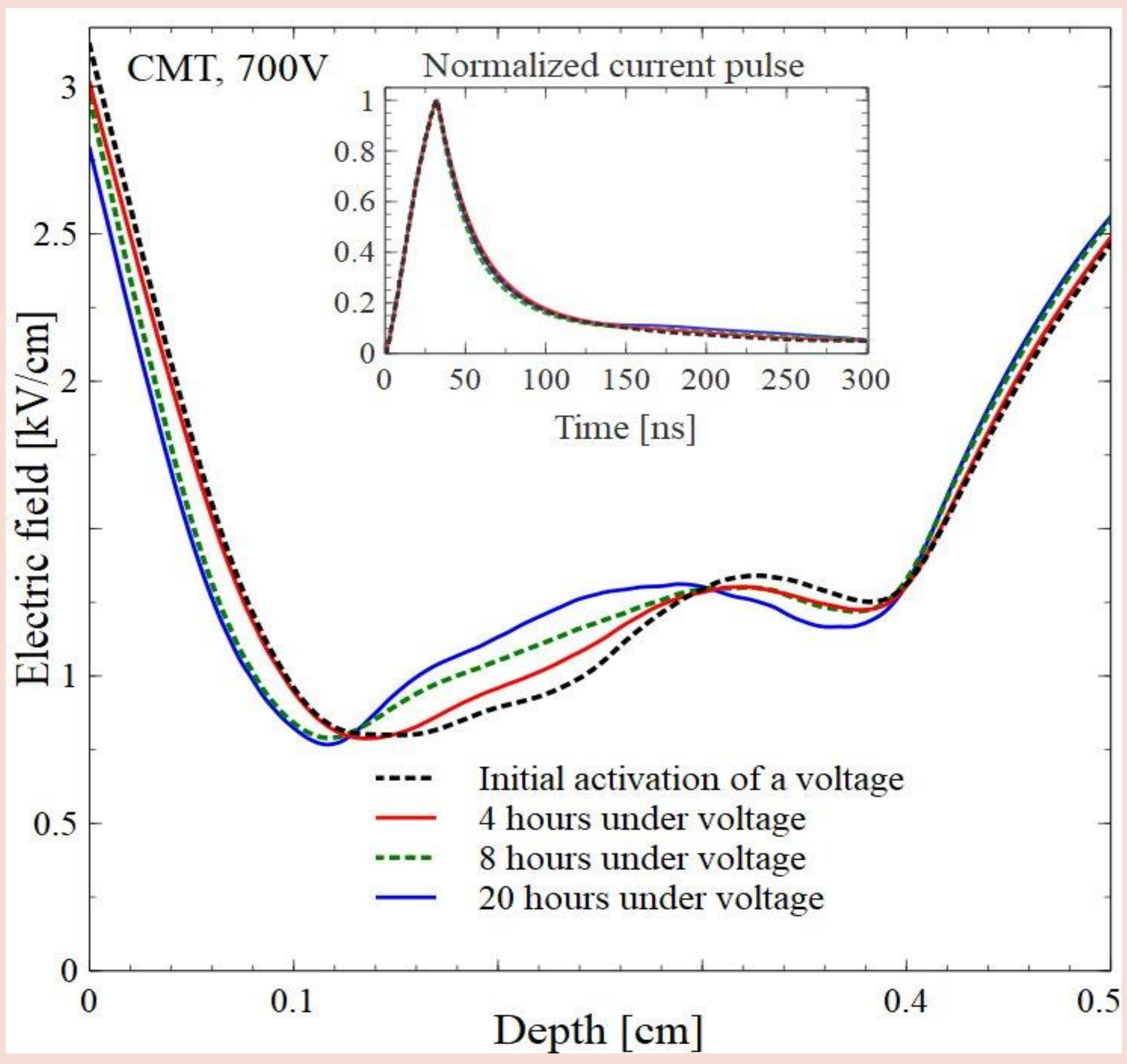
life time, $\tau_{eff,e}$, was extracted from lower voltage measurements. Estimated electron's mobility: $\mu_e = 1000\frac{V \cdot s}{cm^2}$.

CZT

CMT

Voltage of (-) 700V is on





Absorption depth [cm]		0	0.125	0.25	0.375	0.5
$\frac{CCE_{ss}}{CCE_i}$	CZT	1.063	0.912	0.905	0.881	0.841
	CMT	1.051	1.146	1.098	0.820	1.002

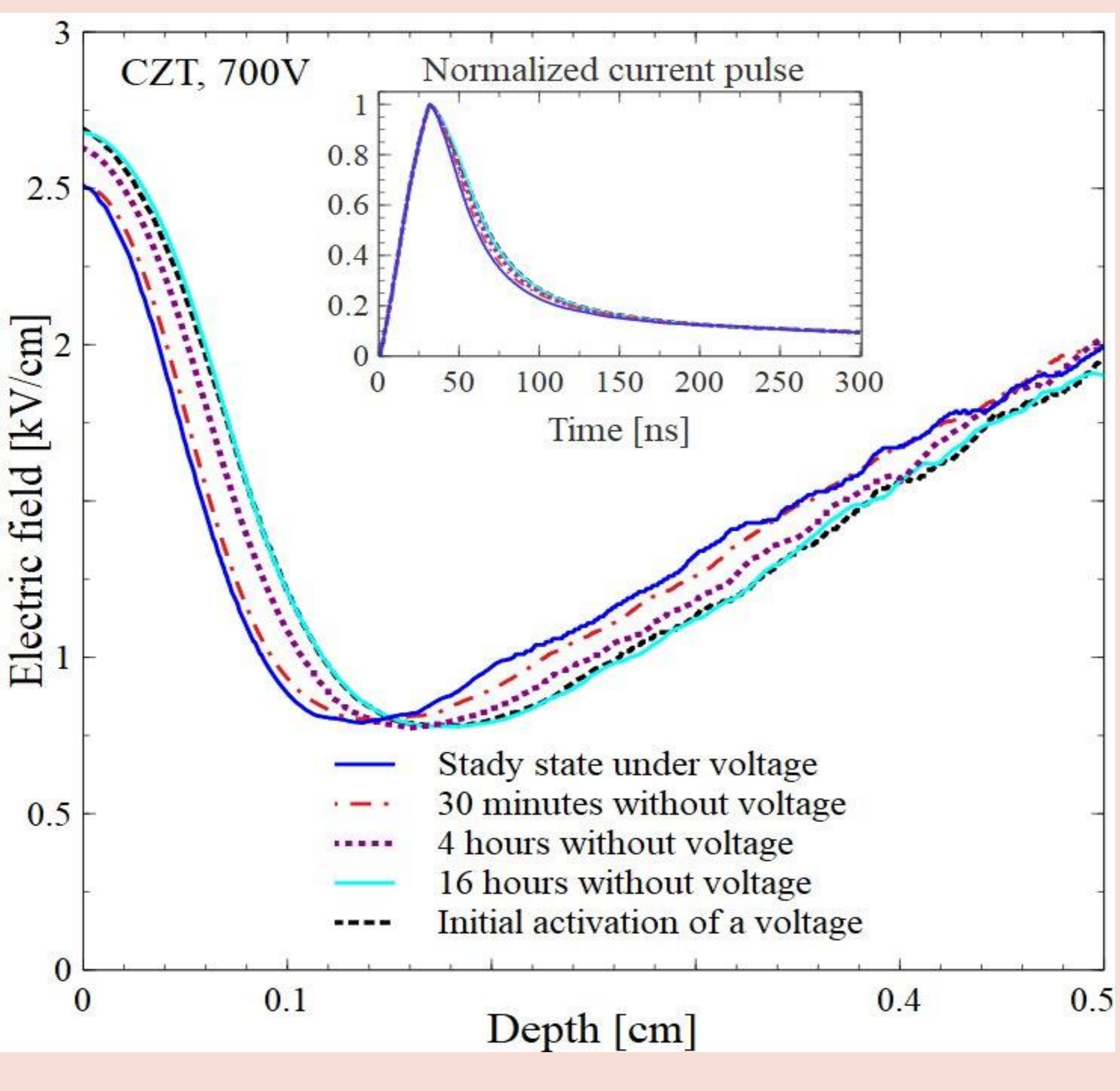
$$\frac{CCE_{CZT}}{CCE_{CMT}} = 1.25$$

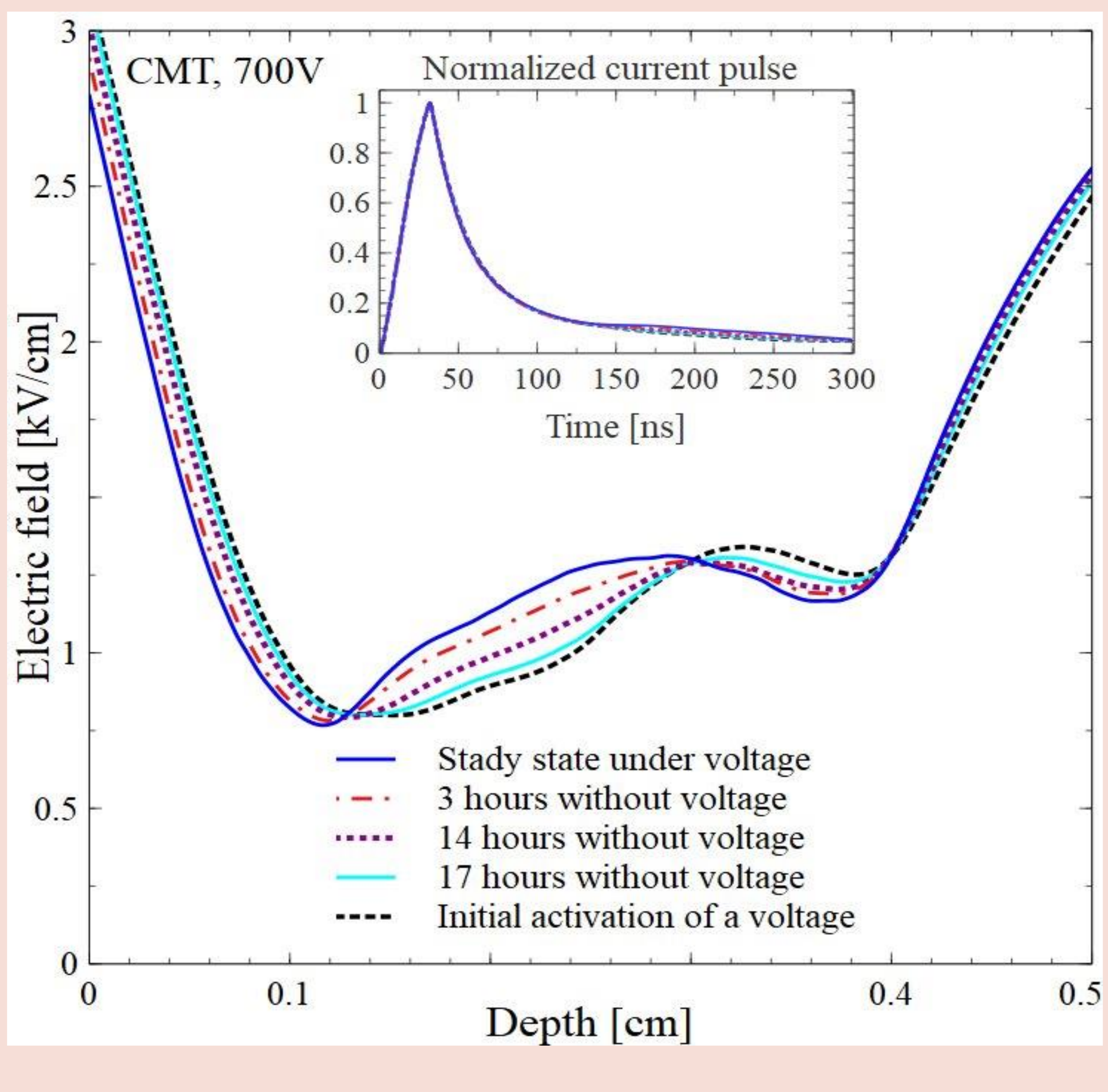
Maximal change in CCE:

→ for 0.5 [cm] absorption depth there is a decrease of 15.9 %

→ for 0.375 [cm] absorption depth there is a decrease of 18 %

Voltage is off between measurements





Recombination in the front electrode (near the generation area)

Alloy	$\frac{Q_{ss}}{Q_i} = \frac{I_{ss,(max)}}{I_{i,(max)}} \cdot \frac{E_{i,(x=0)}}{E_{ss,(x=0)}}$
CZT	1.425
CMT	1.452

For measured results, laser absorption near the front contact (x=0).

For both alloy, the CCE increased by at least 42%

The effect of recombination in the front electrode is significant for a shallow radiation absorption - low energy gamma rays, alpha, low energy x rays.

- U-shape of the field distribution is expected, as the detectors produced uniformly and underwent annealing treatment.
- The asymmetry in the electric field around the center of the detector (0.25 [cm]) can be a result of limit recombination velocity in the contact or no uniform absorption and mobility.
- In CZT, the stabilization under voltage is faster than in CMT.
- The duration of depolarization is similar in both detectors (16 /17 hours).
- In CZT, the electric field near the front contact becomes lower and higher near the back contact under voltage.
- In CMT, the main change in the electric field is in the detector's depth.

The effect of populating the traps under voltage is significant for a deep absorption - high energy gamma rays and high energy x rays.

The CCE in CZT is 25% greater than in CMT. The effect of polarization on the characteristics of CZT and CMT detectors, must be taken into account. Especially when it comes to a shallow radiation absorption.

Future research: Polarization effect in $Cd_{1-x}Zn_xTe$ and $Cd_{1-x}Mn_xTe$ detectors under radiation.