ANALYSIS AND CHARACTERIZATION OF CdTe Material Surface Defects

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INTRODUCTION

- CdTe is a optimal material for X-ray, γ detection due to the high atomic number, wide band gap, and ability to operate on room temperatures
- However, the material is very brittle, processing temperature has to be kept below $200^{o}C$,and it is difficult to grow as it is never fully mono-crystalline
- Crystallographic defects such as grain boundaries, twins, tellurium (Te) inclusions affect detector performance
- We employed layers of Aluminium Oxide (Al_2O_3) grown by Atomic Layer Deposition on single, semi-insulating CdTe crystals
- Metal contacts were created by RF magnetron sputtering of 20nm Ti, $Ti_{0.1}W_{0.9}$ metal layers

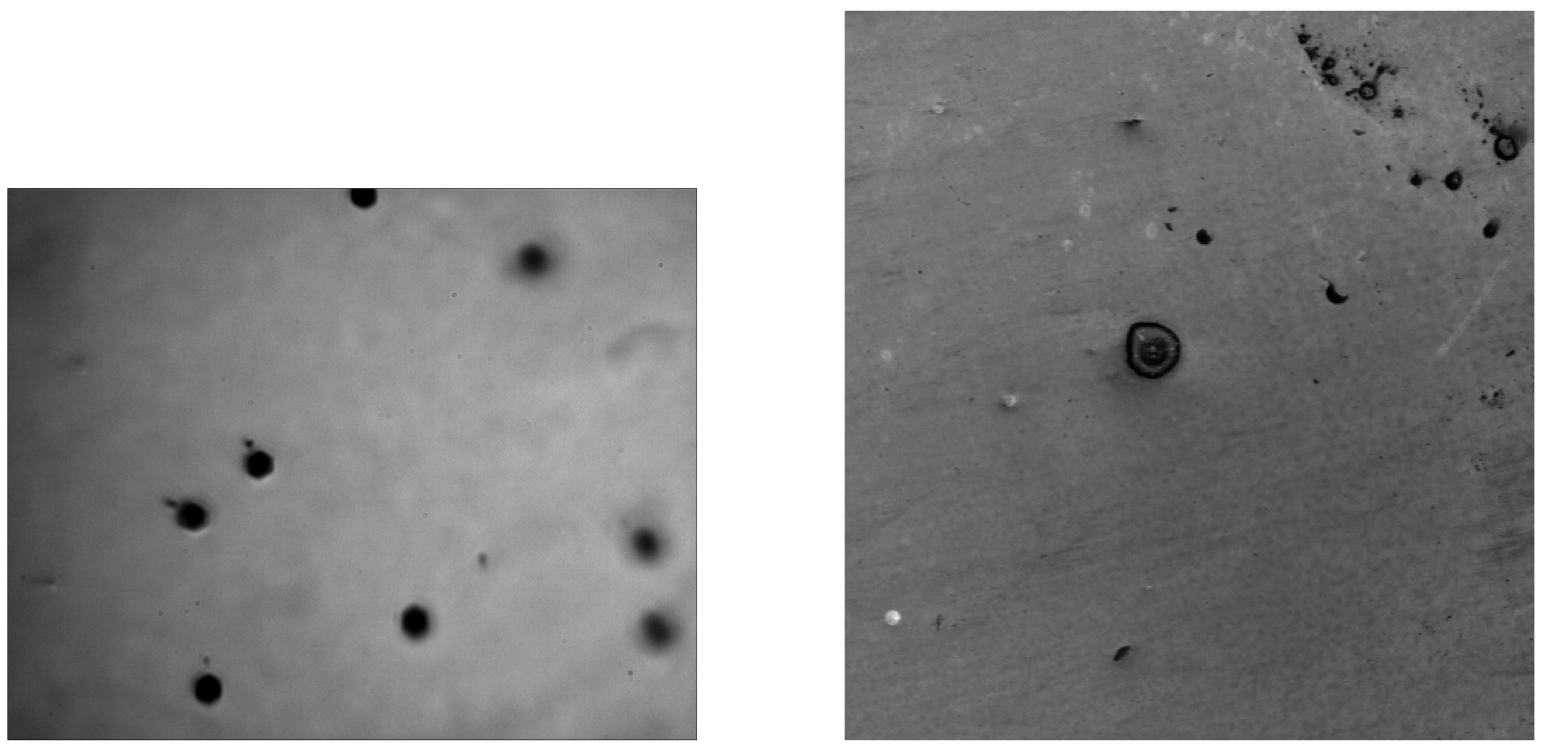

Figure 1: a) Infrared image of an area (200x160 μm) close to the CdTe crystal's surface b) Electron Microscope image of CdTe surface, here due to the slightly higher atomic number, Te inclusions appearer lighter.

OBJECTIVES

- High dielectric constant and dielectric strength of Al_2O_3 layer separates the signal from the significantly increased leakage currents caused by various defects in the detectors material
- Negative fixed charge can be achieved by choosing water as the source of oxygen
- Hydrogen, released in the growing process, affects the interface by removing the native Te-Ox oxides
- Moreover, pulsed cycles of Trimethylaluminum (TMA), before the growing process, directly reduce the native oxides and therefore help alumina to build up more fixed, negative charge on the Tellurium side

MEASUREMENTS

- I-V characteristics of processed Schottky diodes were measured in the dark while operating the devices at different temperatures
- Current waveforms induced by an 660 nm focused laser were studied as well
- Electron/ hole pairs are produced at the depth of a few micrometers from the surface which gives great opportunity to study the semiconductor- metal as well as the CdTe-Al_2O_3 interface

RESULTS

- All measured diodes show rectifying properties
- Second electron breakthrough was observed on all structures containing Al_2O_3 layer

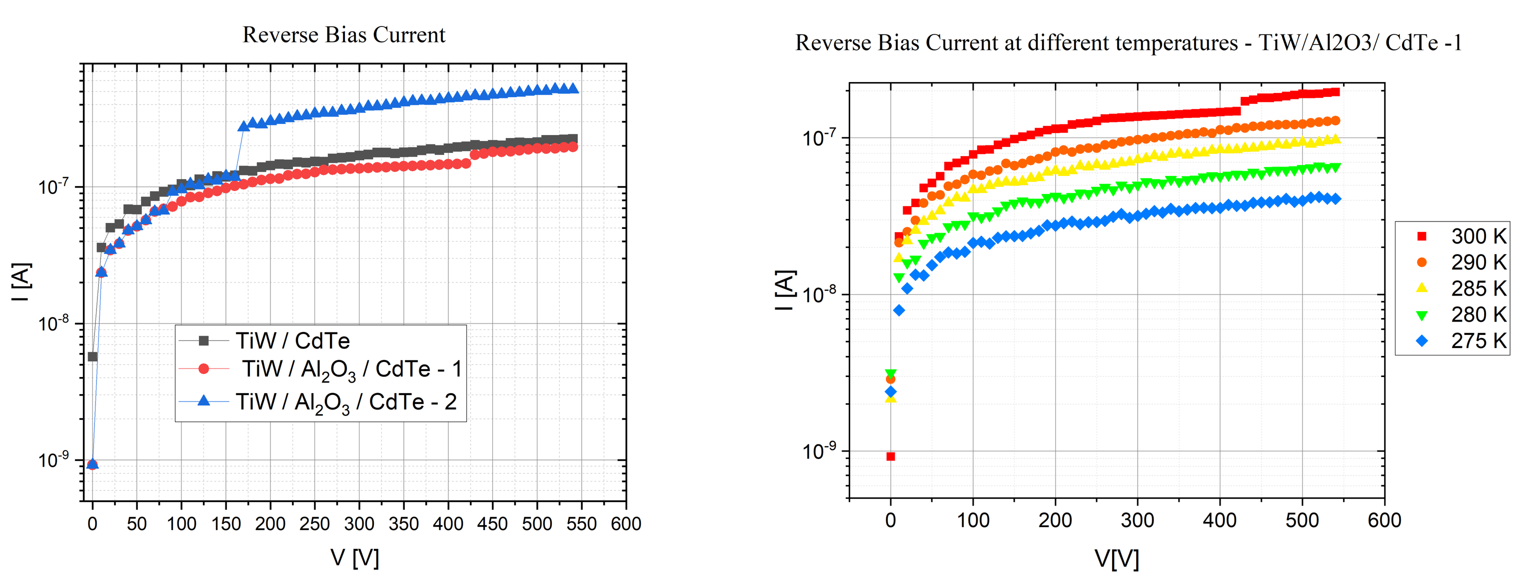

Figure 2: a) Room temperature I-V characteristic of TiW/CdTe/TiW, and TiW/Al_2O_3/TiW Schottky detectors. Second electron breakthrough depends on the trapped negative space charge b) Reverse current at different temperatures.

- Indicated strong temperature dependence, and relatively, low leakage currents, imply to a **high resistivity CdTe** detector material with a successful semiconductor metal interface
- While processing the metal contacts, and establishing the interface, it is important to control the working pressure to prevent self-abasement and island building - otherwise, dark currents are in order of mA
- Leakage current decreases with lowering the temperature. According to the theory, intrinsic carrier concentration n_i are located closer to the middle band gap and therefore the proportional current is lower
- Square-root region was observed for 10-150V region - indicates **generation-recombination mechanism** as the **main charge carriers transport mechanism**

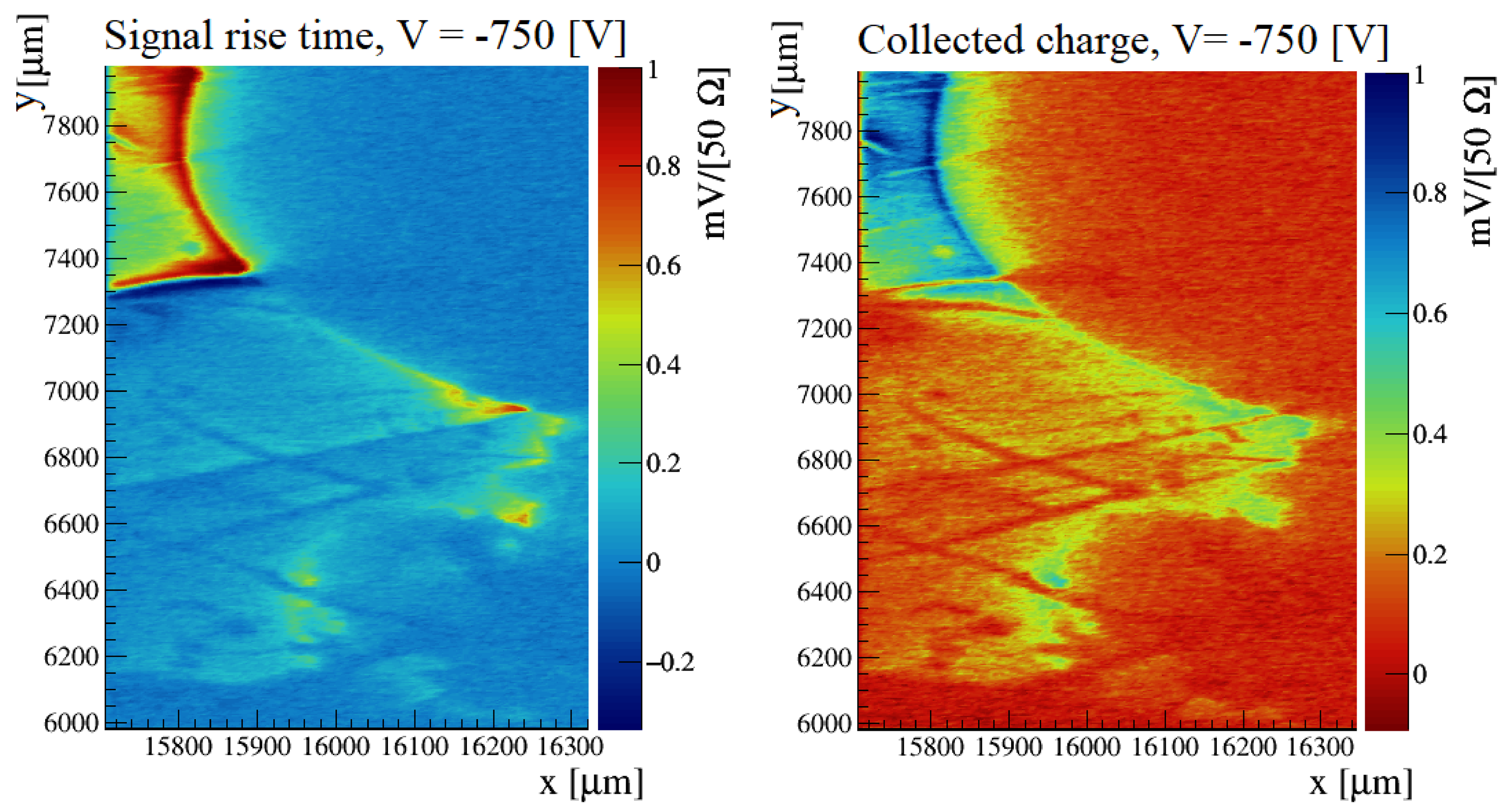

Figure 3: Transient current obtained at room temperature. a) Rise time of negative signal (normalized). Areas of opposite signs indicate current signals of opposite charge carrier.
b) Integral of current signal at t=14 ns, when the localized charge under the metal changes signs - localized electrical field gets distorted.

- Areas of uneven, high amplitude rise are areas where we experience laser light scattering (increase of charge) from metal atoms being deposited on a grain boundary

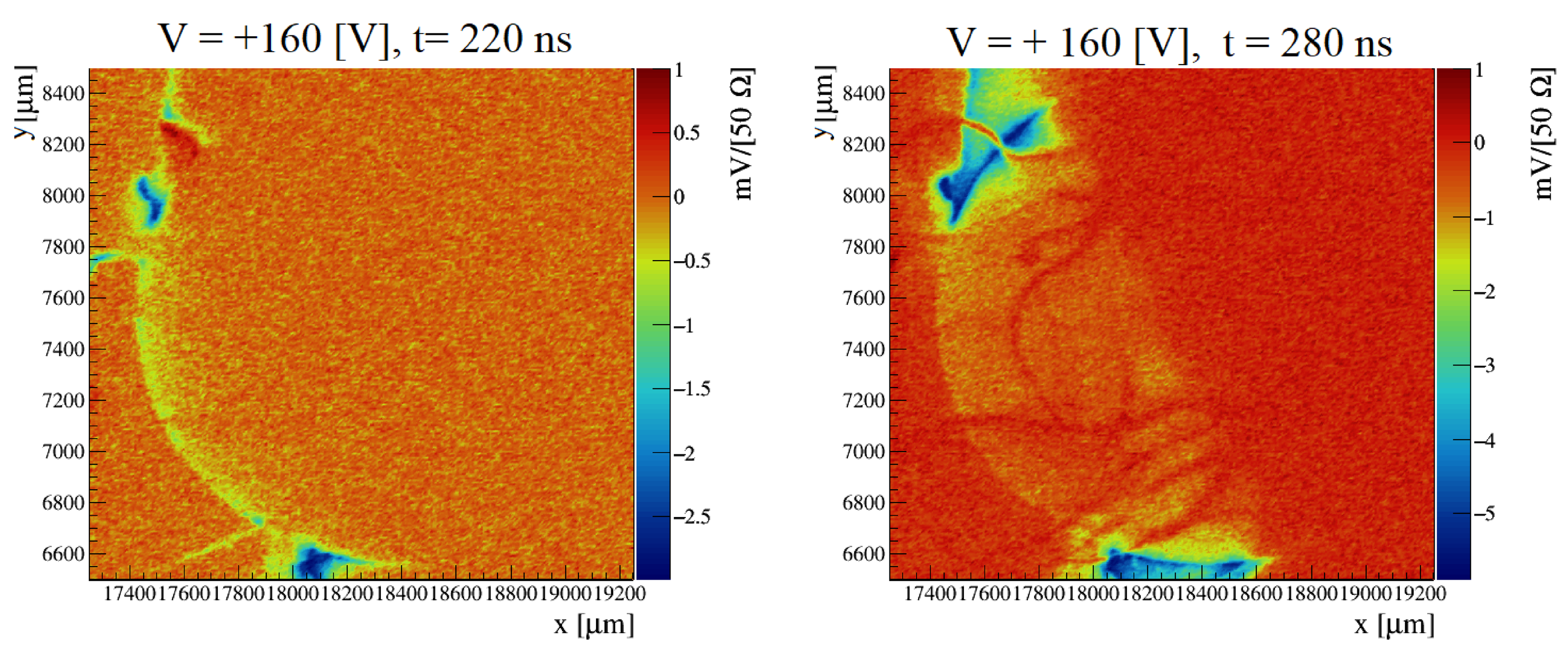

Figure 4: Transient current at room temperature with positive voltage applied. Signal is dominated by current generated by electron movement

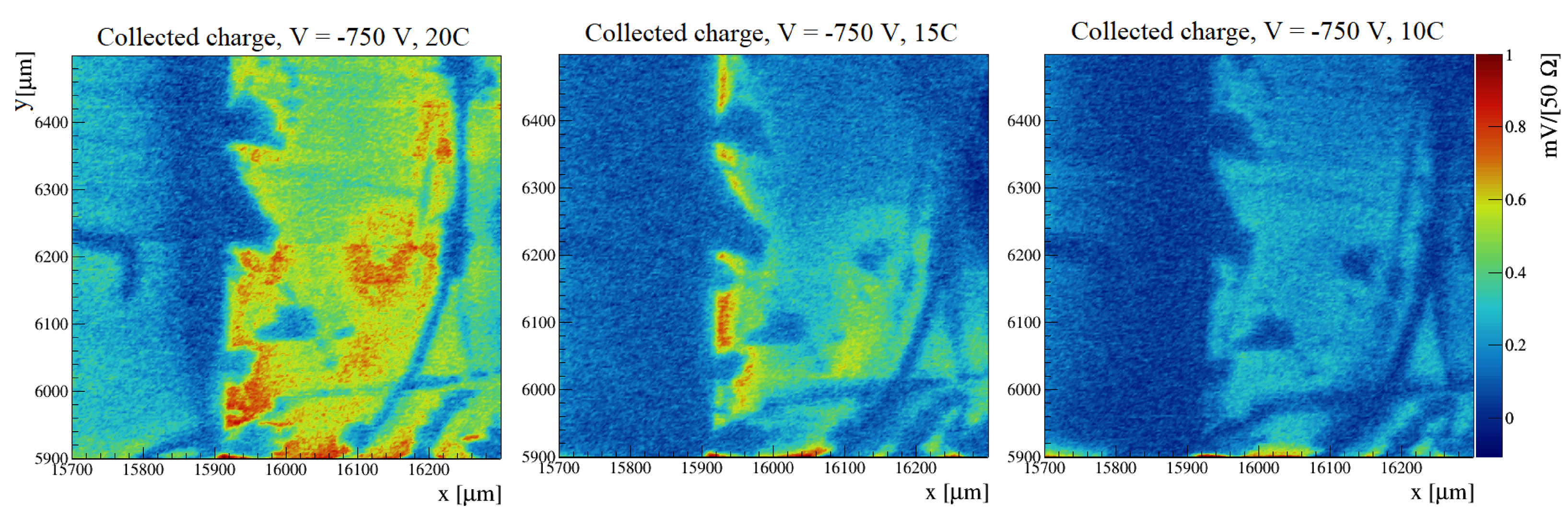

Figure 5: Transient current at different temperatures. Carrier concentration and mobility are reduced while the Tellurium inclusions are getting more pronounced.

CONCLUSION

- Al_2O_3 reduces the polarization and accumulation on positive charge under the cathode
- IV measurements show lower leakage currents, but second electron breakthrough is seen as in measurements
- Reducing the temperature, intrinsic carrier concentration reduces, while the charge traps are get more pronounced - mobility changes, and electrical field from localized points can be extracted

REFERENCES

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[2] A. Gädda et al., Nucl. Instrum. Meth. A 924 (2019).