Effect of Surface Passivation of CZTS Semiconductor Detector on Leakage Current

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Introduction

Cadmium Zinc Telluride Selenide (CdZnTeSe or CZTS)has shown high crystal quality for room-temperature gamma ray and X-ray detection applications compared to Cadmium Zinc Telluride (CdZnTe or CZT) [1,2]. Current applications of CZT include medical imaging, homeland security, and X-ray and gamma ray astronomy [3]. CZST has similar potential applications.

CZT has performance limitations due to high tellurium inclusion and sub-grain boundary network and other impurities that affect detector performance. The addition of Selenium (Se) to form r CZTS to addresses some of these challenges [1,2]. Surfaces preparation methods such as polishing can be a source of undesired leakage current. Surface passivation with oxides can help contain the leakage as well improve long-term stability [4].

The long-term effects of surface passivation with different passivating solutions were evaluated by taking measurements of the current vs applied voltage and over a period of one year for three detector samples using different passivation chemical, of CZTS grown by the Bridgman technique.

CZTS Crystal Passivation and Characterization Methods

Fabrication of the CZTS Crystal

- A CZTS crystal was grown using the Bridgman growth method. Figures 1 a and 1b show the growth furnace and the grown CZTS ingot.
- Three samples were prepared and coated with gold on the top and bottom to form planar detector geometry.
  - DET# M2 (7.23x6.33x1.55)mm^3
  - DET# M3 (6.54x6.18x2.43)mm^3
  - DET# M4 (6.54x6.18x2.43)mm^3

Surface Passivation

- Samples were cut and polished.
- Surface polishing creates a smoother surface.
- These samples were then passivated with three different solutions:
  - i) 15 wt% KOH in DI water solution for 40 minutes
  - ii) 10 wt% NH_4F + 10 wt% H_2O_2 in DI water for 20 minutes
  - iii) 50% by vol. H_2O_2 + 50% by vol. DI water + 1.5 Wt. % KOH
- Surface passivation (oxide coating) aims to reduce surface conductivity (insulation), reduce surface defect states as well as to prevent detector degradation over time.

Current/Voltage Measurements

- The setup for current/voltage (I-V) measurements is shown in Figure 2. Due to the sensitivity of the measurements with currents in nA range, the sample is enclosed in a thick shielded iron case and covered in a black cloth while measurements are carried out.
- The results over the year are shown in the I-V graphs Figures 3a, 3b, and 3c for M2, M3, and M4 samples.

Chemically Passivated CZTS, Experimental Setup, and Results

Figure 1. Bridgman Method Furnace

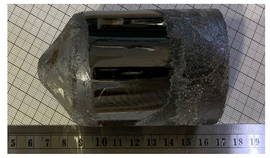

Figure 2. CZTS ingot grown using the Bridgman method

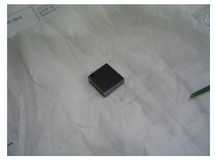

Figure 3. CZTS sample cut and polished

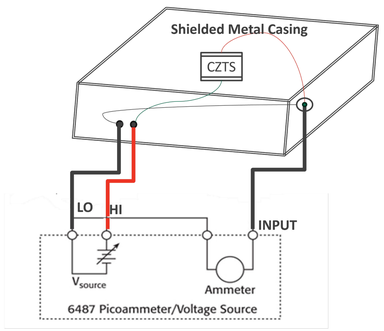

Figure 4. Setup for the CZTS current/voltage characterization

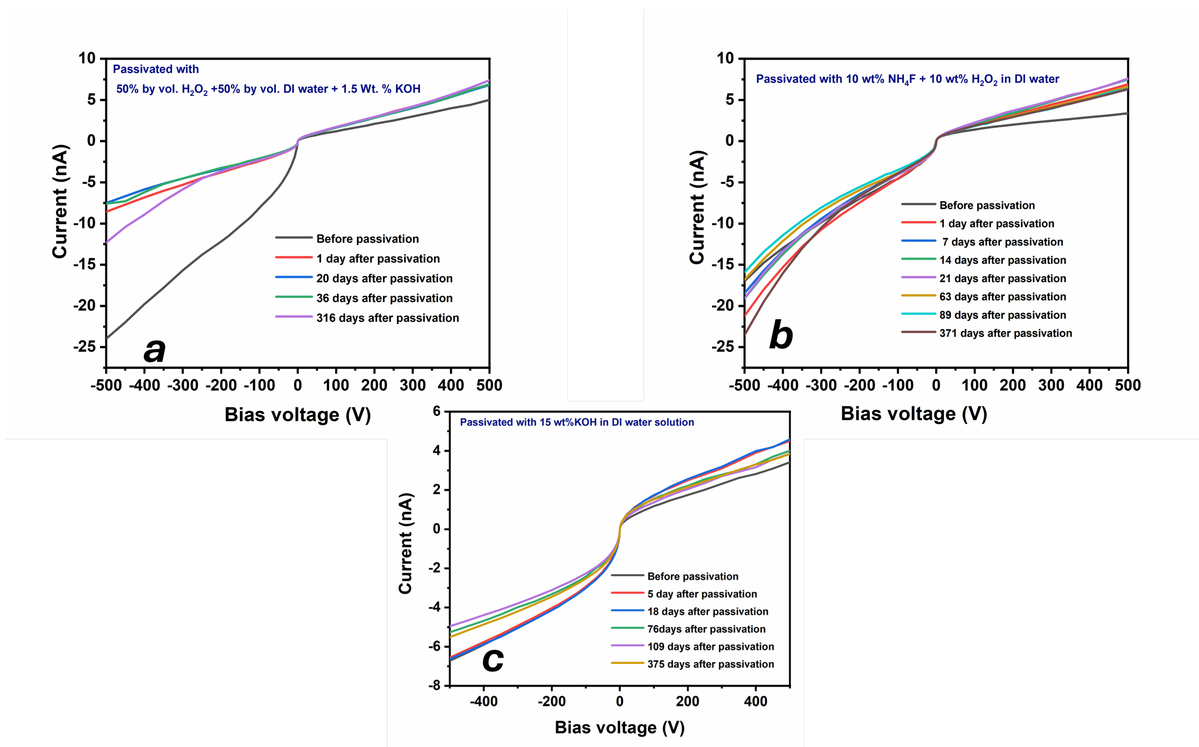

Figure 5. I-V Characteristics of three different CZTS samples with different passivation chemicals

Conclusion

The current vs voltage plots for the three samples (M2, M3, and M4) taken over a period of one year are shown in Figures 5a, 5b, and 5c. Drastic reduction of current was observed for the sample passivated with 50% by vol. H_2O_2 + 50% by vol. DI water + 1.5 Wt. % KOH solution.

Since the bulk of the CZTS wafer remains the same, the changes in the observed current are because of the effects of the passivation chemicals on the surfaces.

The long-term study shows the currents to be steady over this period proving stability of the detector over time.

Future studies will be continued monitoring the long-term performance of the three samples.

References

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