Design, Fabrication, and Characterization of Multilayer Thin Film Solid State Batteries

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INTRODUCTION

Abstract: Thermoelectric materials generate electricity from temperature gradients. Thin film batteries (also called micro batteries) are solid-state batteries comprised of anode, cathode, and electrolyte layers. These solid-state batteries can be fabricated using a thermal, electrical and optical characterization techniques

Current Collector (Cu + Al)
Anode (Si/Si+Sn Multilayer)
Aluminum Oxide (Al_2O_3)
Buffer Layer (Li_3PO_4) (LIPON)
Cathode ($LiCoO_2$)
Current Collector (Cu + Al)
Substrate (SiO_2)

Current Collector (Cu + Al)
Anode (Ge/Ge+Sn Multilayer)
Aluminum Oxide (Al_2O_3)
Buffer Layer (Li_3PO_4) (LIPON)
Cathode ($LiCoO_2$)
Current Collector (Cu + Al)
Substrate (SiO_2)

Fig. 1. The geometric compositions of two separate thin film Lithium-Ion batteries with unique anode materials

Advanced manufacturing techniques were used including DC/RF Sputtering, thermal annealing.

Important Parameters

- $ZT = S^2\sigma T/\kappa$ Figure of Merit (Efficiency of the thermoelectric devices and materials)
  - S Seebeck coefficient,
  - σ Electrical conductivity,
  - T Temperature,
  - κ Thermal conductivity.
- I-V characterization of batteries
- Impedance measurements for batteries
- Four probe van der Pauw resistivity, mobility, density , Hall effect measurements

EXPERIMENTAL

The SiO_2 substrates were cut into varying sizes and underwent the process of deposition in the DC/RF Magnetron Sputtering system. Upon it's first deposition, Copper Aluminum was used. It was then cut again for various measurements and then underwent the process of deposition once more, this time using Lithium Cobalt Oxide and LIPON (Lithium Phosphate) targets.

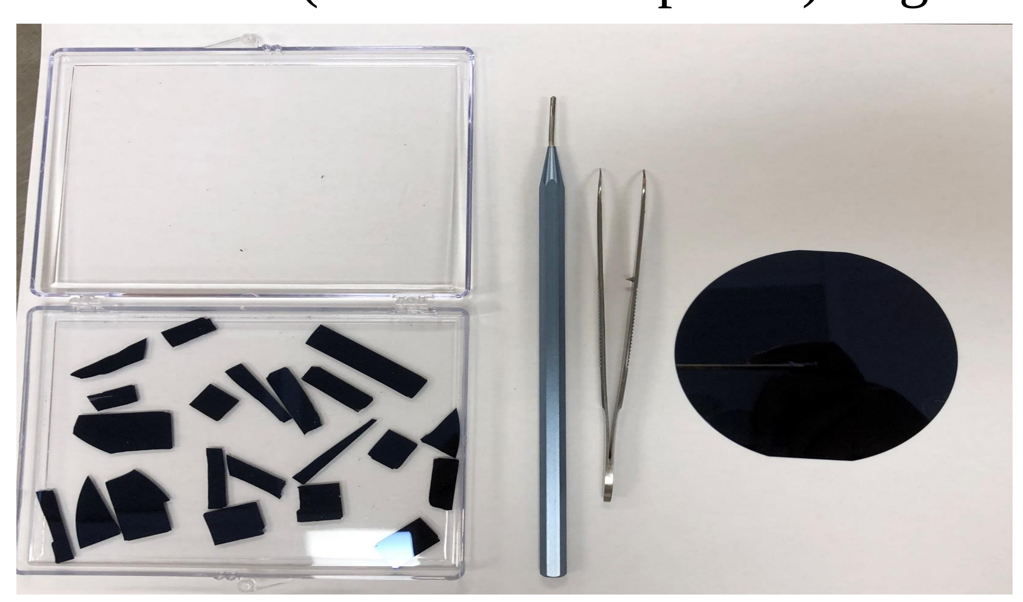

Fig. 2. Cutting of SiO_2 at different geometries

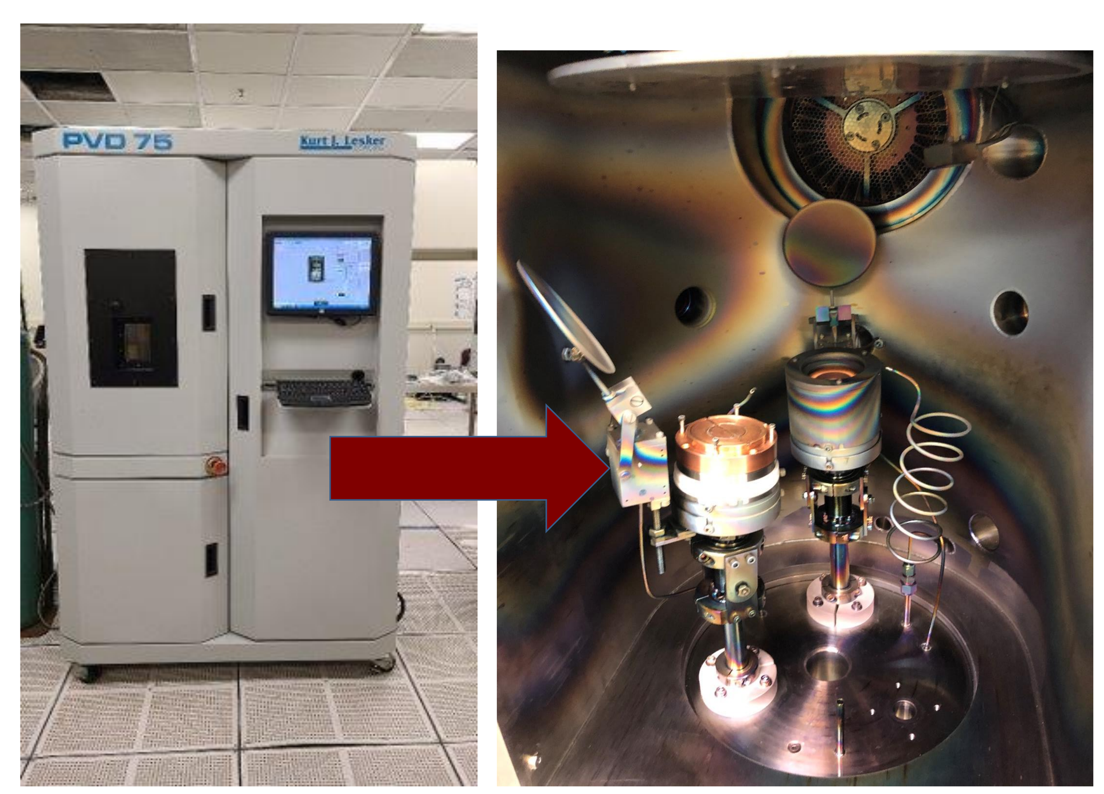

Fig. 3. Loading of the samples to the DC/RF Magnetron sputtering system

RESULTS

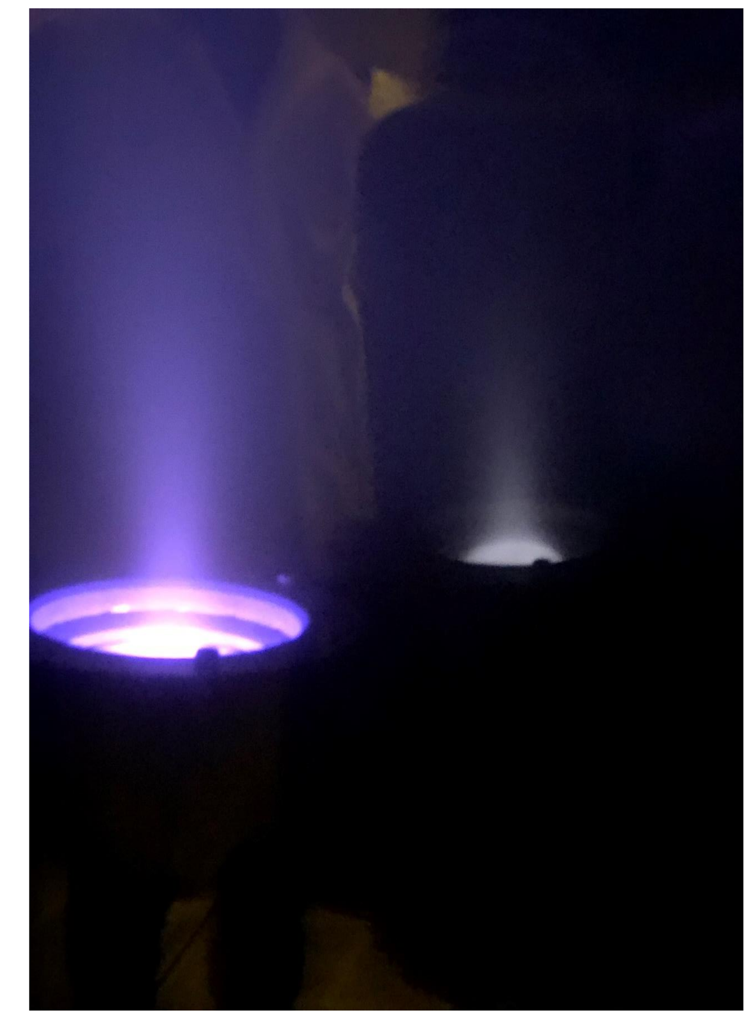

Figure 4a: Deposition of Cu+Al Thin Films.

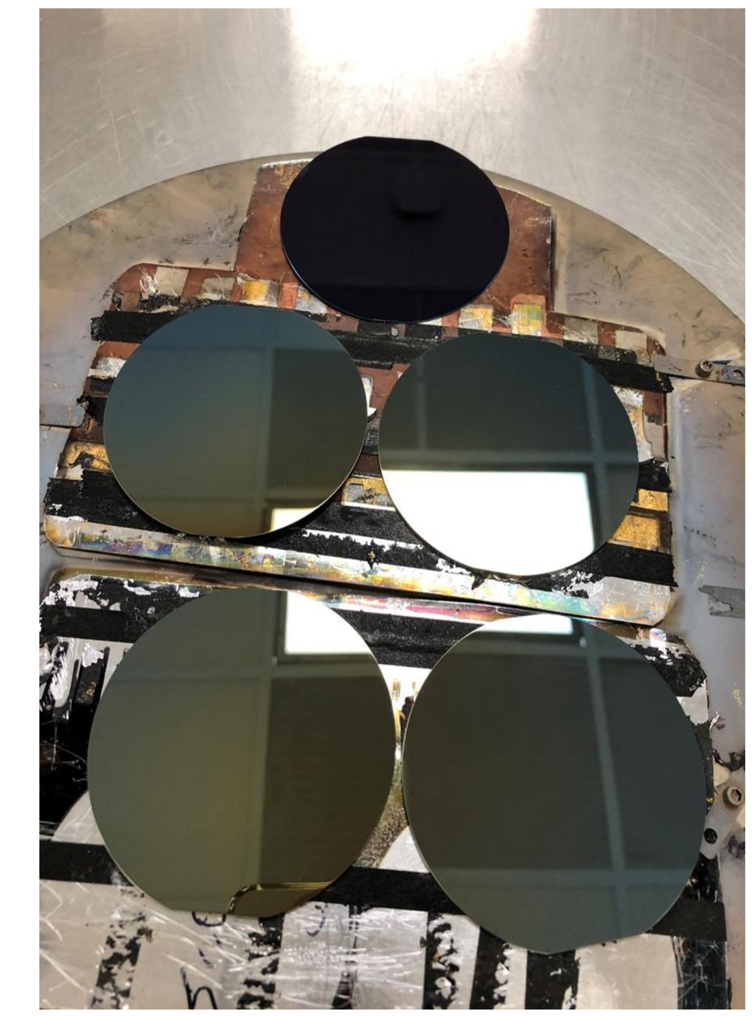

Figure 4b: After Deposition of Cu + Al Thin Films.

Figure 5: Team congregating during deposition in clean room

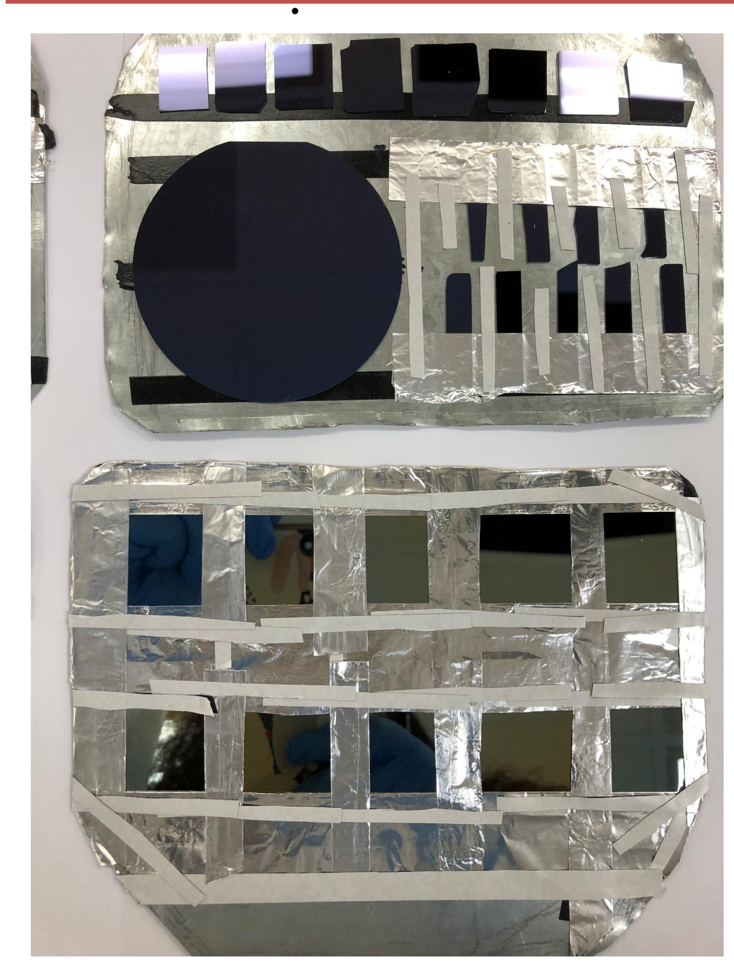

Figure 6: Masking of substrates for deposition

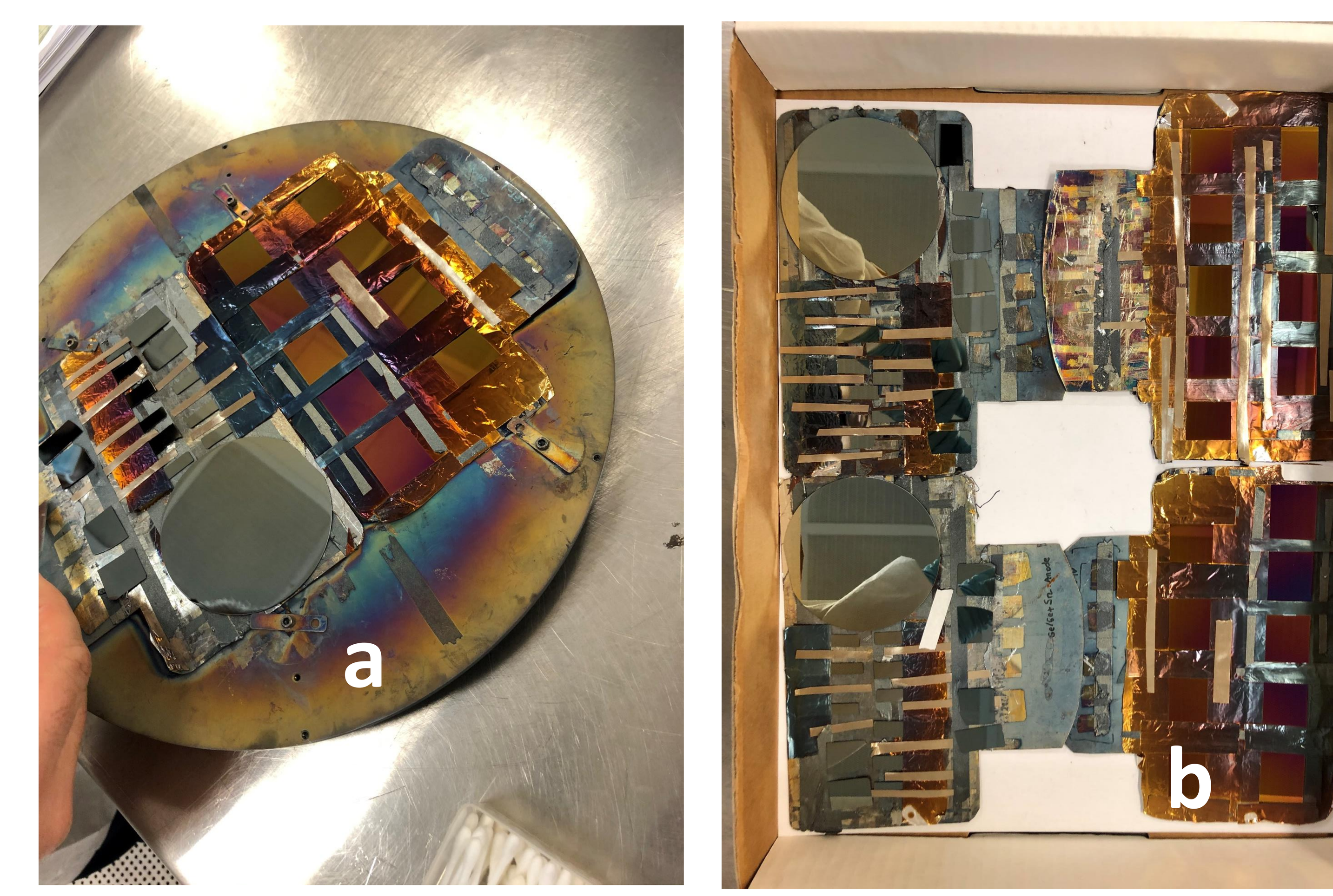

Figure 7a and 7b: The substrate material after many layered depositions.

DISCUSSION / CONCLUSION

Thin-film solid-state batteries were designed as shown in figure 1 and fabrication process started. First the substrates were deposited with Cu+Al thin films for electrical contacts. Then, cathode materials (Lithium Cobalt Oxide) were deposited at the top of Cu+Al. Next, LIPON (Lithium Phosphate) buffer layer was deposited as in electrolyte for the thin-film batteries. Then, Al_2O_3 (Aluminum Oxide) layer was coated on the top of the LIPON layer to protect the cathode and for having longer life cycles for the batteries. The progress for the completion of the fabrication of thin-film batteries is still ongoing due to the starting date of project was at Jan 24,2022. Completed results of the research project will be presented during the next STEM day in 2023.