The Synthesis, Characterization of $SrZrO_3$ ceramics and Pulsed-Laser Deposition of $SrZrO_3$ Thin Films

Shravan Hariharan (shravanhariharan2@gmail.com)
University High School, Class of 2019
Mork Family Department of Chemical and Materials Science Engineering, SHINE 2017

SHINE
Summer High School Intensive in Next-Generation Engineering

Introduction

The research being conducted is about the synthesis and formation of fully dense perovskites. All perovskites are defined to have a cubic structure and follow a default chemical formula of ABO_3, where A and B can be most transition metals. Perovskites can be used to create different dielectric materials such as transistors and capacitors. The research group works with many different perovskites, but my research was on the perovskite $SrZrO_3$ (known as SZO or Strontium Zirconate).

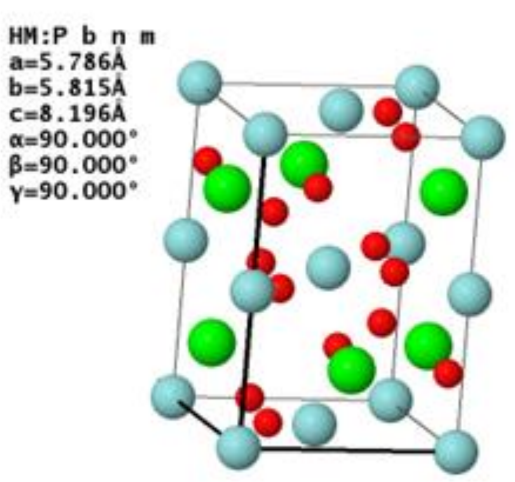

Figure 1a. SZO 3D Structure. Dimensions of SZO. (PC: ICSD)

Figure 1b. SZO Pellet After Calcination. (PC: Shravan Hariharan)

Objective & Impact of Professor's Research

Dr. Ravichandran's research, as described above, is about attempting to make high quality perovskite oxide thin films. Achieving the highest quality will create more durable dielectric materials such as gate materials of transistors and capacitors that can withstand high voltage and high frequency. Also due to the complexity of structure, different perovskites can induce lots of interesting properties that can be eventually used in the industry such as for superconductors.

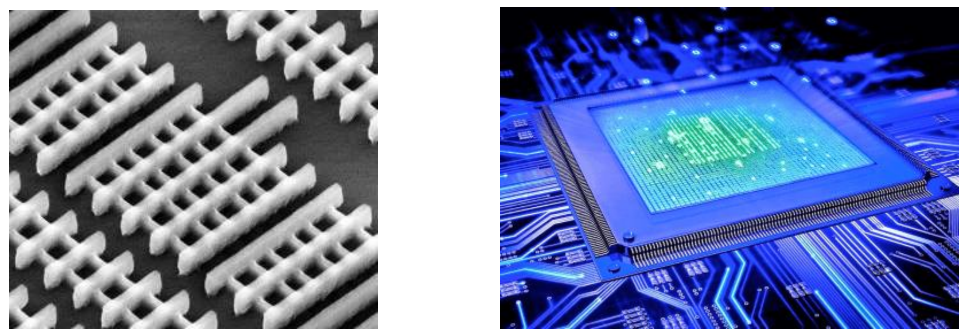

Figure 2. 14nm scale Transistors and CPU. Products of thin films. (PC: TreeHugger)

Synthesis Process

Formation

$$SrCO_3 + ZrO_2 \rightarrow SrZrO_3 + CO_2$$

The formation process includes weighing the amount of Strontium Carbonate and Zirconium Oxide needed in grams, mixing them together in a mortar and pestle, pressing the resulting mixture in a press, and ending up with a very fragile pellet.

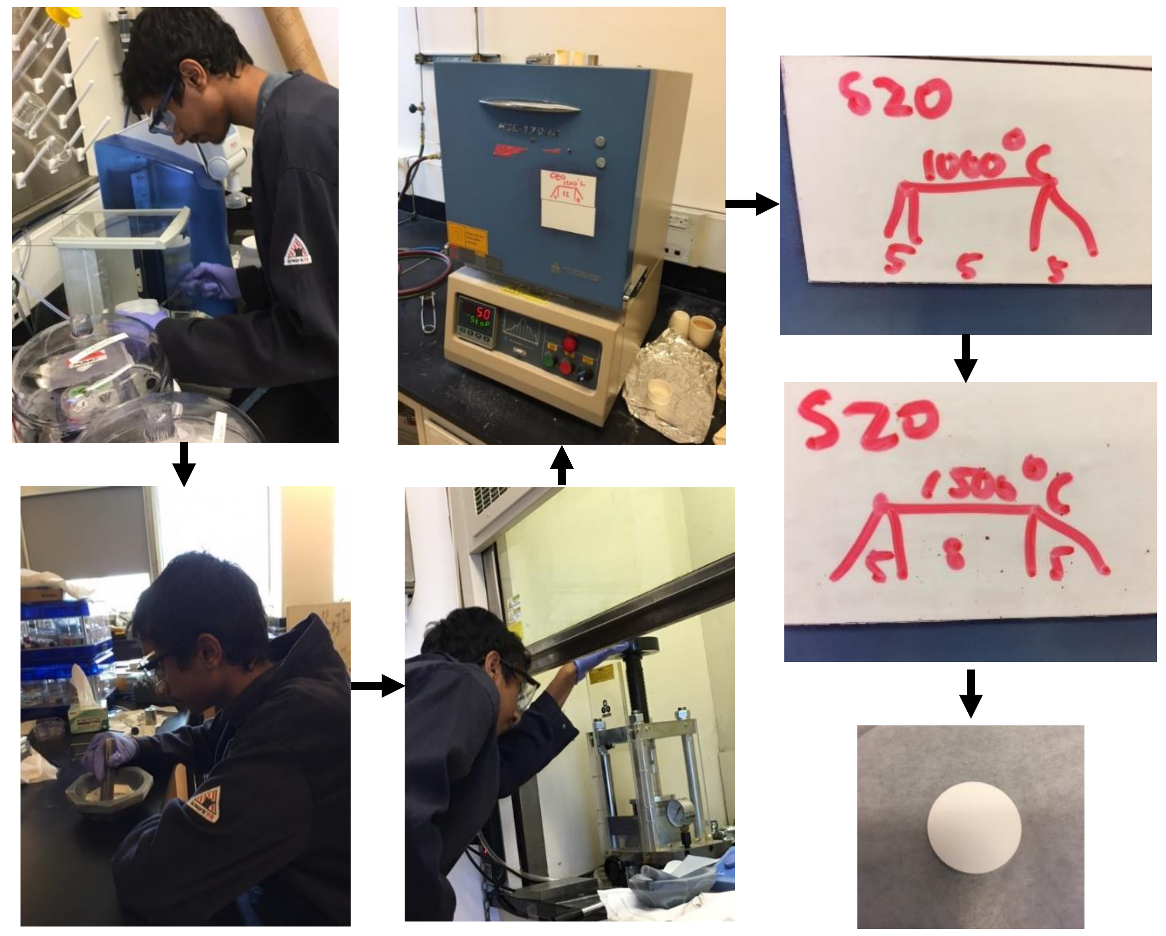

Figure 3. Process of synthesizing the SZO pellet and temperature profiles. (PC: Shravan Hariharan)

Calcination

The Calcination process involved cooking the pellet in a furnace for a set temperature for a set time to let the reaction happen and get rid of the carbon dioxide. A dense SZO pellet is formed from the calcination.

Densification

To further increase the density, the second step of solid state reaction, densification, is performed. A higher temperature is used in the densification in order to receive a highly densified pellet. After this we calculate the density of the pellet using the mass and volume and compare it with the theoretical density of SZO. The density of the pellet created was 68%.

Characterization

XRD Characterization

Characterization involves analyzing the structure of the material and impurities inside the pellet using the X-Ray Diffraction method (XRD). The X-Ray Diffractometer is a box-like machine that uses X-Rays to scan the material at different angles and produces a diffraction intensity measure, showing how intense the x-rays are at a given angle.

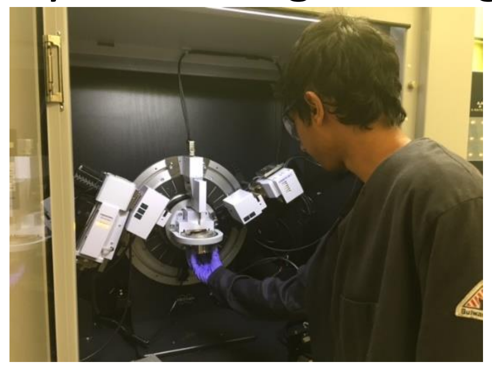

Figure 4a. X-Ray Diffractometer (PC: Shravan Hariharan).

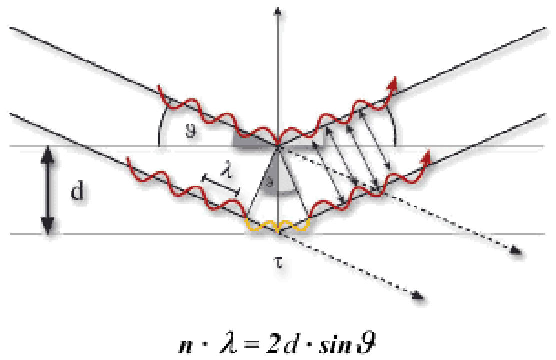

Figure 4b. XRD Analysis. The concept of XRD (PC: Terrachem GmbH).

XRD allows us to characterize the sample, determine unit cell dimensions, and most importantly, find the purity of the substance. Purity is represented in an XRD graph by peaks at different angles. When compared to a reference graph, if there are any excess peaks, we know that there exists impurities and we can determine what they came from by analyzing reference reactant graphs.

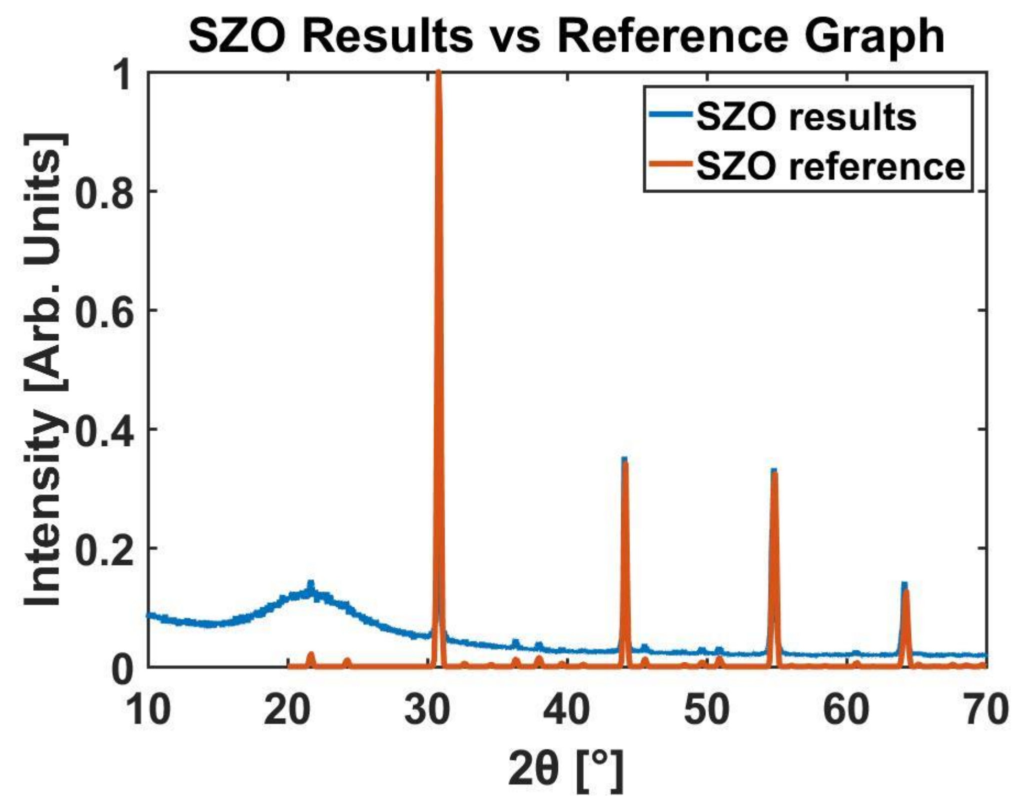

Figure 5. $SrZrO_3$ XRD Pellet and ICSD Reference Pattern. (PC: Shravan Hariharan).

Pulsed Laser Deposition

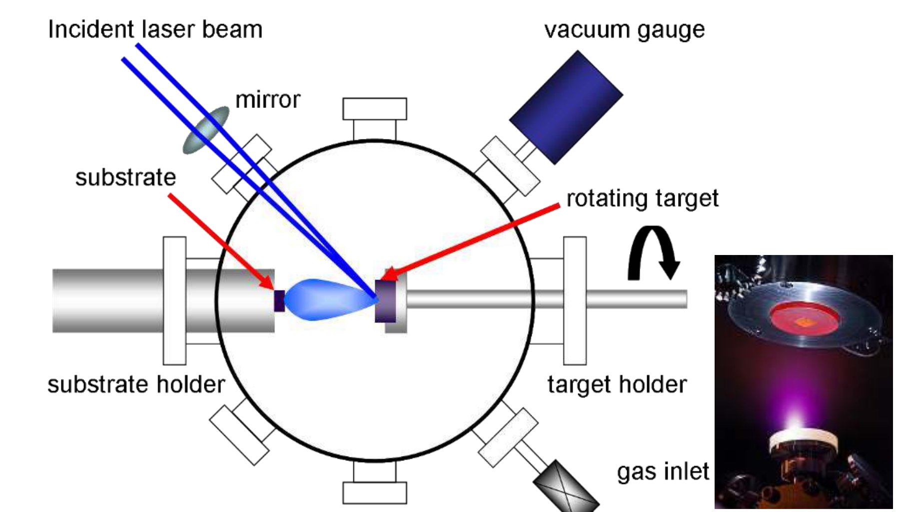

Figure 5a. Configuration of PLD Chamber and Visual (insert). (PC: Wikipedia and InTechOpen).

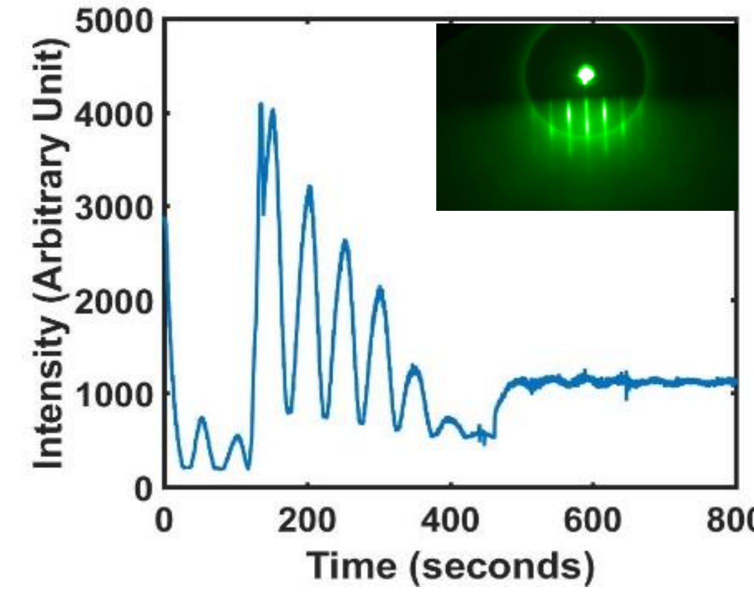

Figure 5b. $SrZrO_3$ PLD Oscillations Graph and RHEED pattern. (PC: Shravan Hariharan).

Next Steps

Working on getting a higher density would be the immediate next step for this experiment. The SZO thin film can be used as a gate material in transistors. Testing the thin film on a transistor to see how easily the transistor switches on and off will show how correctly the experiment was done.

Acknowledgements

Yang Liu
Thomas Orvis
Brian Huang
Dr. Mills
Dr. Ravichandran
Michael Simpson
Shanyuan Niu
Boyang Zhao
Yucheng Zhou
Yihong Fan