Preparation of $SrVO_3$/ $SrTiO_3$ (001) Epitaxial Thin Films by Pulse Laser Deposition

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Motivation

- Strontium Vanadate, $SrVO_3$ (SVO), is a cubic perovskite that exhibits highly conductive behavior making it a candidate as a transparent conducting oxide (TCO).[1]
- When $SrVO_3$ is doped or reduced in dimensionality, it undergoes metal-insulator transition (MIT) due to $SrVO_3$ being a highly correlated material, making it of great interest to research.[2,3,4]
- The goal of this project is to successfully synthesize a Strontium Vanadate thin film using Strontium Titanate, $SrTiO_3$ (STO) as the substrate and $Sr_2V_2O_7$ as the target.[5]

Target Preparation

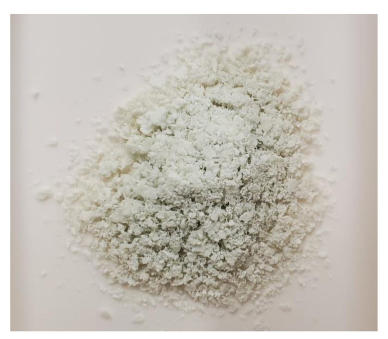
A. Synthesizing $Sr_2V_2O_7$

Chemical Reaction for $Sr_2V_2O_7$:

$$2SrCO_3 + V_2O_5 \rightarrow Sr_2V_2O_7 + 2CO_2$$

- Stoichiometric amounts of $SrCO_3$ and V_2O_5 were grounded, where the molar ratio is 2:1[6,7].
- The resulting mixture was then transferred to an alumina crucible and heated to 1000 ˚C for 24 hours in a furnace to calcine, ramping up to 1000 ˚C in 4 hours.
- The homogenously mixed powders are reground and reheated until only or mostly $Sr_2V_2O_7$ is present as observed through XRD.
- The calcined powder is pressed into 2mm diameter pellets at 21 tons of pressure for 1 hour and sintered at 1000 ˚C for 24 hours.

Powder pre-calcination, the yellow color indicts a small band gap.



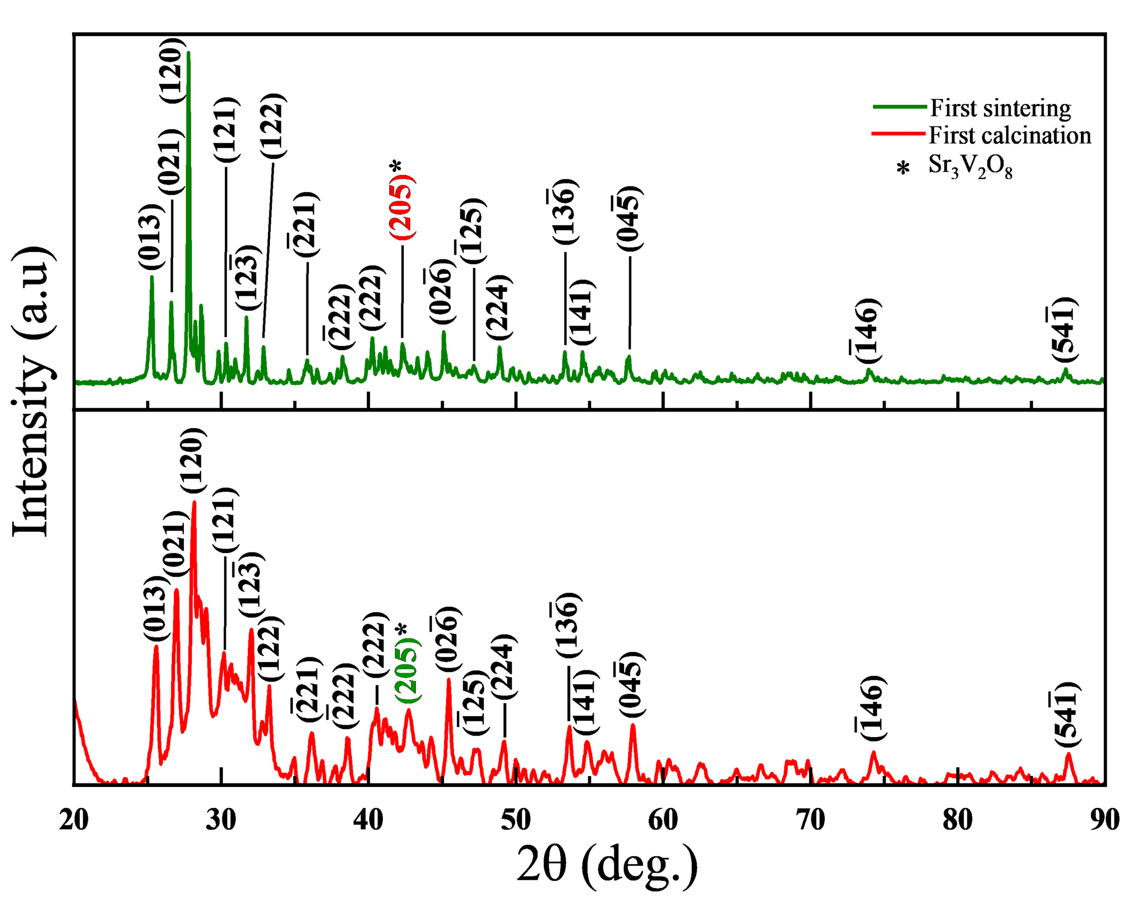
Powder post-calcination, the blue-white color indicts a large band gap.

Pellet pre-sinter.

Pellet post-sinter. The white peaks indicate the powder may not have been ground enough.

B. X-Ray Diffraction (XRD)

- XRD allows for us to determine the crystal structure, purity, and its current phase; this is important due to $SrVO_3$ having several secondary phase like $Sr_2V_2O_7$ and $Sr_3V_2O_8$.
- The crystal structure for $Sr_2V_2O_7$ is triclinic meaning that the length of the crystal is unequal and the angles between them are also different making this crystal structure unsymmetrical which results in numerous peaks.
- $SrVO_3$ has a cubic crystal structure, which is what makes it symmetrical and have relatively fewer peaks compared to $Sr_2V_2O_7$.



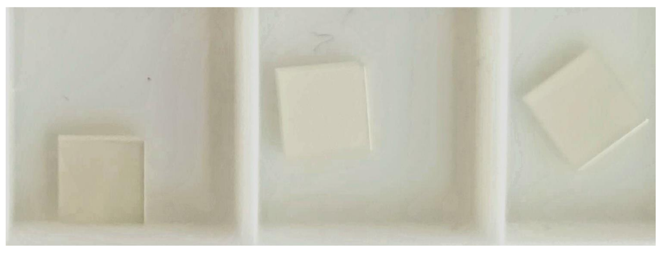
XRD patterns of $Sr_2V_2O_7$ pre-calcination (bottom) and post-calcination (top), where the asterisk is used to denote the secondary phase, $Sr_3V_2O_8$, which has a triagonal crystal structure.

While the current sample still retains some of the other phase, this is not concerning as the presence of it is few and there having been experiments conducted with $SrVO_3$ with 85% $SrVO_3$ and 15% of its secondary phase.[7]

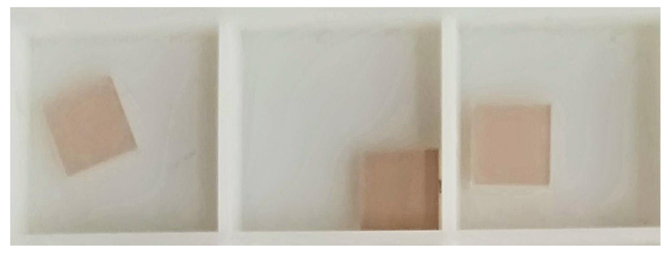
Substrate Preparation

A. Deionized-Water Leeching and Thermal-Annealing

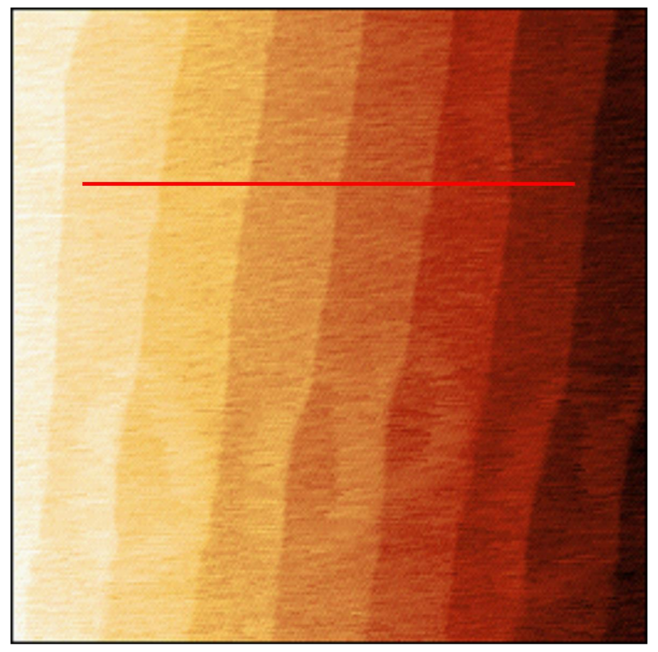
- Achieving an atomically flat surface of a substrate is crucial to prepare well-characterized samples and to exhibit interesting properties.[8]
- The substrate used was $SrTiO_3$ due to its lattice constant matching $SrVO_3$ and it being used in several experiments as the substrate to grow $SrVO_3$.
- To preform the water-leeching, $SrTiO_3$ was rinsed in DI-water by agitating it for approximately 30 seconds and, subsequently, is dried using air.
- The thermal-annealing process involves heating the substrate in a furnace at 1000 °C for 1 hour.
- There were 5 $SrTiO_3$ samples used and for each, the water leeching, and annealing was preformed twice, where the sample yielding the best result was chosen.
- The surface was characterized after each water leeching and annealing process using an atomic force microscope (AFM).

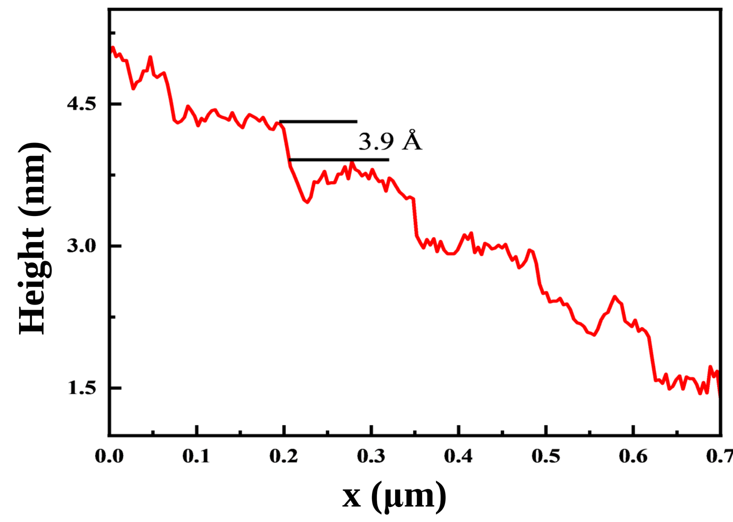


$SrTiO_3$ substrates before the 2nd water leeching and annealing.



$SrTiO_3$ substrates after the 2nd water leeching and annealing.

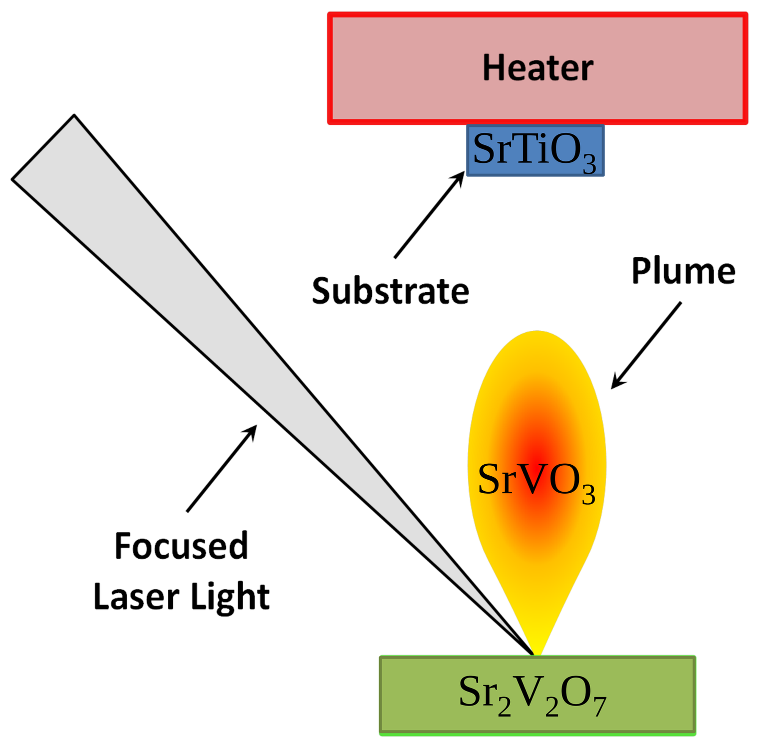


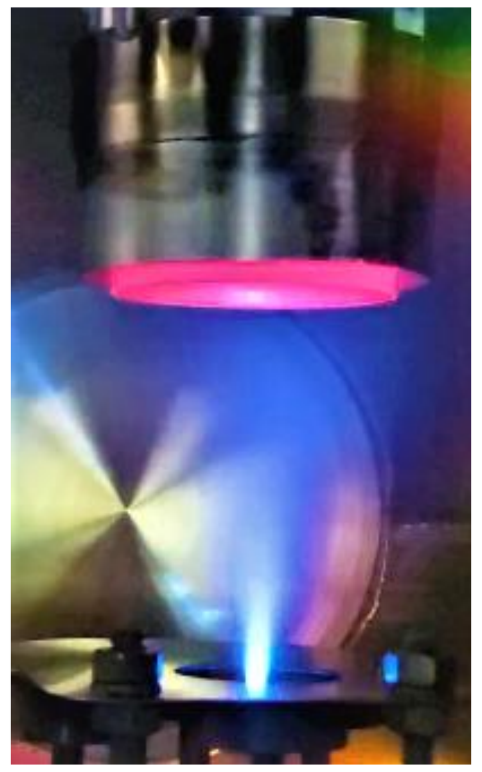


AFM topography of $SrTiO_3$ substrate after first deionized-water leeching and thermal-annealing process with the line profile, where the step height is 3.9 Å.

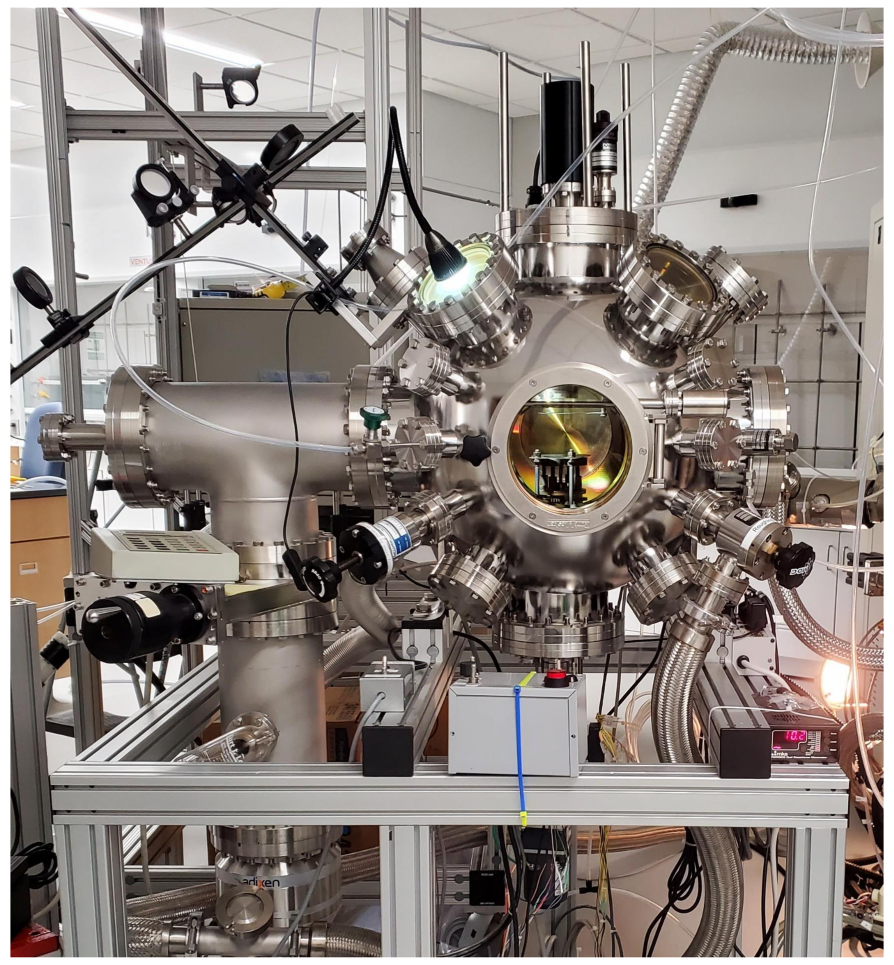
Pulse Laser Deposition (PLD)

- PLD is a technique used to prepare thin films by irradiating a target, thus creating a plasma plume.[9]
- The plume expands outwards towards the substrate, where then the target material is deposited on it, this deposition is what creates the thin film.
- When perovskites are structured in layers using techniques like PLD, new types of interesting properties are exhibited by the thin films.
- The properties exhibited by layered perovskites include ferroelectricity, superconductivity, etc.[9]



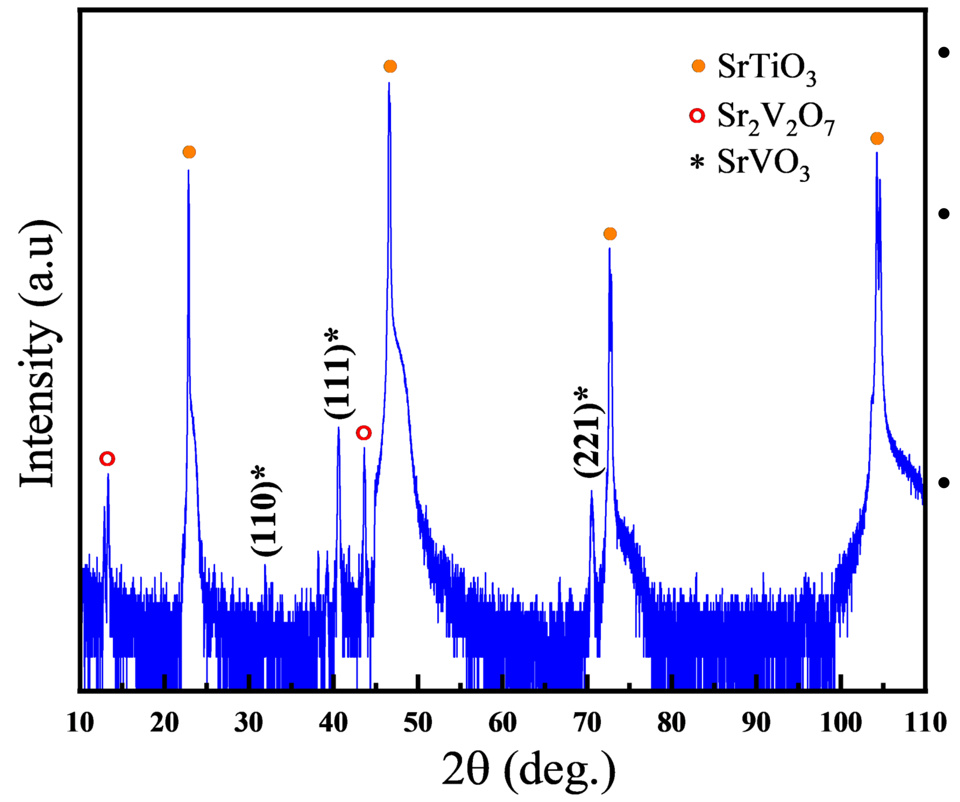


Demonstrates how the irradiated target is deposited on the substrate.



Chamber 2 was used to grow the thin film.

- The $SrVO_3$ (SVO) thin-film was deposited using PLD on a (001)-oriented $SrTiO_3$ (STO) substrate.
- Before deposition was done, the surface of the target was laser cleaned for 5 minutes.
- The thin-film was deposited at 750 °C with 10 mtorr O_2 for 40 minutes with 467 mJ of energy.
- While the $Sr_2V_2O_7$ target has an excess of oxygen, the 10 mtorr of O_2 is used to slow down the plume for better growth.



- XRD was used to determined if $SrVO_3$ had successfully deposited onto $SrTiO_3$.[10]
- It is expected for the highest intensity peaks to be $SrTiO_3$ due to the thin film only having a thin layer of $SrVO_3$ and the rest being $SrTiO_3$.
- It was determined that there are $SrVO_3$ and $Sr_2V_2O_7$ peaks, indicating that while the deposition was successful, the quality was poor.

Conclusion and Future Works

- Despite $Sr_2V_2O_7$ being a secondary phase of $SrVO_3$, the thin film was determined to have $SrVO_3$ peaks indicating that $SrVO_3$ was successfully grown on $SrTiO_3$.
- For future work, the $Sr_2V_2O_7$ could be better synthesized to further reduce other secondary phases from appearing and to yield a better quality $SrVO_3$ thin film.
- Instead of using 10 mtorr of O_2, the deposition can be done in a vacuum, or with less O_2
- The overall growth conditions should be better optimized to grow higher quality $SrVO_3$ thin films.
- Furthermore, instead of using $Sr_2V_2O_7$ as the target, $SrVO_3$ could be synthesized and used as the target.

References

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