Pulsed Laser Deposition and Characterization of VO_2 Thin Films

Oscar Chou (oscarchouhi@gmail.com)
Walnut High School, Class of 2019
Mork Family Department of Chemical and Materials Science Engineering, SHINE 2018

USC Viterbi School of Engineering

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Introduction

Vanadium oxides have been the focus of many studies over the past years because of a phase transition that many of the oxides display. Especially important is VO_2, which displays both anisotropic properties and a large transition that causes many of the material's properties to change. This transition is being further studied to see if it can be utilized in special and everyday purposes.

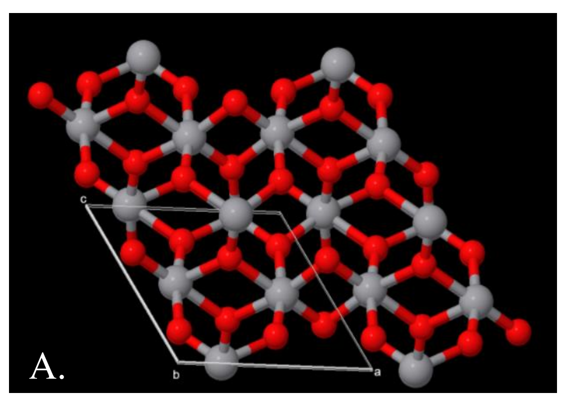

Figure 1a. VO_2 lattice structure (PC: ICSD)

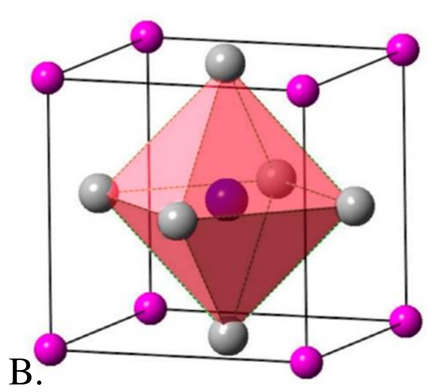

Figure 1b. Perovskite (PC: MDPI)

Objective & Impact of Professor's Research

Our professor's research focuses on studying the innate properties of materials when they are organized as thin film crystals. In these lattices, materials tend to display different properties than when they are mixed together(i.e. alloys). We create these thin films using pulsed laser deposition, and monitor the surface characteristics with *in situ* RHEED, AFM, and XRD. Epitaxial thin films have many potential uses in large and small scale electronics.

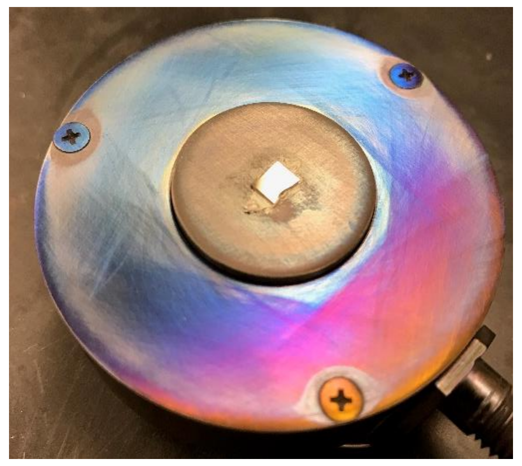

Figure 2a. VO_2 thin film on STO substrate. (PC: Oscar Chou)

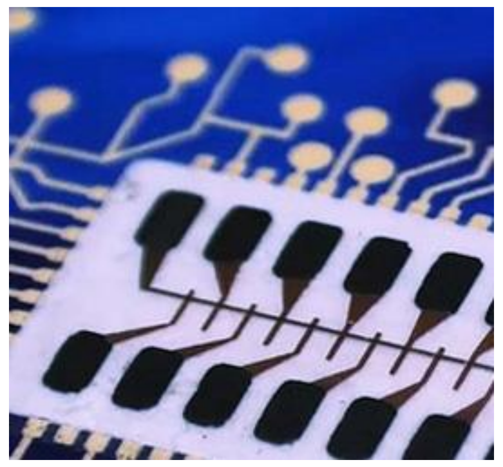

Figure 2b. Circuit board utilizing thin films.. (PC: Thinfilm)

PLD

V_2O_5 Target:

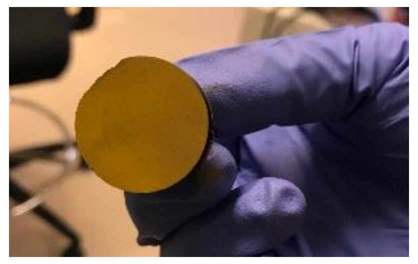

Figure 3. V_2O_5 before PLD (PC: Oscar Chou)

During deposition, the pressure in the chamber determines the final vanadium oxide that is deposited on the substrate.

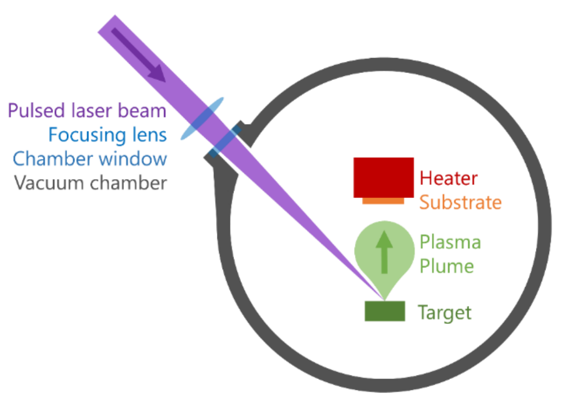

Figure 4. Diagram of PLD (PC: Wikipedia)

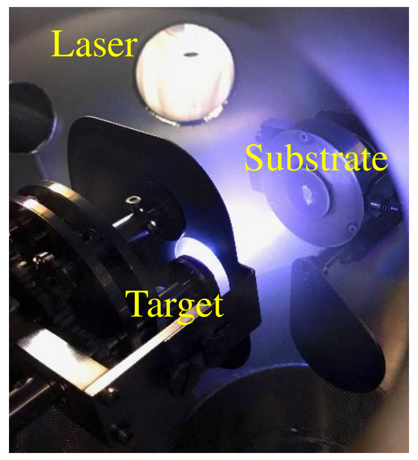

Figure 5. VO_2 Deposition (PC: Oscar Chou)

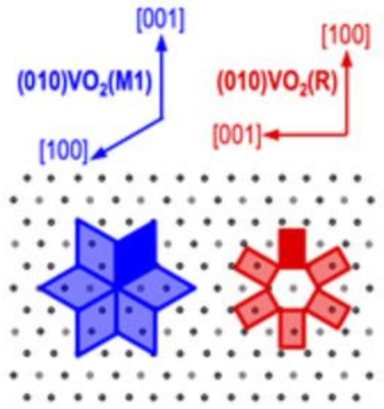

Figure 6. VO_2 on <111> STO substrate (Lee, Shinbuhm & Ivanov, Ilia & Keum, Jong & Lee, Ho. Scientific Reports. 6. 10.1038/srep19621.)

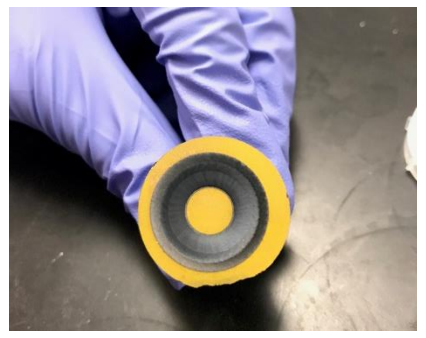

Figure 7. V_2O_5 target after deposition (PC: Oscar Chou)

RHEED analysis:
We can measure the surface smoothness and count the layers of the deposited crystal by the intensity of electrons that are reflected off the surface.

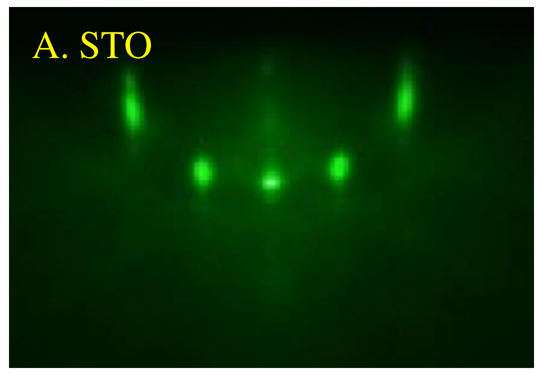

Figure 8a. Intensity of electrons reflecting and diffracting off of STO during RHEED (PC: Yang Liu)

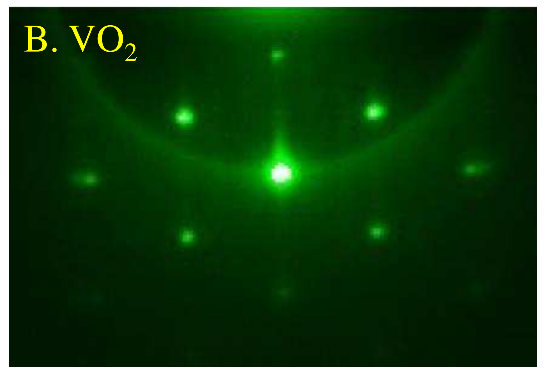

Figure 8b. Intensity of electrons reflecting and diffracting off of VO_2 during RHEED (PC: Yang Liu)

Characterization

XRD: We use x-ray diffraction in order to measure the structure of the film.

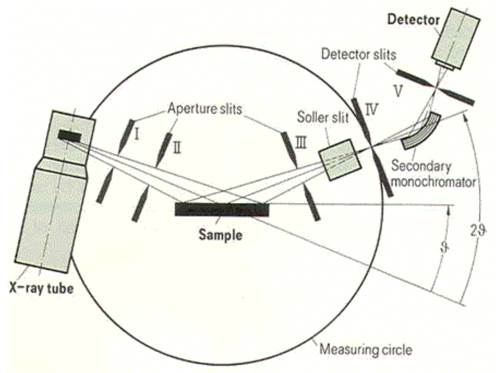

Figure 9. X-ray diffractometer (PC: Ccuart)

Different materials have different spacings between atoms, so each compound has its own "set" of peaks on the graph, compounds can be identified by these peaks.

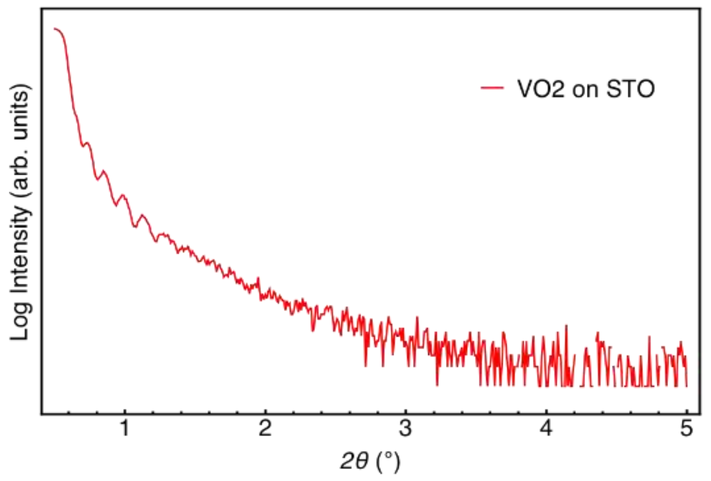

Figure 10. XRR graph of VO_2 (PC: Yang Liu)

Using Bragg's Law, I calculated the thickness of the thin film to be about 60 nm.

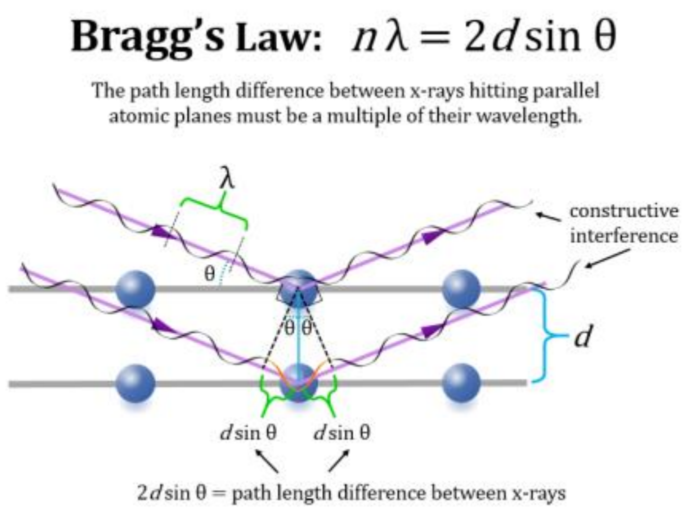

Figure 11. Illustration of Bragg's Law (PC: Cantor Science)

AFM

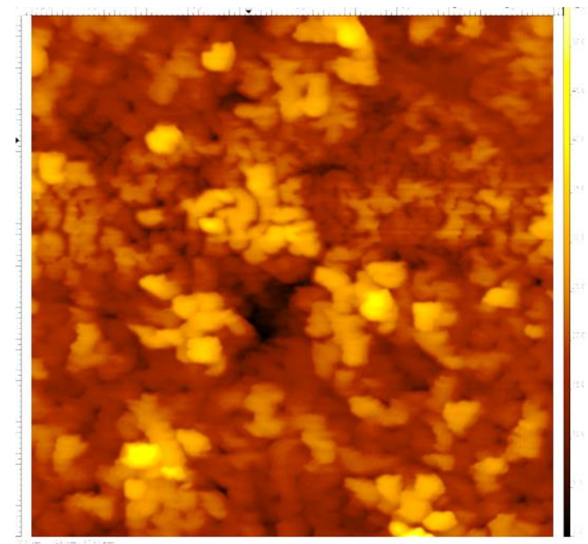

Figure 12. AFM topography of VO_2 (PC: Yang Liu)

Characterization

We used a four probe measurement to measure the resistance of the VO_2 thin film in different directions.

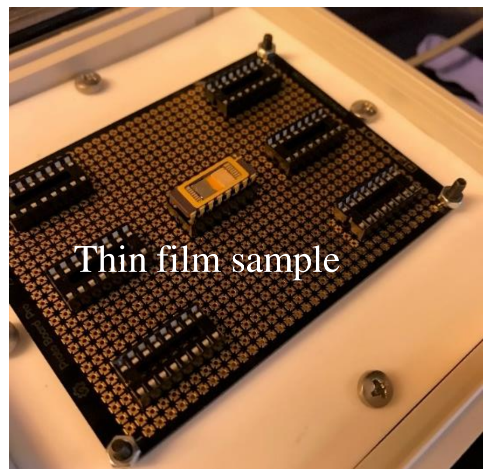

Figure 13. 4 probe resistance measurement (PC: Oscar Chou)

We can use the Van der Pauw method and the measurements to determine whether or not the thin film has anisotropic electrical conductivity.

Datasets	Direction	Resistance
Set 1	Horizontal	0.66
	Vertical	0.67
Set 2	Horizontal	0.52
	Vertical	0.56
Set 3	Horizontal	0.4
	Vertical	0.33

Figure 14. Resistant calculations (PC: Oscar Chou)

Next Steps

The next steps to further this research would be creating more VO2 thin films and testing their dc conductivities. Next summer, I plan to return to the lab in order to further study the properties of superlattices and complex oxides.

Acknowledgements

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