Perovskite Thin Film Synthesis by Pulsed Laser Deposition

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Introduction

Perovskites are minerals classified by their composition, ABX_3 (fig.1). They have been found to have intriguing properties, such as tunable structure, composition and bandgaps. This results in remarkable properties and applications such as high temperature electronics, ferroelectrics, and photovoltaics. Synthesis of both ABO_3 and ABS_3 thin films using pulsed laser deposition (PLD) is used to study these properties further.

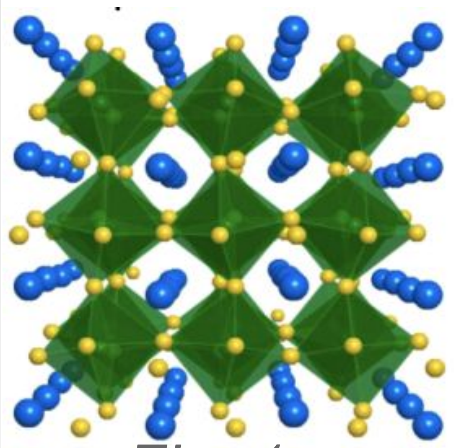

Fig. 1: Perovskite structure. PC: Shanyuan Niu

Objectives of Research

Few papers describe the synthesis process of some of the compounds researched in the lab. Professor Ravichandran's Laboratory for Complex Materials and Devices aims to develop and document a process for creating thin films as epitaxial (fig. 4) as possible with those under- researched materials. These films already show promise in electronics and photonics applications such as ferroelectrics and energy-effective solar cells.

The other, more researched compounds have applications in electronics. Ultra small components are necessary for most common devices, making thin films integral to the modern tech market and instrumental to further innovation in the electrical engineering field.

Method

I. Target Preparation

To make the targets, powdered AX and BX_2 form a perovskite compound in a solid-state reaction at 1050°C.

$$AX + BX_2 \rightarrow ABX_3$$

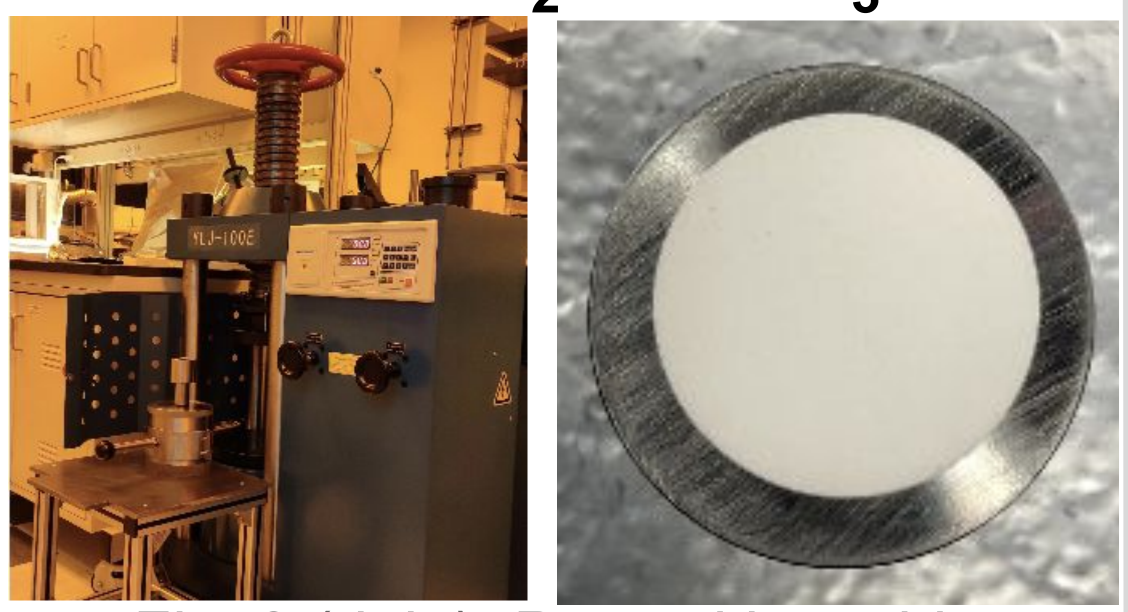

Fig. 3 (right): Perovskite oxide mounted on stage. Fig. 4 (left): cold isostatic pressing (CIP) unit for shaping targets. PC: Mythili Surendran

The result (fig. 3) is then compacted (fig. 4) and sintered.

II. Deposition

The sintered puck is then shot with a KrF laser in the PLD chamber (fig. 2). This generates a plume of molecules, which stick to a compatible substrate in the chamber in the form of thin, organized sheets. The result is then characterized and tested for epitaxy.

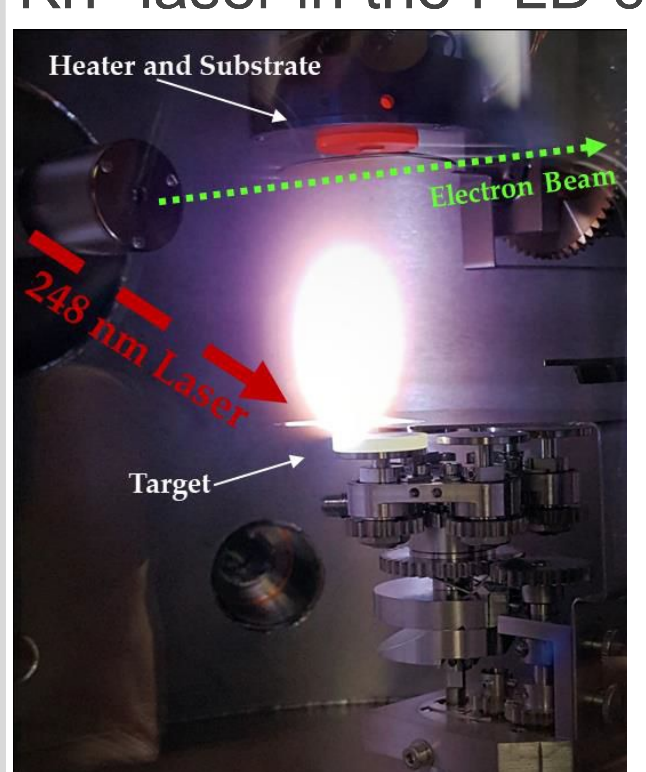

Fig. 2: Internals of active chamber. PC: ResearchGate

Characterization

I. Purity

After growth completion, the film is subjected to measurements to determine its quality. X-ray diffraction (XRD) measures the film's stoichiometry (fig 5).

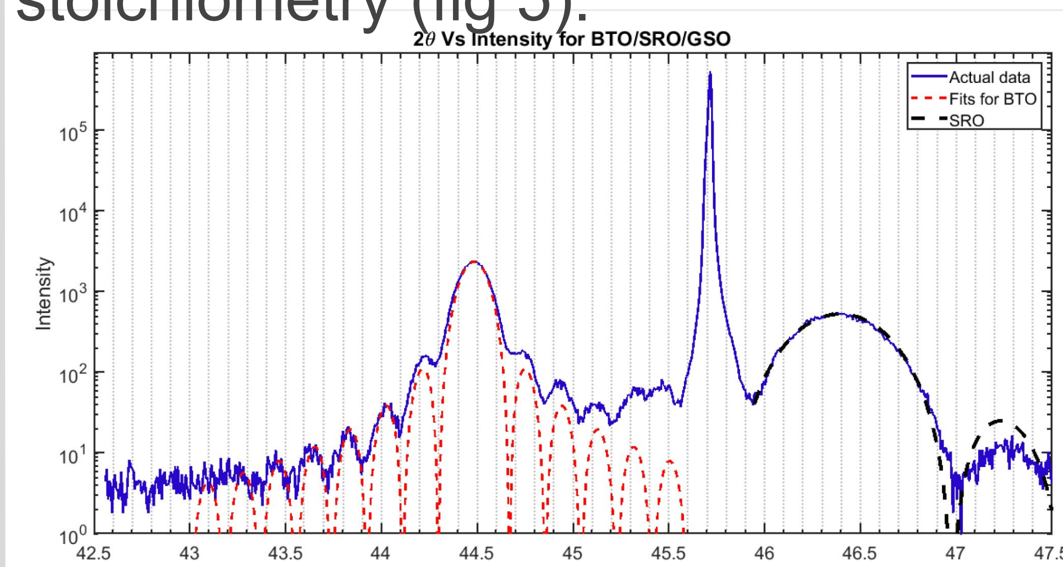

Fig. 5: This XRD chart shows diffraction of a three-layer perovskite made of $GdScO_3$, 17nm of $SrRuO_3$, and 51nm of $BaTiO_3$ (BTO). PC: Harish Kumarasubramanian

II. Surface Epitaxy

The film's thickness and smoothness can be measured in-situ through a RHEED (reflection high-energy electron diffraction) gun (fig 6). The chart tracks the smoothness as the film grows, with a lowering number corresponding to decreasing epitaxy.

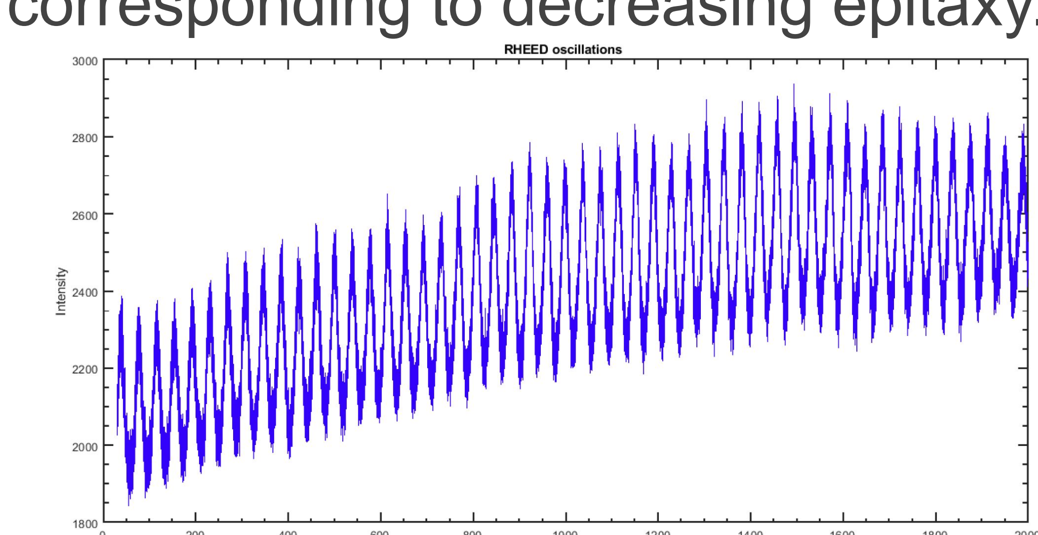

Fig. 6: RHEED diagram of BTO synthesis. PC: Harish Kumarasubramanian

and every peak representing a new layer. As a new layer begins, atoms attach at random and scatter the electrons, roughening the surface and causing the oscillating patterns.

Skills Learned

In any lab, the ability to read and translate scientific diction into something digestible is invaluable, and that remains true for this project. In a similar vein, finding credible sources on new topics is harder than it looks and is an important skill in any academic career.

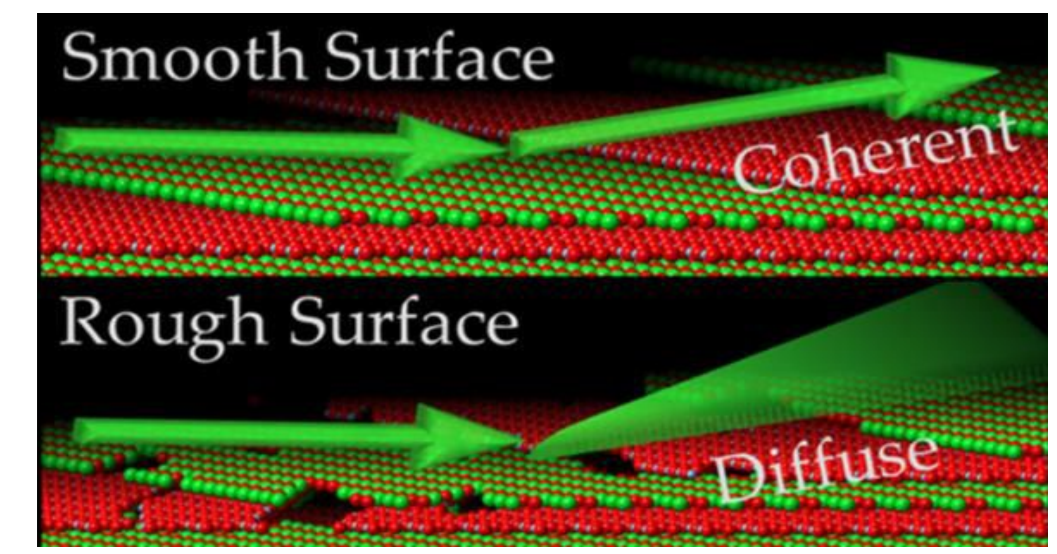

Fig. 4: Epitaxial film surface (above) vs. non-epitaxial film surface (below). PC: Harish Kumarasubramanian.

Acknowledgements

Professor Ravichandran, thank you for allowing me to use and learn from this space. Thank you, Mythili Surendran and Harish Kumarasubramanian, for guiding me through this process and being flexible with my schedule. I'd also like to thank the other people in the lab for tolerating my questions and allowing me to share the office space with them. Of course, I'd like to thank my parents for helping me coordinate with my mentors, and a huge thank-you to Dr. Mills for answering my questions and creating this opportunity for me!