Pulsed Laser Deposition Growth from Highly Densified Perovskites Ceramics to Form 2DEG

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Introduction

A two-dimensional electron gas (2DEG) was discovered accidently in 2004 at the interface between two insulators, $LaAlO_3$ and $SrTiO_3$. Due to the tight confinement in the third direction, it has quantized energy level for motion and offers a system of high mobility electrons.

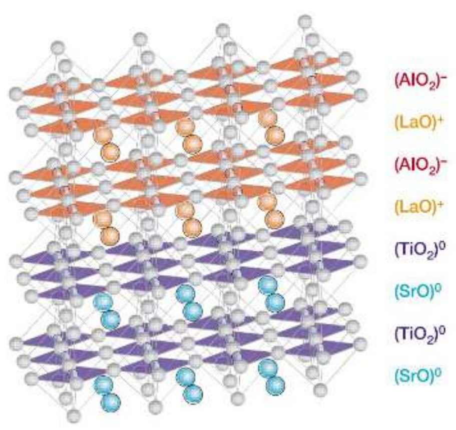


Fig 1. Schematic of the resulting (LaO)/(TiO2) interface. (PC: 2004_NLett_Ohtomo)

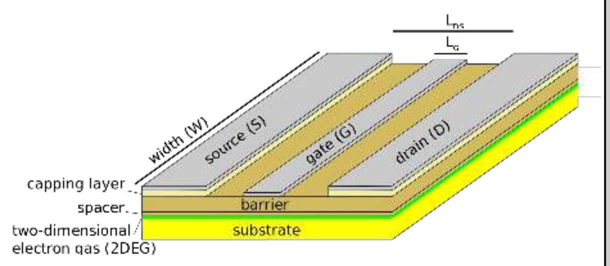


Fig 2. High electron mobility transistors (HEMTs) are one of the most common ways to utilize 2DEGs. It intentionally used an undoped material to achieve higher electron mobility. (PC: Bialek 2009)

Professor's Research & My Role

Professor Ravichandran's group focus their research on synthesis and characterization of complex oxides such as perovskites. Using various testing methods such as XRD and AFM, we were able to identify the structure and surface quality of thin films as well as the bulk material. Perovskites have the general formula of ABO_3, where A is a cation from alkaline earth metal family such as Ca, Sr or Ba and B is a cation of a 4+ transition metal such as Ti or Zr. I have synthesized AZO_3 and particularly studied BZO and CZO. These materials have potential applications in electronics.

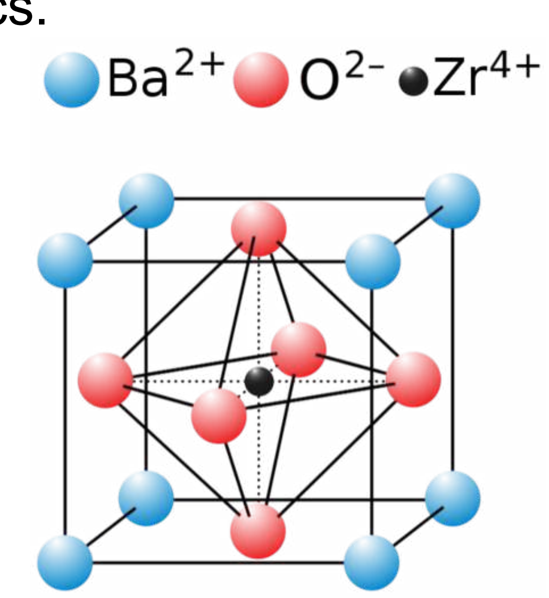
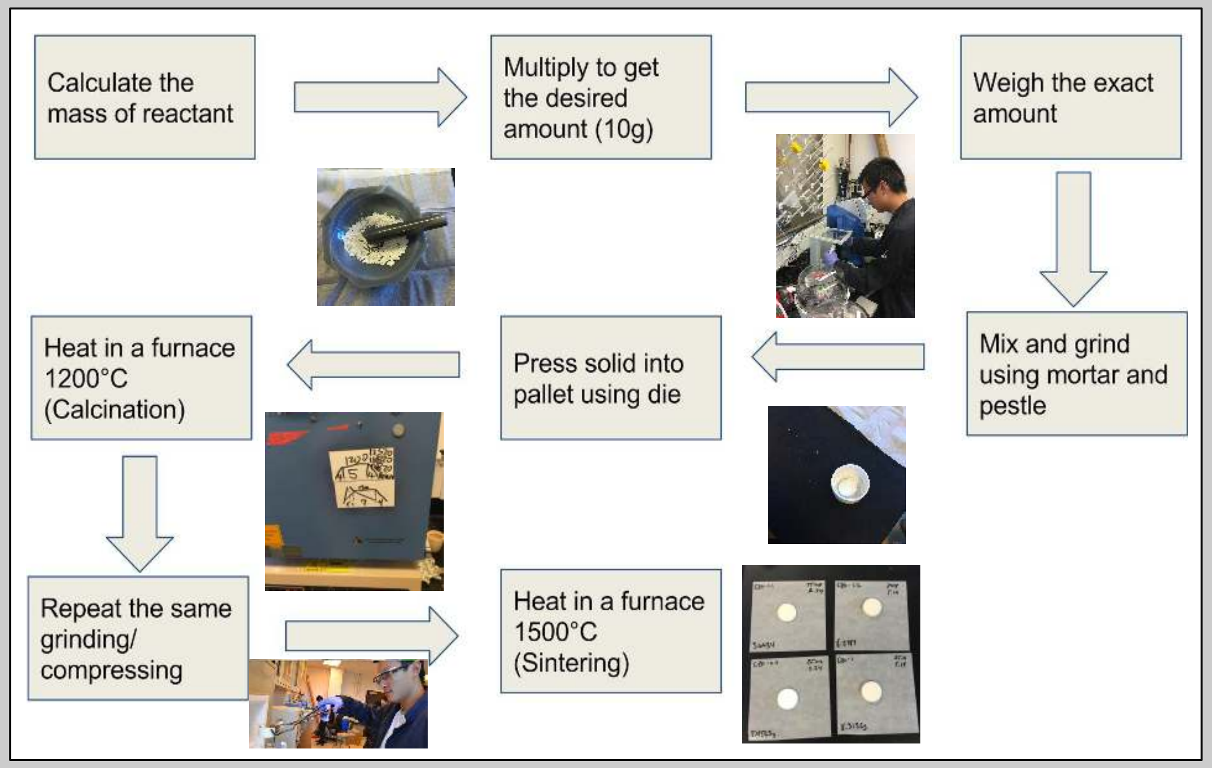


Fig 3. Unit cell of the BZO structure. It forms a general cubic shape similar to the typical perovskite structure. (PC: Haskel et al.)

Synthesis Process



Characterization Process

X-Ray Diffraction (XRD) of my BZO Sample

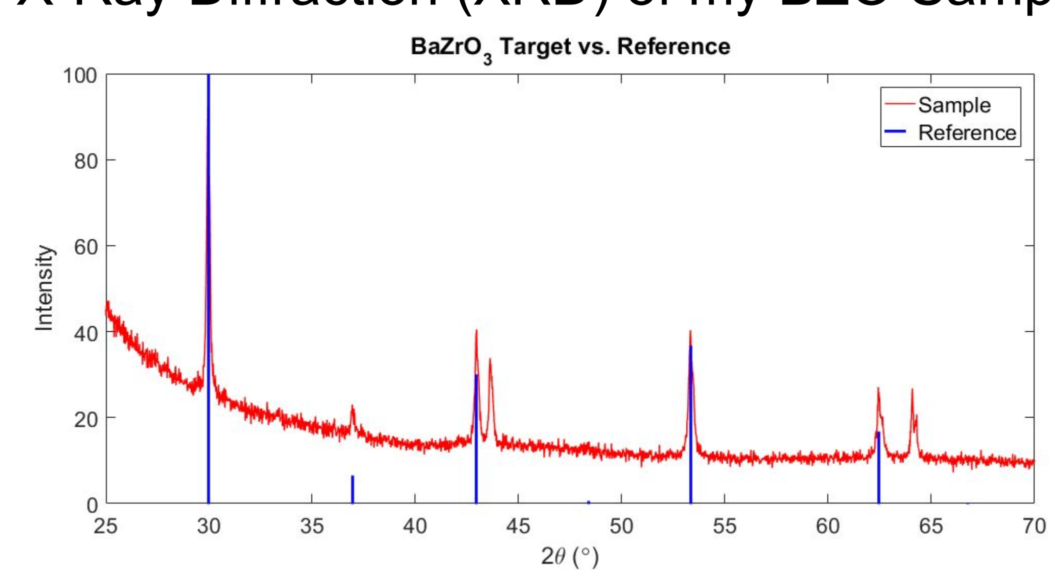


Fig 5. Based on thousands of data points from 25 to 70 degrees as 2 theta, I plotted this XRD graph using MATLAB and compared it to ICSD reference data. (PC: Yizhi Huang)

Atomic Force Microscopy (AFM) Scan of BZO

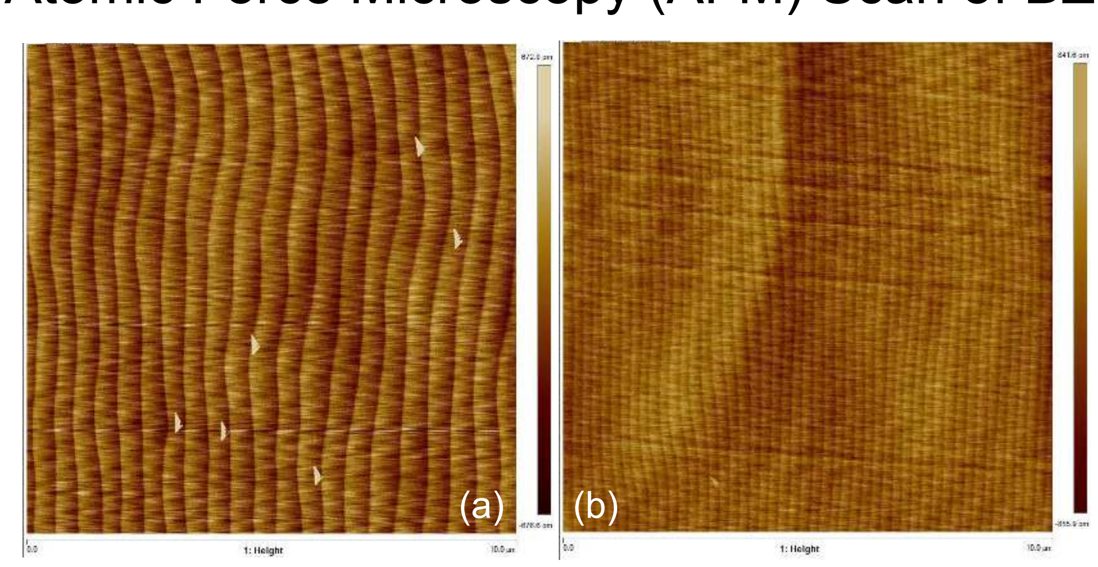


Fig 6. (a) $SrTiO_3$ substrate before the growth. The vertical lines show 4 Angstrom high atomic steps. (b) BZO on STO after 25 unit cells of growth. Apparent atomic steps are observed showing it is a successful growth. (PC: Thomas Orvis)

PLD Concepts & Results

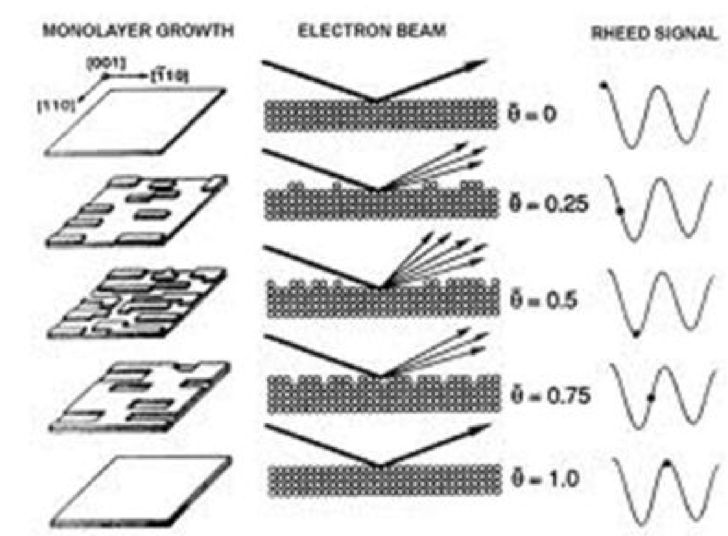


Fig 7. RHEED oscillation diagram. (PC: Neave et al, 1983.)

RHEED Oscillation Graph

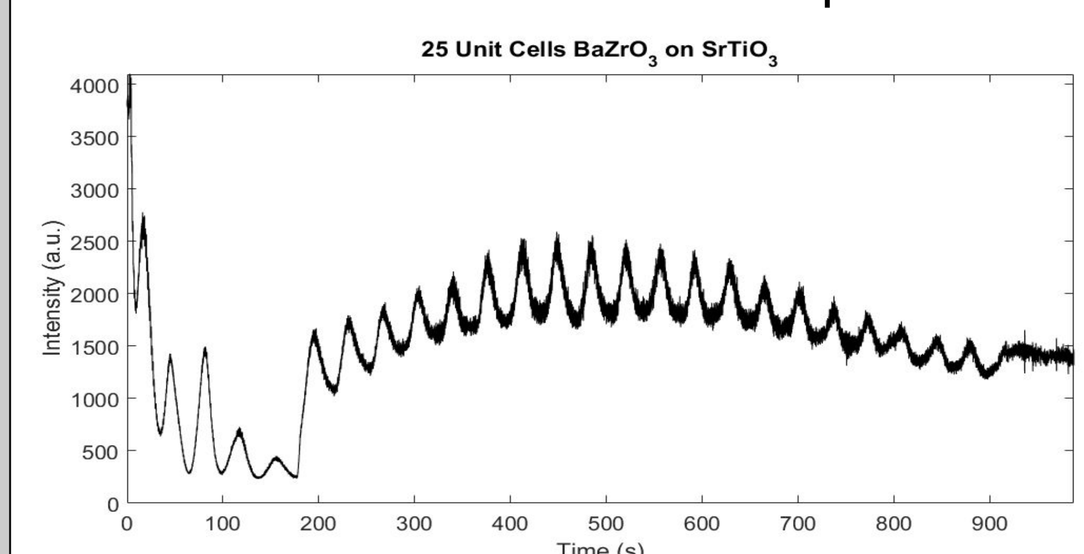


Fig 8. RHEED oscillations for my thin film sample. The oscillations can be counted to calculate film thickness. (PC:Yizhi Huang)

Pulsed laser deposition (PLD) is a process to ablate a target, such as perovskites, and deposit it on a substrate. Some PLD thin films can form 2DEGs while others are suitable for capacitors or transistors. UV light is pulsed from a KrF laser at the target I made. Reflection High-Energy Electron Diffraction (RHEED) gathers information from the surface of the sample.

RHEED Pattern

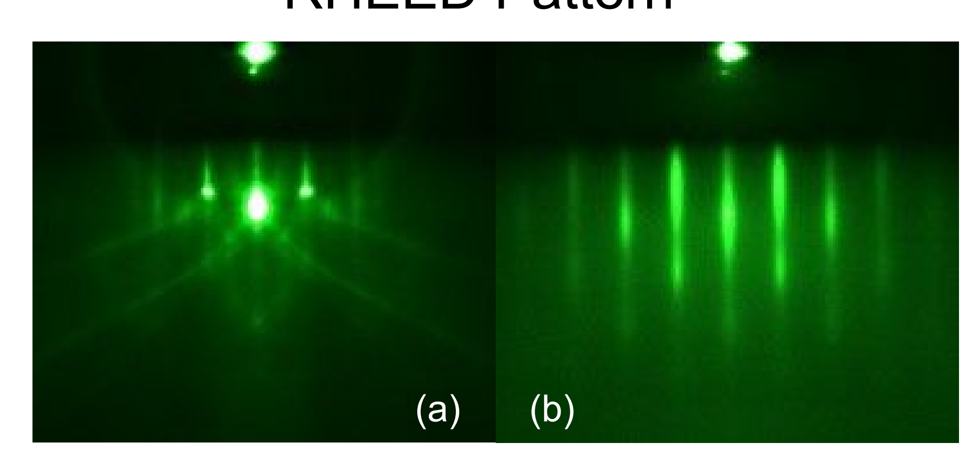


Fig 9 (a) Specular spot of the substrate before the PLD growth. (b) Diffraction pattern after 815 pulses, at the end of the PLD growth. (PC: Yizhi Huang)

Applications

Researchers working with 2DEGs are hoping to create transistors with high electron mobility, which have great potential for applications in high speed devices. For instance, HEMTs are responsible for 4G cellular communication technology. Furthermore, perovskites might one day replace silicon in the semiconductor industry because of its adjustable structure.

Next Steps

Working in Dr. Ravichandran's group with other Ph.D. mentors has provided me with perfect research opportunities to understand basics of engineering and prepare for challenging research tasks in college. I will share my experience with my friends who are also interested in STEM fields. Aside from exciting projects I completed, I have maintained strong relationships and am looking forward to returning to the lab some days in summer.

Fig 10. Adjusting the substrate position for ideal growth conditions. (PC: Thomas Orvis)

Acknowledgements

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