Atomically Smooth $SrTiO_3$ Substrate by HF Etching and Annealing

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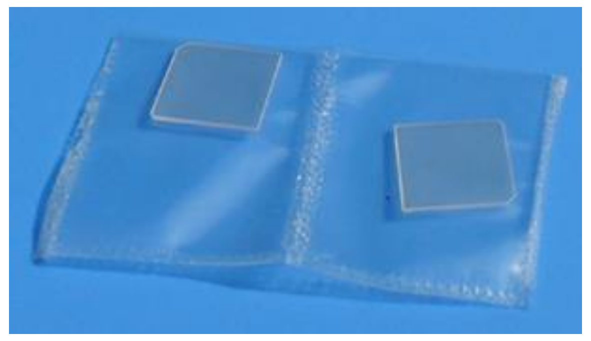
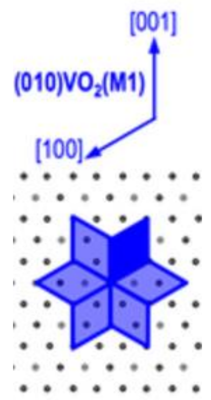
Introduction

Substrates are the materials on which other processes are conducted, such as pulsed laser deposition growths. Because they are crucial in contributing to the quality of the material grown on it, their structure must be compatible with the target. $SrTiO_3$ (STO) is the substrate we used for research. However, the quality of substrates degrade over time, and we are looking for ways to restore its original quality.



STO substrate (PC: Biotain Crystal Co., Ltd)



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

Objective & Impact of Professor's Research

Professor Ravichandran's research focuses on the synthesis and analysis of complex oxides (i.e. perovskites – general structure ABO_3). In order to do so, high-quality epitaxial thin films need to be synthesized in order to observe properties not seen in bulk materials. We use In situ RHEED to monitor surface characteristics of superlattice crystal growth (grown by pulsed laser deposition) and also AFM and XRD to better understand the surface and structure, respectively of the material grown. These materials may show characteristics that can play a role in both large and small-scale electronics.

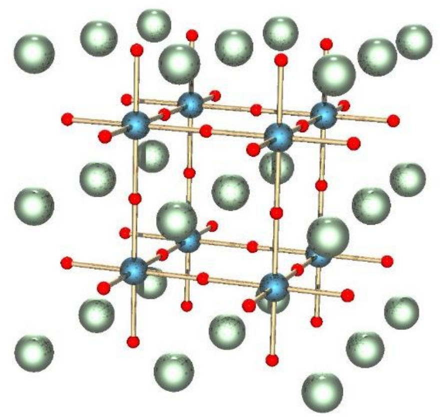


Fig 1. Perovskite structure (PC: Wikipedia)

CPU possible product of thin films (PC: Treehugger)

Preparation

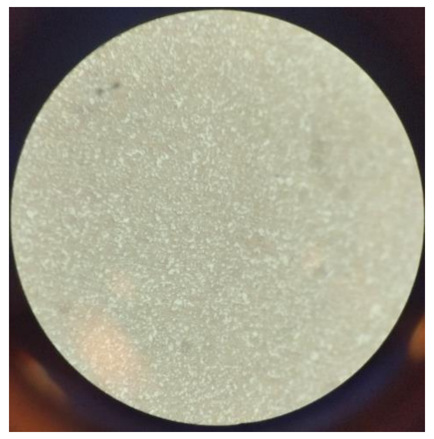
Since the structure of substrates really matters in the synthesis of other materials, it cannot contain any impurities. Old substrates usually have some form of contamination from the surroundings (i.e. dust particles or deposits of other elements) and we generally use etching and annealing in order to get exactly the material we want to use as a substrate.

Etching:

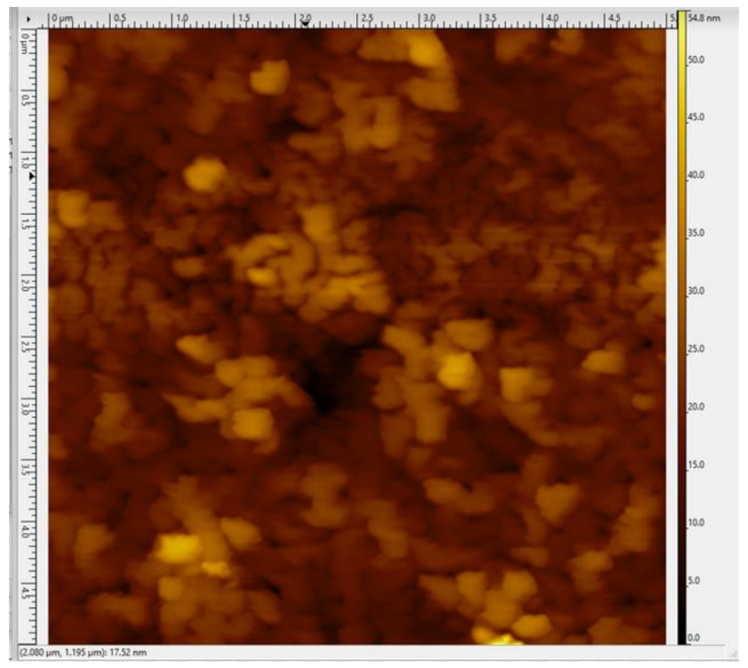
Etching is a process to remove certain layers from a structured specimen in order to obtain only the layer we want. Since STO is structured with distinct layers (each with their own atoms and configuration), etching works well in isolating the layer we want (TiO_2 surface termination). In order to do so (with the case of STO), we use a buffered HF solution to remove the impurities.

Annealing:

Etching cannot guarantee a smooth surface (which is what we need for growths). Thus, we use annealing. Annealing is a process in which a material is heated to a high temperature in the presence of a gas (in our case, pure O_2) in order to help the atoms on the surface settle. This can help make a rough surface smoother.

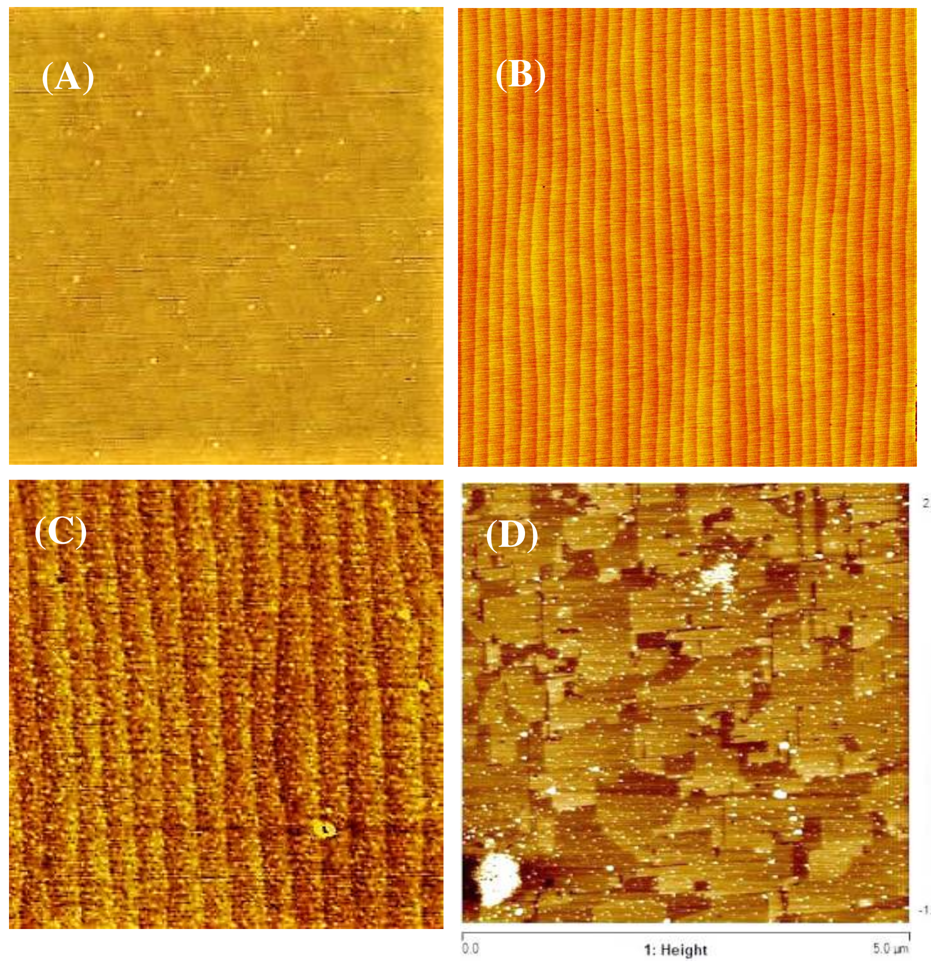


Example Rough Surface – 50x magnification of BTO target (PC: Derick Tseng)



AFM of VO2 grown on STO substrate (PC: Yang Liu)

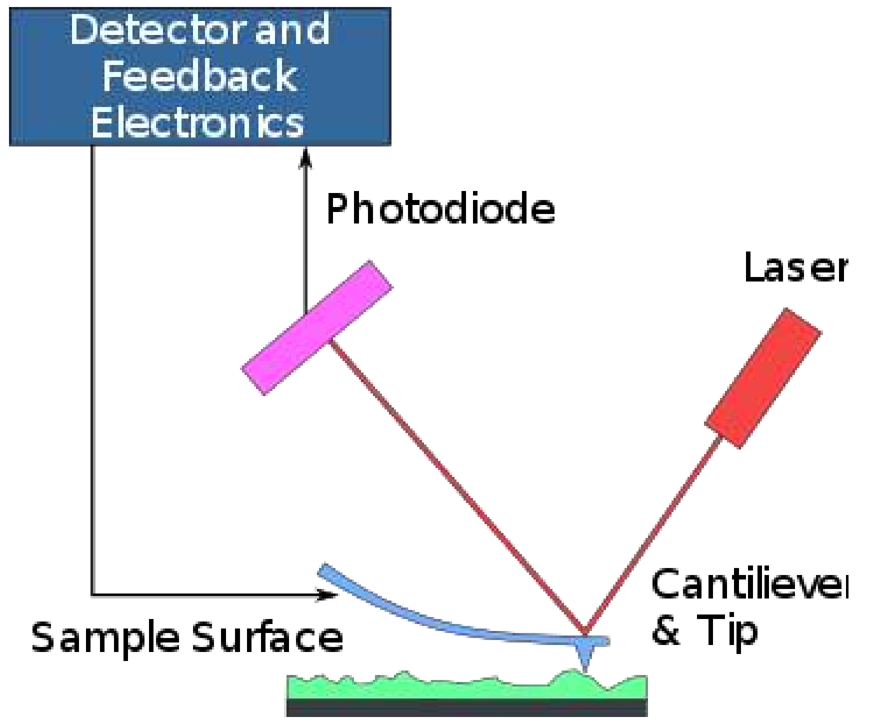
Analysis



PC: Mythili Surendran; AFM Images
Fig. A: STO as received
Fig. B: STO after etching & annealing
Fig. C: LAO film grown on etched STO
Fig. D: old STO (6 months)

Atomic Force Microscopy:

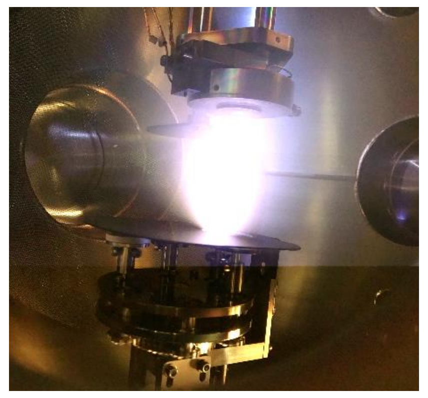
AFM is a process to visualize the surface of a material. A tip is attached to a cantilever and the machine uses this to tap the material's surface. A laser is pointed at the backside of the tip and fires a beam which is then reflected and collected by a photodiode. The cantilever bends, and this causes the reflected angle to change, which allows for imaging of surface.



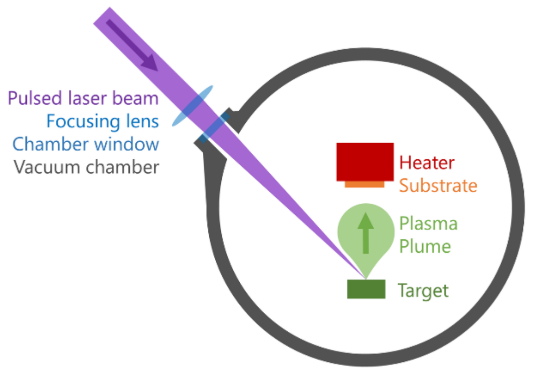
PC: Wikipedia; AFM Schematic

Applications

Pulsed Laser Deposition:

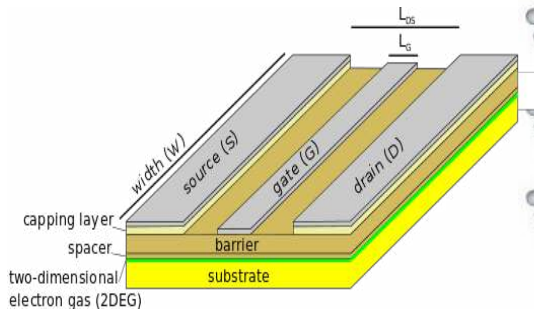


PC: Derick Tseng; PLD of $SrRuO_3$ on $GdScO_3$ substrate

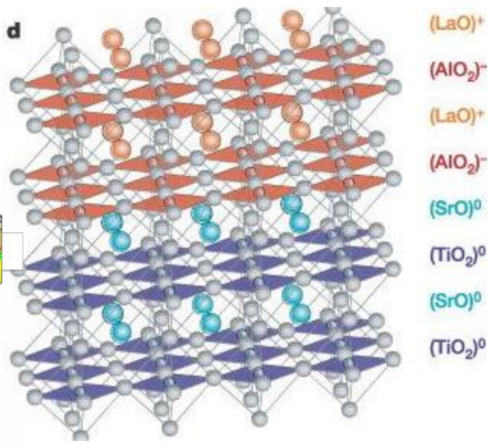


PC: Wikipedia; PLD Schematic

2DEG:



High electron mobility transistor (PC: Wikipedia)



Ohtomo, Akira & Hwang, HY. (2004). Ohtomo, A. & Hwang, H. Y. A high-mobility electron gas at the LaAlO3/SrTiO3 heterointerface. Nature 427, 423-426. Nature. 427. 423-6. 10.1038/nature02308.

Next Steps

The next step would be to experimentally find a way to obtain consistent better quality step-terraces for the STO substrates. We can also find the cause of degradation of the surface over time.

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