$SrTiO_3$ (001) Substrate Preparation and Characterization

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Abstract:

We utilize atomic force microscopy (AFM) to characterize single crystal $SrTiO_3$ (001) substrates before depositing heteroepitaxial thin films of complex oxides. Only those substrates with straight, single unit cell high steps separating large, atomically smooth terraces produce high quality thin films.

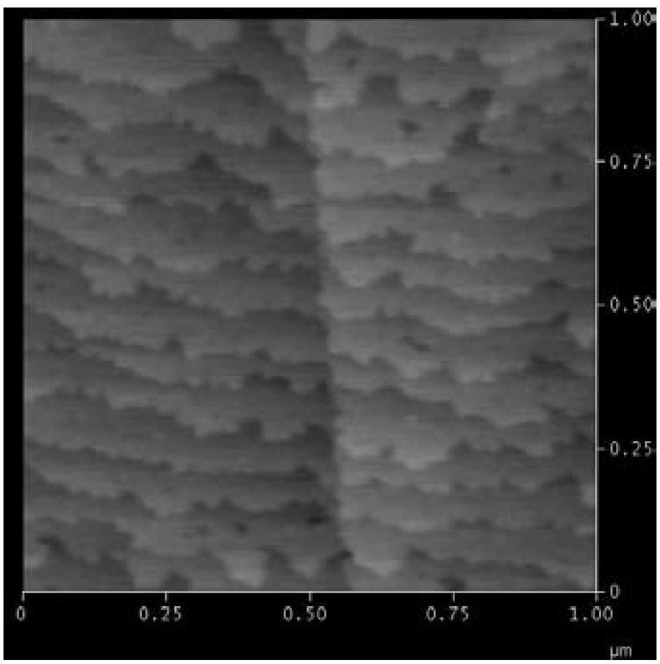

Figure 1: AFM image of a single crystal $SrTiO_3$ substrate, which is used in the growth experiments.

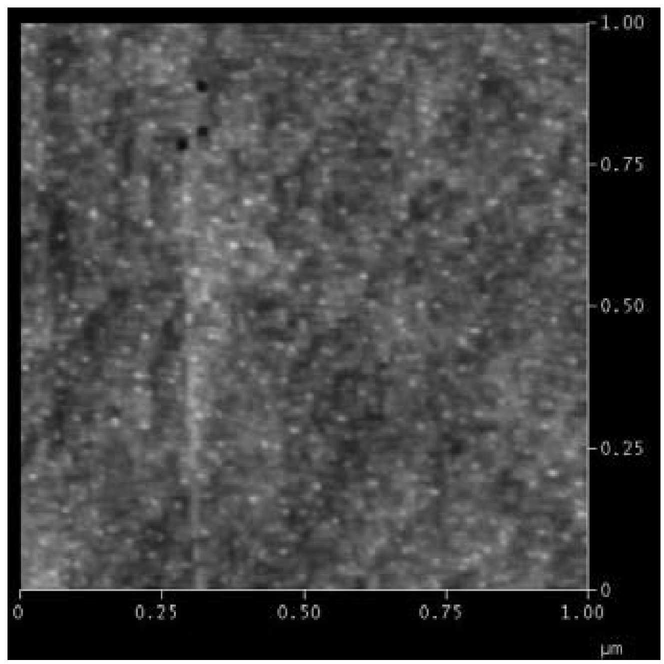

Figure 2: AFM image of a single crystal $SrTiO_3$ substrate, which is NOT used in the growth experiments.

Summary of Research:

$SrTiO_3$ has become a widely used substrate in the area of inorganic thin film growth in the recent years. A smooth and single atomic layer terminated substrate should be prepared in order to grow high quality thin films and heterostructures. The substrate preparation directions reported by Blank et al, enables us to achieve high quality substrates [1]. The technique that we adapted and applied to our substrates consists of ultrasonic soaking of the as-received substrates in ultrapure water for 10 minutes, and then 8:1 buffered oxide etch for 30 seconds. A final step of annealing at 1000°C under flowing oxygen for 24 hours is required to remove the remnants of the etching and to prepare straight step edges. It is important to note that all of the glassware used in the process needs to be cleaned perfectly to achieve reproducible results. Finally, since a significant fraction of the substrates have remaining defects, the prepared substrates need to be characterized by AFM to ensure sample quality.

Figure 1 shows the AFM image of a typical substrate used in our experiments. The direction and orientation of the steps are visible and no indication of etch pits are present. However, the variations in the quality of the substrates purchased from different vendors, variations between substrates purchased from the vendor but cut from different wafers, and the sensitivity of the etching and annealing process to the substrate terrace size may cause variations in the desired substrate properties. In order to guarantee substrate quality, we must characterize very single substrate with AFM prior to the thin film growth.

Figure 2 shows the AFM image of a typical substrate that should not be used in the growth experiments. The direction and orientation of the steps are not visible and the number of etch pits and islands are large.

In conclusion, atomically smooth, single atomic layer terminated substrates can be obtained by following the procedure reported in Ref. [1]. However, variations in the substrate quality may cause differences in the surface structure. Hence, every single substrate prepared in the way stated above needs to be characterized by AFM prior to thin film growth.

References:

[1] D. Blank et al., Applied Physics Letters 73, 2920 (1998).