THE MICROSTRUCTURE OF $SrRuO_3$ THIN FILMS ON (001) $SrTiO_3$ SUBSTRATES.

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$SrRuO_3$ (SRO) is a ferromagnetic metallic perovskite with properties that make it suitable for different device application. The physical properties are influenced by the atomic structure of the material. In thin films, new phenomena are observed compared to the corresponding bulk material, which can be due to the interfacial interaction between the film and the substrate. It is therefore important to correlate the properties to the microstructure of the films. There have been several studies reported of the influence of substrate miscut on the film [1][2]. However, more work is needed to get a clear understanding of this relationship. Bulk SRO is known to have an orthorhombic, distorted, pseudo-cubic structure with the space group Pbnm (no. 62) with dimensions of a = 5.53 Å b= 5.57 Å and c = 7.84 Å [3]. The SRO film may grow with its [001] axis parallel to the [100], [010] or [001] axis of the STO substrate. [4] (See figure 1). The distribution of the different orientations in the film along with the film quality has been suggested to be strongly dependent on the degree of substrate miscut [1] [2].

We have studied the microstructure of epitaxial SRO films grown on (001) $SrTiO_3$ (STO) substrates with different growth parameters, such as temperature and vicinal miscut. The samples where grown with pulsed laser deposition (PLD) using a KrF excimer laser (λ = 248 nm, τ = 30 ns) operating at 10 Hz. Samples where grown at temperatures between 690°C and 780°C on STO substrates with a small vicinal miscut of ~0.06°. Atomic force microscopy (AFM) measurements of the film surface were carried out using a Dimension 3100 SPM operating in tapping mode. Transmission electron microscope (TEM) investigation was performed using a Philips CM200 field emission gun operated at 200kV. Electron backscatter diffraction (EBSD) was carried out using a LEO Ultra 55 scanning electron microscope equipped with a HKL Channel 5 EBSD system.

High-resolution data of the fine scale microstructure of the SRO films and film/substrate interface as well as selected area electron diffraction (SAED) obtained from cross-section views showed that the deposition temperature affected the microstructure. Two different orientations of the SRO were observed in the films. The SAED showed that they were the X and Y type of orientation, where the SRO [001] axis is parallel to the STO [100] or [010] axis, respectively (see Figure 2). The TEM results also indicated a decrease in the dislocation density with increasing growth temperature. The transitions from one orientation to another were observed in the areas in the vicinity of dislocations and also in areas with a change in contrast in comparison to the rest of the film. These transitions were seen close to the film/substrate interface with a regular distance from each other, for films grown at 780°C. For films grown at 765°C the transitions were seen throughout the whole film with no apparent ordering. The AFM images of the film surface show a smooth surface with unit cell high steps, which suggest a step flow film growth mechanism. The step-to-step distance was approximately the same as the distance between the orientation transitions in the film grown at 780°C.

References
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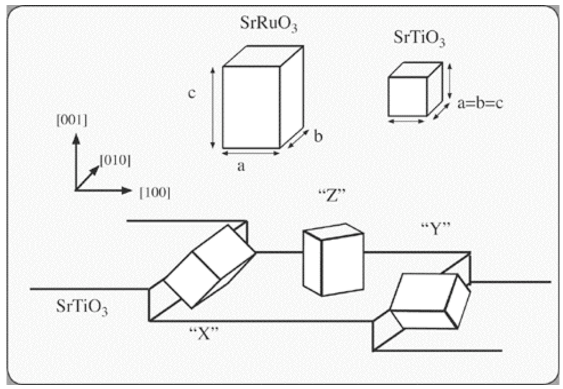

Figure 1.
A schematic of the SRO and STO unit cells (top), and the different SRO growth orientations X, Y and Z on the miscut STO substrate. The crystallographic directions are shown for STO.

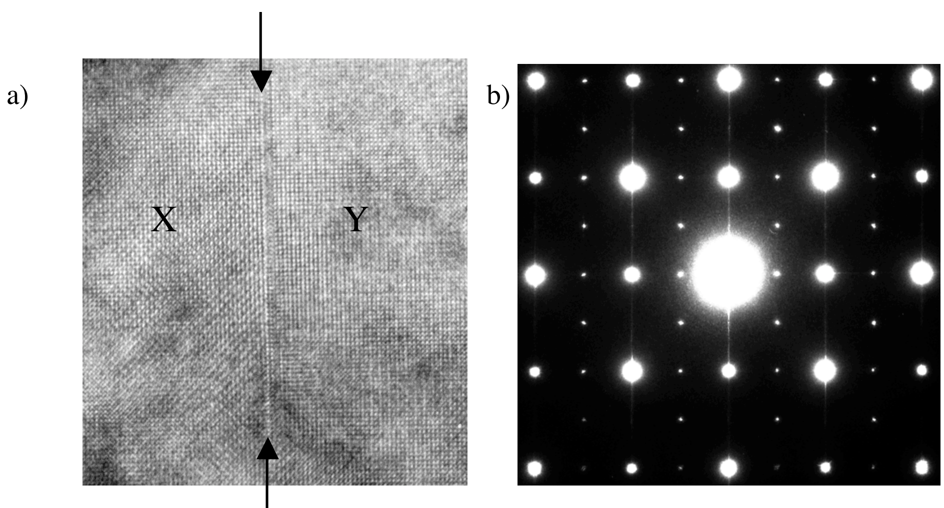

Figure 2.
(a) A high resolution TEM micrograph of the SRO thin film. The two different orientations X and Y can be seen on each side of a boundary (marked with arrows). (b) A SAED pattern from the SRO film superimposed on the pattern from the STO substrate. The weak diffraction spots indicate the presence of both X and Y SRO orientations.