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Thickness-induced metal-insulator transition in Sr doped thin film manganites

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Introduction: Manganese oxides with perovskite structure are an active field of current research, because of its unusual physical properties and its possible applications. It is found that the metal-insulator behavior of these materials depend strongly on band filling (doping degree), temperature, magnetic field and lattice distortion [1]. In epitaxially strained thin films additionally clamping to a given substrate, different crystal structures, lattice mismatch and strain energy influence the physical properties of the manganites: e.g. in contrast to the bulk manganites, our Sr doped (x=0.1) thin films (< 50 nm), grown on a $SrTiO_3$ (001) substrate, are metallic at low temperature [2].

Methods and Materials: X-ray diffraction is an ideal tool to study spatial periodicities in electron densities, allowing to determe structure and symmetry of the investigated material. We have studied the temperature dependence (10K ≤ T ≤ 290K) of the intensity of several reflections of thin film manganites $La_{1-x}Sr_xMnO_3$ / $SrTiO_3$ (001) for films of thickness 75 nm (x=0.1) and 360 nm (x=1/8) and have investigated further the structural properties for each phase found. Additionally, a detailed structural investigation of a thin film (25 nm, x=0.1) was performed at room temperature.

Results: One result of our studies is that for the 360 nm thick film, apart from the onset of a so-called tilting peak (e.g. (0.5 0 4) **) below T=200K, which we observed in earlier measurements [3], no further structural changes were found in the investigated temperature range. The film essentially has two pairs of orthorhombic, coherent twin domains. In order to overcome the misfit of the lattices between film and substrate, the orthorhombic film axes a and b, which only have been found in-plane, are mirrored along the cubic (100)- or (010)-plane. Maybe, because of epitaxial relationships only two of six possible pairs of twin domains are observed.

Another interesting result is found for the 75 nm thin film: Although the Q-dependence of its side peak positions is different from the 25 nm thin film [3], when cooling down, the Bragg peaks in specular direction of both samples increase more than one order in intensity, and their side peaks disappear (see Fig.1). This temperature dependence goes parallel with the rise of orthorhombic peaks (e.g. (-1 0 3.5)) at low temperatures. Further investigation showed that the structure changes from orthorhombic below T_c = 250 K to a more complicated one above T_c, which could be rhombohedral. Analogous to the 360 nm thick film, weak tilting peaks (e.g. (0 0.5 4)) were found at temperatures below T= 210 K.

The structural investigations at room temperature of the 25 nm thin film revealed that only peaks around (e/2 e/2 e/2) or (o/2 o/2 o/2) (o..odd, e..even) are found all having satellite peaks due to modulation of the film, which could fit to a rhombohedral structure. In contrast to Bragg peaks in specular direction, where the position of the satellites differs from the central one only in the H- or K- component, most the other film peaks additionally differ in the L- component.

Conclusions: The structure strongly depends on the film thickness. The transition temperature between rhombohedral and orthorhombic phases decreases with decreasing film thickness. The 25 nm thin film structure is coherently modulated, the 360 nm thick film is twinned, whereas the 75 nm has some properties which are seen as well for modulated structures as well as for twinned ones.

References:

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** All reflections are indexed in pseudocubic notation, where L is the out-of-plane component.

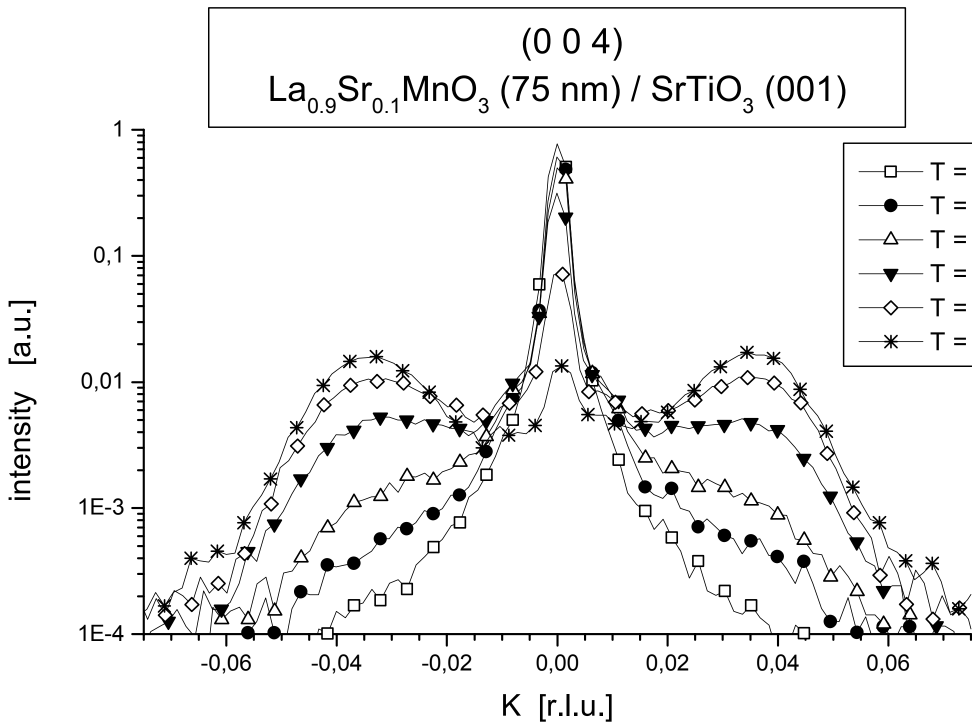

Figure 1: Transverse scans of the (0 0 4) Bragg reflection of the 75 nm thin LSMO film as a function of temperature.