ESRF	**Experiment title:** X-ray diffraction analysis of buried nanosized tunnel barriers in Ferromagnetic/Insulator/Ferromagnetic heterostructures made of complex oxide	**Experiment number**: **SI-793**
Beamline: ID32	**Date of experiment**: from: 17 April 2002 to: 22 April 2002	**Date of report**:
Shifts: 15	**Local contact(s)**: Dr. Jörg ZEGENHAGEN	*Received at ESRF:*

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Report:

We have performed x-ray reflectivity and diffraction measurements at 16 KeV energy, with the modified 2+2 (W21V) diffractometer of ID32. The energy was selected by the silicon (111) double crystal monochromator and the vertical focusing of the beam and harmonic rejection were obtained with a Pt coated stripe of the bimorph mirror. Heterostructures based on $SrRuO_3$ (SRO) and $SrTiO_3$ (STO) compounds were grown by PLD on STO substrates with *in situ* reflection high energy electron diffraction (RHEED) diagnostics. The samples were three different (SRO)M/(STO)N/(SRO)M heteroepitaxial structures (M/N/M structures), consisting of N unit cells of STO sandwiched between M unit cells of SRO: namely 11/5/11, 9/9/9 and 7/13/7 heterostructures. The total thickness was maintained constant (N +2 M =27 for all heterostructures). A SRO thin film, having approximately the same overall thickness, was measured for the purpose of comparison.

Some results of X-ray reflectivity measurements are reported in fig.1 for three heterostructures together with the SRO "thin" film: a) refers to the SRO film while b), c)and d) refer to the 11/5/11, 9/9/9 and 7/13/7 heterostructure respectively. Theoretical curves (shown by dashed lines) were obtained using the IMD extension of the XOP package. This analysis demonstrated that the thickness is in agreement with the expectations and therefore each intensity oscillation of the RHEED specular spot corresponds strictly to the growth of a single perovskite unit cell, either $SrRuO_3$ or $SrTiO_3$. Howevere we obtained that in these structures, the interfaces between the different constituent blocks are very sharp with a roughness of only one unit cell. The results were confirmed by the

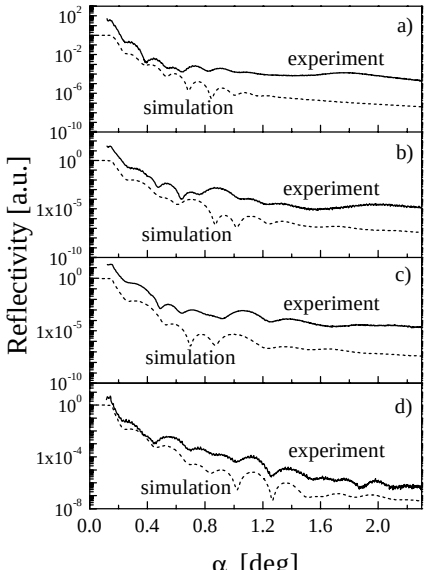

Fig.1

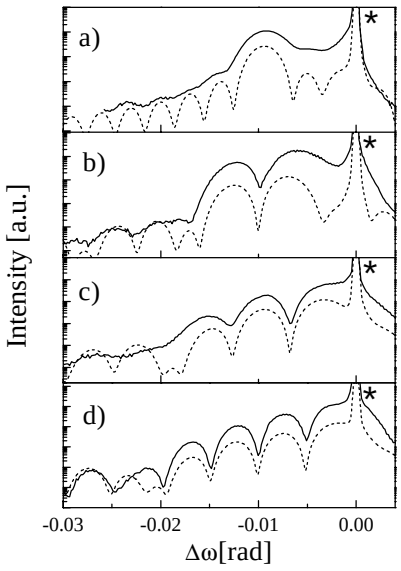

Fig.2

diffraction measurements in specular configuration reported in fig. 2 for the same heterostructures of fig.1. Diffraction spectra are reported in a narrow angular range around the (002) peak of the substrate (the intense peak indicated by an asterisk in the figure). Experimental data were simulated using a program based on the Takagi-Taupin equation of dynamical theory. These results have been reported in ref. [1].

Grazing incidence configuration was also employed to obtain information on the in-plane structural properties. We performed H-K reciprocal space mapping around around several reciprocal lattice points. In fig.3 are reported the measurements around the (022) (on the right) and (022) (on the left) reflections for the same heterostrucures of fig.1 and 2. We have observed that the strain field induces a distortion of the orthorhombic cell which is influenced by the number of unit cells of $SrTiO_3$ barrier layers. These results have been submitted for the publication [2].

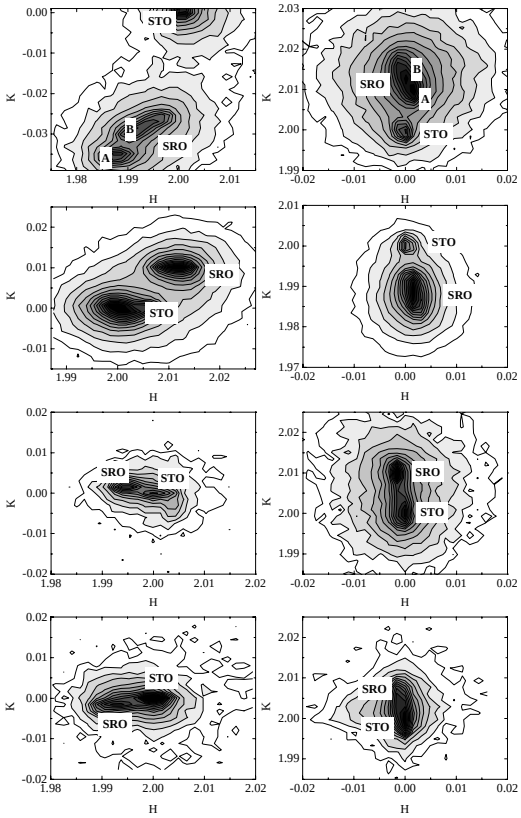

Fig.3

Grazing incidence x-ray diffraction and reflectivity measurements were also carried out on ultrathin (a few unit cells thick) superconducting heterostructures, based on $Ba_{0.9}Nd_{0.1}CuO_{2+x}$ and $CaCuO_2$ individual blocks. We investigated films with different thicknesses of the intermediate $CaCuO_2$ block, grown on (001)$SrTiO_3$ substrates by the pulsed-laser deposition technique with no *in situ* diagnostic. The same analysis as in the previous samples have been performed, demonstrating again the expected thickness of each constituent layer and the very low interface roughness (less than one unit cell). We were able to directly probe the crystallographic properties of one single unit cell of $CaCuO_2$, which is demonstrated to be the minimal necessary unit for the establishment of the superconductivity. Two examples of the obtained results are reported in fig. 4 and fig.5. In fig. 4 is reported the reflectivity measurement of a 5/1/5 heterostructure: experimental data (dotted curve) and simulation (continuous curve). In the inset, are reported the simulations curves of three different model structures: a) 5/0/5, b) 5/1/5 and c) 5/2/5. In fig.5 is reported the grazing incidence x-ray diffraction measurement in reciprocal lattice units of a 5/2/5 heterostructure around the (202) reflection of the STO substrate: experimental data (dotted curve) and simulation (continuous curve). In the inset, the simulation curves of four model structures with a different number of $CaCuO_2$ unit cells are reported: a) 5/0/5, b) 5/1/5, c) 5/2/5, and d) 5/3/5. These results have been also published [3].

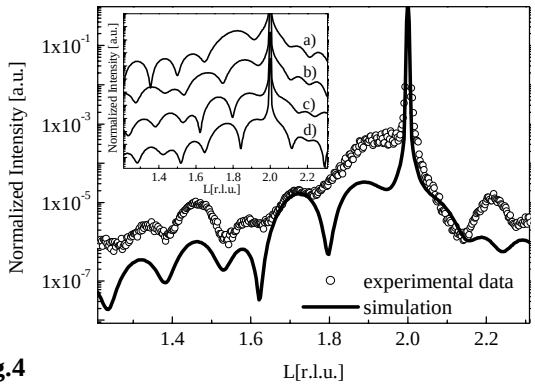

Fig.4

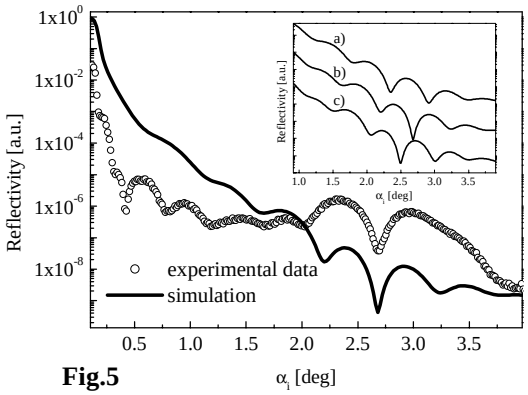

Fig.5

References

[1] "*$SrRuO_3$ based heterostructures grown by pulsed laser deposition*", M. Angeloni, C. Aruta, G. Balestrino, P. Orgiani, A. Tebano, P.G. Medaglia, Eur. Phys. J. B 29, 561 (2002).

[2] "*X-ray synchrotron radiation diffraction study of $SrRuO_3$ based heterostructures grown by pulsed laser deposition*", C.Aruta, M.Angeloni, G.Balestrino, P.G.Medaglia, P.Orgiani, A.Tebano, J.Zegenhagen, submitted.

[3] "*Structural characterization of ultrathin cuprate artificial superconducting structures by x-ray synchrotron radiation*", C. Aruta, M.Angeloni, G.Balestrino, P.G.Medaglia, P.Orgiani, A.Tebano, J. of Appl. Phys. 94, 6991 (2003).