High resolution STEM and analytical electron microscopic characterization of $SrRuO_3$ based multiferroic heterostructures

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We performed atomically resolved characterisation and electron energy loss spectroscopy (EELS) as well as energy dispersive X-ray spectroscopy (EDXS) by use of an aberration-corrected (C_s probe corrector) FEI TITAN 80-300 analytical scanning transmission electron microscope, allowing a spatial resolution of better than 1 Å in the STEM mode. Applying a high angle annular dark field detector (HAADF), elastic, thermal diffuse scattering (TDS) events could be recorded. As the inner detector angle is high enough (70 mrad in our case), the intensity of these highly localized, incoherent scatter processes is proportional to Z^2, and thus, the position of atom columns or individual atoms was imaged with a brightness related to their atomic number Z. This is usually referred to as Z-contrast technique, a powerful tool in materials science and nanoanalysis [1]. In particular, performing in such images simple intensity profiles along complicated crystallographic structures or across interfaces may provide first rough information on the arrangement of individual atomic columns without applying extensive spectroscopic techniques.
Multiferroic materials that possess both ferroelectric and (anti-)ferromagnetic ordering are appealing for applications in devices based on the magneto-electric effects. An important class of multiferroics are the oxide perovskites, as in some of them ferroelectricity or/and (anti-)ferromagnetism may be simultaneously exhibited. $BiFeO_3$, for example, is ferroelectric below T_C^{FE}= 1103 K and antiferromagnetic below T_N= 640 K, whereas $SrRuO_3$ and $La_{0.7}Sr_{0.3}MnO_3$ are metallic ferromagnetic below T_C^{FM}= 160 K and T_C^{FM}= 370 K, respectively. $BaTiO_3$ is the first discovered ferroelectric perovskite, with a T_C^{FE}= 393 K. Combining these ferroelectric and ferromagnetic perovskites in high structural quality epitaxial heterostructures (HSs) and superlattices (SLs), artificial magneto-electric materials can be fabricated, or by growing SLs of ferromagnetic perovskites with different magnetic structures, such as $SrRuO_3$ and $La_{0.7}Sr_{0.3}MnO_3$, antiferromagnetic-like structures can be achieved. A Z-contrast STEM micrograph of such a $SrRuO_3$ / $La_{0.7}Sr_{0.3}MnO_3$ SL is shown in Fig. 1, and, at higher magnification, the atomic structure of the SL layers and their interfaces is studied in Fig. 2. All the HSs and SLs investigated in this work were grown by pulsed-laser deposition (PLD) on $SrTiO_3$(100) and $DyScO_3$(110) single crystal substrates [2].

1. P.D. Nellist, and S.J. Pennycook, Advances in Imaging and Electron Physics, **113** (2000) p147.
2. I. Vrejoiu, M. Alexe, D. Hesse, and U. Gösele, Adv. Funct. Mater. **18** (2008) p3892.

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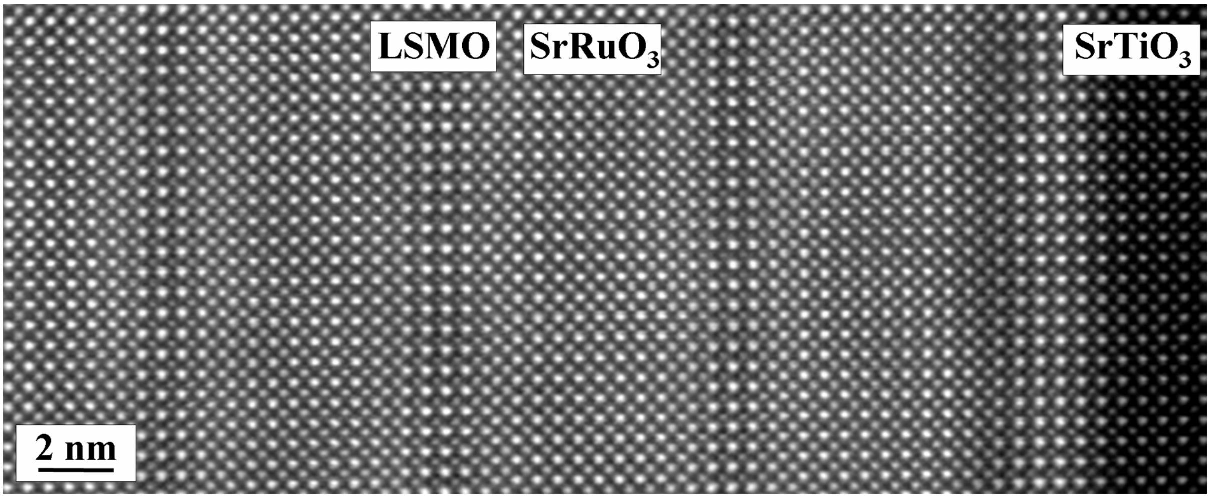

Figure 1. Z-contrast STEM image of a $SrRuO_3$ / $La_{0.7}Sr_{0.3}MnO_3$ SL with 15 bilayers, grown on $SrTiO_3$(100) by PLD.

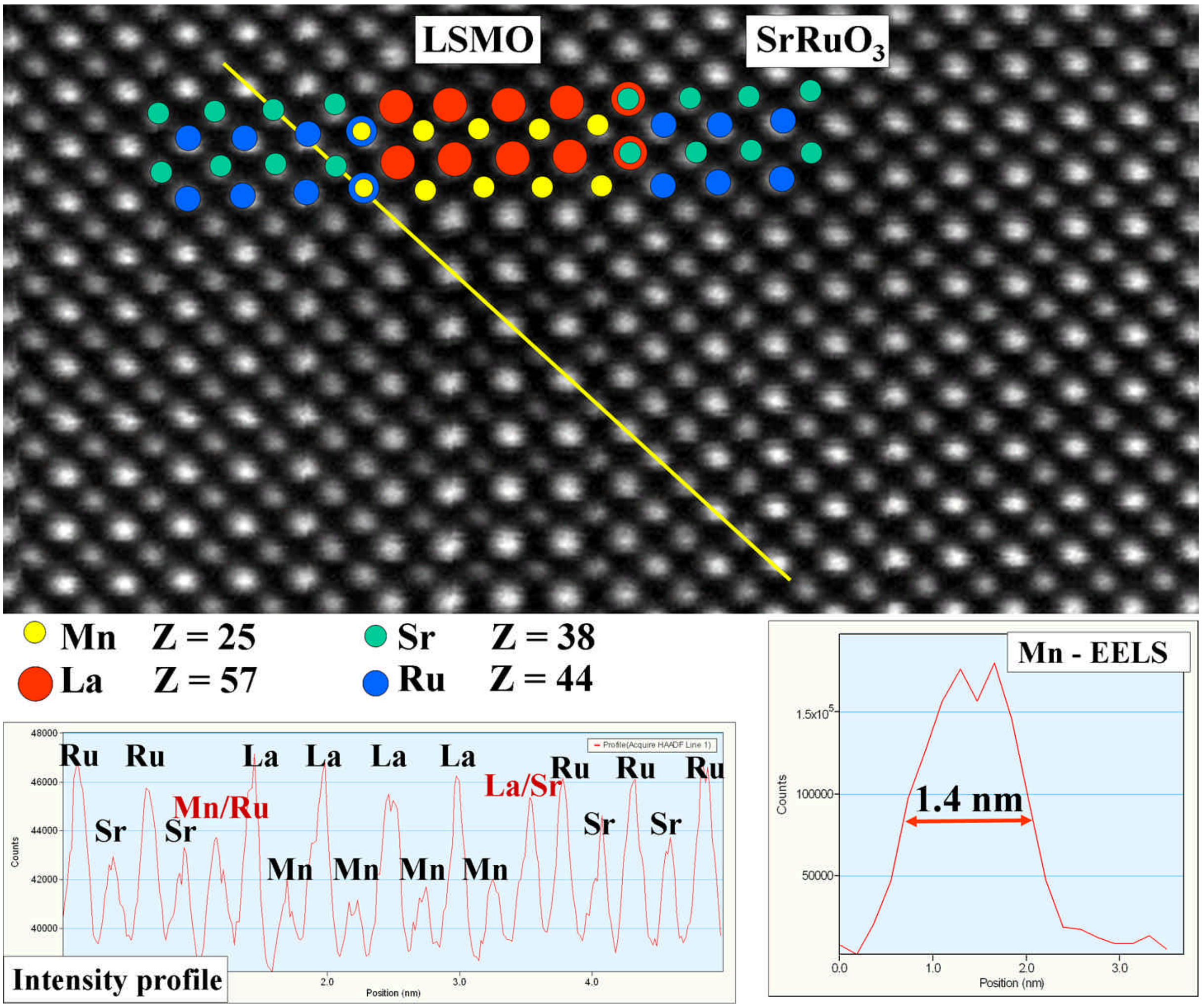

Figure 2. Z-contrast STEM image of the same $SrRuO_3$ / $La_{0.7}Sr_{0.3}MnO_3$ SL, with a model of the atomic structure. On the bottom, left an intensity profile across the two $SrRuO_3$ / $La_{0.7}Sr_{0.3}MnO_3$ interfaces, and right a Mn EELS profile across the $La_{0.7}Sr_{0.3}MnO_3$ layer are shown, with both demonstrating a slight interdiffusion of Mn.

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