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NANOSCALE ANALYSIS OF COMPLEX OXIDE INTERFACES

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Aberration correction in the Scanning Transmission Electron Microscope (STEM) is pushing the achievable spatial resolution for imaging and spectroscopy into the sub-angstrom regime, providing a new level of insight into the structure/property relations of complex materials. The combination of atomic-resolution Z-contrast scanning transmission electron microscopy and electron energy loss spectroscopy (EELS) represents a powerful method to link the atomic and electronic structure of solids to macroscopic properties. In the aberration corrected STEM, the electronic structure of solids can now be probed with a spatial resolution close to 1 Å, the approximate value of ionic radii [1,2]. This level of resolution therefore allows the properties of interfaces to be probed in unprecedented detail.

This work presents several examples of atomic resolution studies of the relationship between structure and electronic properties of complex oxide interfaces. The first concerns interfaces in superconducting/ferromagnetic $YBa_2Cu_3O_{7-x}/La_{0.67}Ca_{0.33}MnO_3$ (YBCO/LCMO) superlattices. A high resolution STEM image obtained with a high angle annular field detector is shown in figure 1. Such interfaces are coherent, and free of defects. By means of high spatial resolution EELS disorder parameters like chemical interdiffusion can be analyzed by studying how the intensity associated with the different edges changes across the interface. Figure 2(a) show how the intensity of the edges of La (open circles), Mn (solid circles) and Ba (solid squares) decays abruptly at the interface, so that chemical interdiffusion can be disregarded. From the point of view of the electronic properties, direct evidence of charge injection from the ferromagnetic layer into the superconducting layers will be shown, as depicted in figure 2(b), where the decay of the intensity of the pre peak feature in the O K edge as a function of the distance to the interface is shown. This feature is associated with density of holes in the YBCO layer [3]. This mechanism provides a simple explanation for the depression of the superconducting transition temperature in these superlattices. Another superlattice system, $CaTiO_3/La_{1-x}Ca_xTiO_3$ with low La doping, has been investigated to determine the sensitivity to single La atoms. These can be identified through intensity traces as shown in figure 2, and attempts to obtain single atom EELS data will be described.

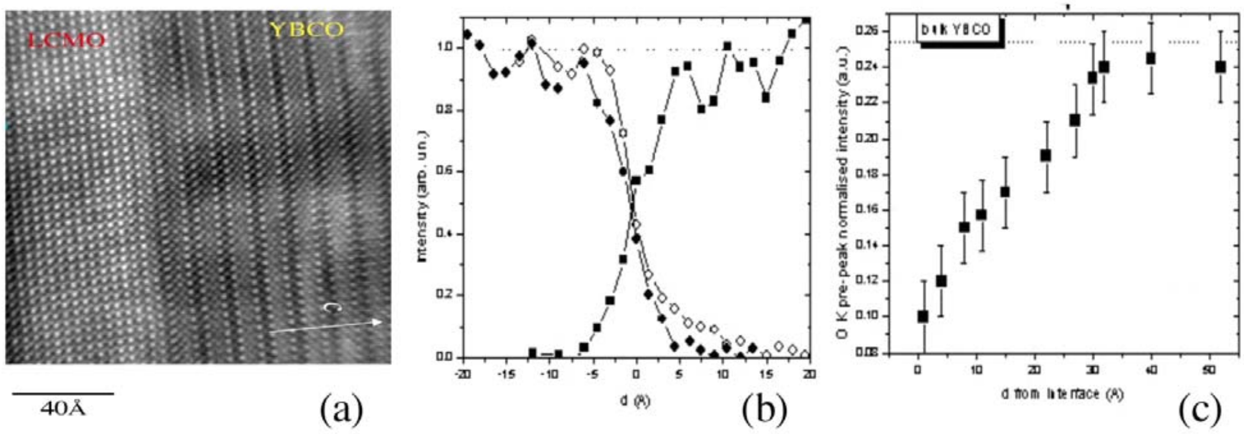

Figure 1: (a) HAADF image of a LCMO/YBCO interface. (b) Intensity of the edges of La (open circles), Mn (solid circles) and Ba (solid squares) as a function of the distance to the interface. (c) Dependence of the integrated intensity of the O K edge prepeak, associated with the density of holes in YBCO, as a function of the distance to the interface.

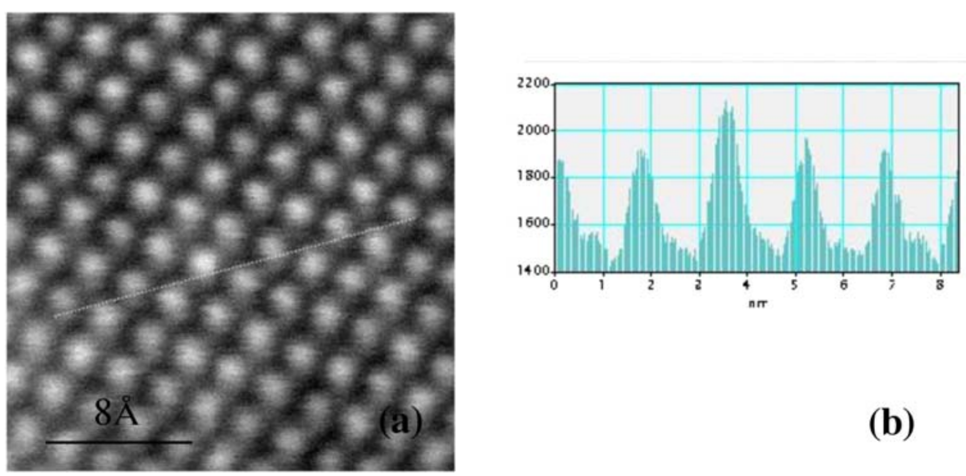

Figure 2: (a) HAADF of a $La_{0.025}Ca_{0.9975}TiO_3$ layer in a $CaTiO_3/La_{1-x}Ca_xTiO_3$ superlattice, showing an isolated La ion. (b) Intensity trace along the white dotted line shown on figure 2(a).

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