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How sharp are atomically sharp high-T_c La_2CuO_4 interfaces?

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Intriguing physical effects at the interfaces of epitaxial oxide systems are induced by the local variation of ionic and electronic species, and the functionalities can be varied by interfacial design [1]. The structural adaptability of La_2CuO_4 allows for designing different interfaces. High-temperature interfacial superconductivity (HT-IS) at the interface between two non-superconducting La_2CuO_4 layers is one of the most prominent examples [2]. In addition to homo-epitaxial systems [3,4], the multilayers of La_2CuO_4 with 214- and 113-type lanthanum nickelate contacts revealed the impact of the interface sharpness on the occurrence of HT-IS [5] and thermoelectric properties [6], respectively.

In this work, we fabricate $(La,Sr)_2CuO_4$–$SrMnO_3$–$LaMnO_3$–La_2CuO_4 cuprate-manganite multilayers [7] (with different La_2CuO_4 layer thicknesses) using atomic-layer-by layer molecular beam epitaxy (ALL-Oxide MBE) [1]. We focus on the interface sharpness and related superconducting mechanisms in comparison with cuprate-cuprate interfaces. We extensively probe the interfaces using aberration-corrected analytical scanning transmission electron microscopy (STEM) techniques including high-angle annular dark-field (HAADF) and annular bright-field (ABF) imaging, electron energy-loss spectroscopy (EELS), and energy-dispersive X-ray spectroscopy (EDXS). A JEOL JEM-ARM200F STEM equipped with a cold field-emission electron source, a probe Cs-corrector (DCOR, CEOS GmbH), a Gatan GIF Quantum ERS spectrometer and a large solid-angle JEOL Centurio SDD-type EDXS detector was used for atomic-resolution analyses. STEM and EELS spectrum imaging were performed at probe semi-convergence angles of 20 mrad and 28 mrad, respectively. The collection angles for HAADF and ABF imaging were 75-310 mrad and 11-23 mrad, respectively. The O-O picker tool [8] and STEM SI Warp [9] software have been used for STEM analyses.

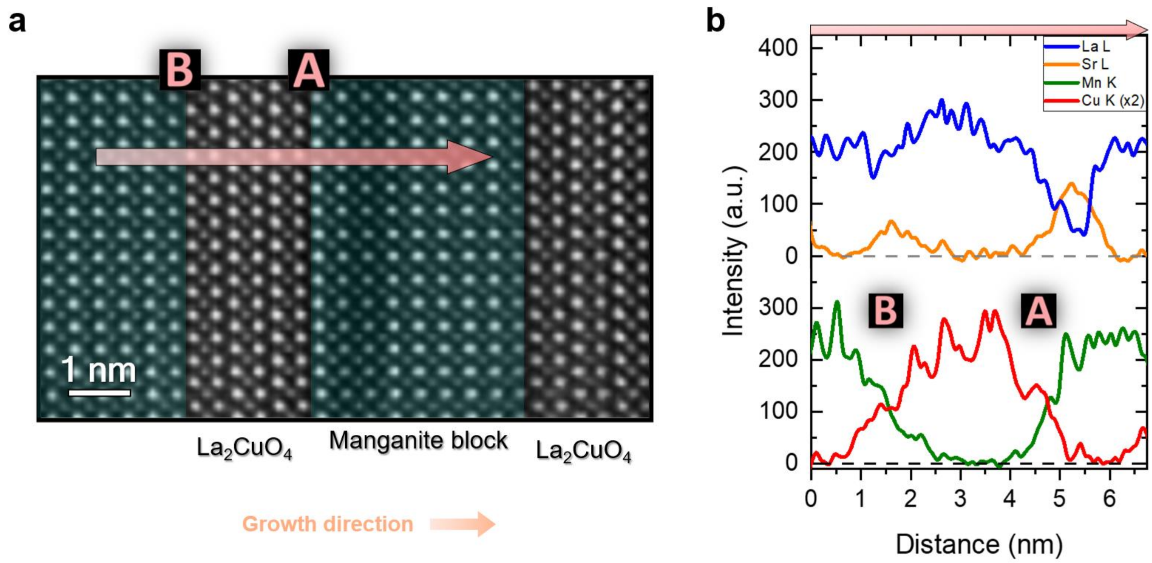

Figure 1. (a) STEM-HAADF image of $(La,Sr)_2CuO_4$–$SrMnO_3$–$LaMnO_3$–La_2CuO_4 multilayer demonstrating the high epitaxial quality. The pink arrow represents the region of the acquired EDX line scan profiles. (b) Cu (red) and Mn (green) profiles indicate the elemental intermixing at the interfaces, while La (blue) and Sr (orange) profiles are given as guide indicating the individual layers.[7]

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