Highlights

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Interface reconstruction in superconducting $CaCuO_2/SrTiO_3$ superlattices: A hard x-ray photoelectron spectroscopy study

C. Aruta,[1] C. Schlueter,[2] T.-L. Lee,[3] D. Di Castro,[1,4] D. Innocenti,[1,4] A. Tebano,[1,4] J. Zegenhagen,[2] G. Balestrino[1,4]

[1] CNR-SPIN, Università di Tor Vergata, Roma (Italy)
[2] European Synchrotron Radiation Facility, Grenoble (France)
[3] Diamond Light Source Ltd., Harwell Science and Innovation Campus, Didcot (United Kingdom)
[4] Dipartimento di Ingegneria Civile ed Ingegneria Informatica, Università di Roma Tor Vergata, Roma (Italy)

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We report on the electronic reconstruction behind the hole doping mechanism in superconducting (SC) artificial superlattices (SLs) based on insulating $CaCuO_2$ (CCO) and $SrTiO_3$ (STO) blocks. Hard x-ray photoelectron spectroscopy (HAXPES) shows that the diverging built-in electrostatic potential arising at the polar/nonpolar CCO/STO interface is suppressed. However, the valence band alignment (Fig.2(d)), calculated by the HAXPES core-level shifts, prevents any electronic reconstruction by direct charge transfer between CCO and STO bands.

A simplified mechanism for the suppression of the electrostatic potential can be based on a purely ionic mechanism, as shown in Fig. 1(b).

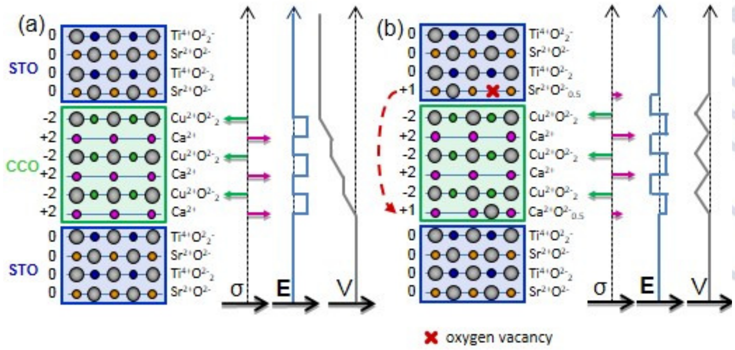

Fig.1 Sketch of CCO/STO SLs. (a) Unreconstructed interfaces with the diverging electrostatic potential. (b) Reconstructed interfaces by oxygen redistribution in the alkaline-earth metal interface planes.

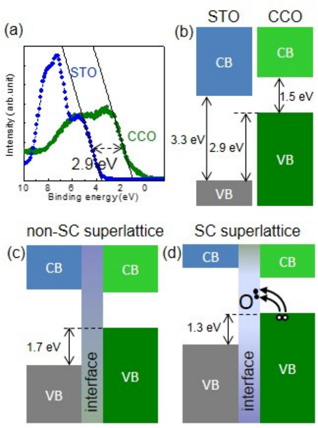

Fig.2 (a) Valence-band spectra for the CCO and the STO. (b)–(d) Schematic diagram of the valence and conducting bands: (b) uncoupled CCO and STO, (c) non-SC SL and (d) SC SL.

The oxygen compositional roughening, resulting from the proposed model, is supported by the presence of additional peaks and doublets in all the measured HAXPES core-level spectra.

Furthermore, by using highly oxidizing growth conditions, the oxygen coordination in the reconstructed interfaces may be increased by excess oxygen introduced at the interfaces. The charge neutrality is preserved by leaving two holes in the valence band of CCO for each extra oxygen ion, as shown in Fig. 2(d), thus making the cuprate block superconducting.