Highlights

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Universal electronic structure of polar oxide hetero-interfaces

Uwe Treske[1], Nadine Heming[1], Martin Knupfer[1], Bernd Büchner[1,2], Andreas Koitzsch[1], Stefan Krause[3], Emiliano Di Gennaro[4,5], Amit Khare[4,6], Umberto Scotti Di Uccio[4,5], Fabio Miletto Granozio[4]

[1] IFW Dresden, P.O.Box 270116, 01171 Dresden, Germany
[2] Institut für Festkörperphysik, Technische Universität Dresden, 01062 Dresden, Germany
[3] BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany
[4] CNR-SPIN, Complesso Universitario Monte S. Angelo, Napoli, Italy
[5] Dipartimento di Fisica, Universita "Federico II" di Napoli, Italy
[6] Department of Physics, Sungkyunkwan University, Suwon, 440-746, South Korea

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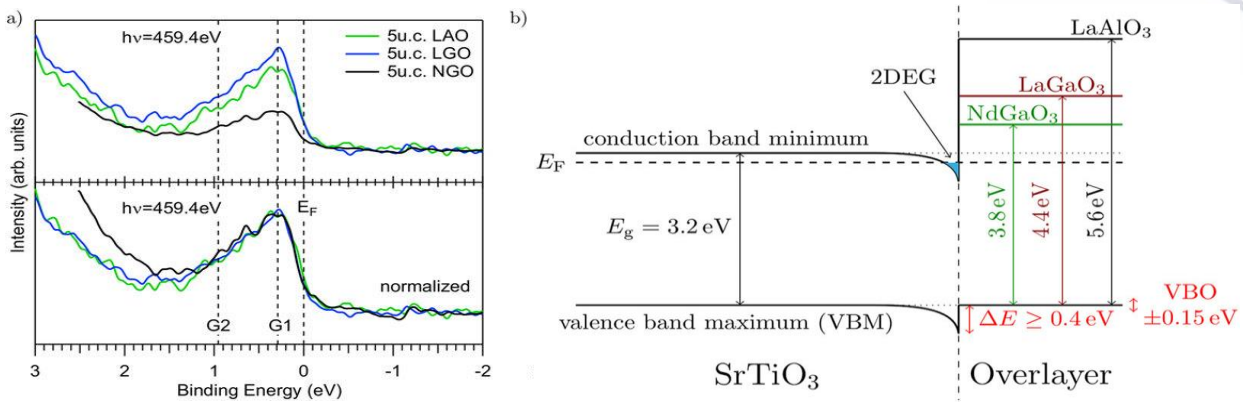
The electronic properties of $NdGaO_3/SrTiO_3$, $LaGaO_3/SrTiO_3$, and $LaAlO_3/SrTiO_3$ interfaces, all showing an insulator-to-metal transition as a function of the overlayer-thickness, are addressed in a comparative study based on x-ray absorption, x-ray photoemission and resonant photoemission spectroscopy. The nature of the charge carriers, their concentration and spatial distribution as well as the interface band alignments and the overall interface band diagrams are studied and quantitatively evaluated. The behavior of the three analyzed heterostructures is found to be remarkably similar. The valence band edge of all the three overlayers aligns to that of bulk $SrTiO_3$. The near-interface $SrTiO_3$ layer is affected, at increasing overlayer thickness, by the building-up of a confining potential. This potential bends both the valence and the conduction band downwards. The latter one crossing the Fermi energy in the proximity of the interface and determines the formation of an interfacial band offset growing as a function of thickness. Quite remarkably, but in agreement with previous reports for $LaAlO_3/SrTiO_3$, no electric field is detected inside any of the polar overlayers. The essential phenomenology emerging from our findings is discussed on the base of different alternative scenarios regarding the origin of interface carriers and their interaction with an intense photon beam.



Left image: Resonant photoemission on the Ti 3+ states of the Ti L-edge. The presence of states at the Fermi level, with similar spectral shape, is seen for all samples. Right image: band diagrams are derived from our data.