Nano-Angle resolved photoemission spectroscopy of STO: segregation, oxygen vacances and waterfall like behavior

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The development of all-oxide electronic devices presents a quickly advancing technological field were $SrTiO_3$ (STO) plays a key role. An important step for oxide electronics was the discovery of a high mobility 2D electron gas (2DEG) on the $LaAlO_3/SrTiO_3$ interface, two otherwise insulating oxides. On the other hand, a similar 2DEG has been recently reported on the bare STO (001) surface. Among other explanations, the physical origin of the aforementioned confined electron gases has been attributed to surface oxygen vacancies.

In this communication we report on the structural and electronic properties of thermally reduced STO single crystals. We have investigated these systems using a probe with real- and reciprocal-space sensitivity: a synchrotron radiation microsopic setup which offers the possibility of Scanning Photoemission Microscopy and Angle Resolved Photoelectron Spectroscopy (ARPES) down to the nanometric scale. For the first time, we have spectroscopically imaged the chemical composition of samples presenting reproducible and suitable low-energy diffraction patterns after following well-established thermal reduction protocols. At the micrometric scale, Ca-rich areas have been directly imaged using high-energy resolution core level photoemission. Moreover, we have monitored the effect of Ca segregation on different features of the STO(100) electronic band structure, measuring ARPES inside, outside and at the interface of the Ca-rich identified areas. In particular, the interaction of Ca with the well-known intragap localized state, previously attributed to oxygen vacancies, has been investigated. Moreover, the combination of direct imaging and spectroscopic techniques with high spatial resolution has clarified the long-standing dilemma related to the bulk or surface character of Ca segregation in STO. Moreover, new data will be discussed on the light of the calcium segregation, oxygen vacancies and waterfall 2DEG sates.