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Electron-Beam Writing of Atomic-Scale Reconstructions at Oxide Interfaces

Greta Segantini[1], Chih-Ying Hsu[1,2], Carl Willem Rischau[1], Patrick Blah[3], Mattias Matthiesen[3], Stefano Gariglio[1], Jean-Marc Triscone[1], Duncan T.L. Alexander[2], Andrea Caviglia[1]

[1]*Department of Quantum Matter Physics, University of Geneva, 24 Quai Ernest-Ansermet, CH-1211 Geneva 4, Switzerland*
[2]*Electron Spectrometry and Microscopy Laboratory (LSME), Institute of Physics (IPHYS), Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland*
[3]*Kavli Institute of Nanoscience, Delft University of Technology, 2628 CJ Delft, The Netherlands*

Transition metal oxides exhibit a variety of functionalities and epitaxial growth enables the synthesis of high-quality films. However, it confines the choice of substrates to those meeting symmetry and lattice parameter constraints. A way to overcome these constraints is releasing epitaxial oxides from their growth substrate, by means of sacrificial layers [1], thus obtaining oxide membranes.

Here, we report on the controlled formation of interfacial ionic bonds between a 30 nm-thick $SrTiO_3$ membrane and a niobium-doped $SrTiO_3$(001) carrier substrate. Scanning transmission electron microscopy in electron energy-loss spectroscopy mode (STEM-EELS) was used to investigate electronic/bonding state of Ti and O going across the interface from the substrate to the membrane as a function of annealing temperature. For a certain annealing temperature, and for a certain flux of STEM electron-beam, rastering it across the interface between the membrane and the substrate induces a perfect interface reconstruction with formation of ionic bonds between the membrane and the substrate. STEM-EELS analysis confirmed a change of Ti valence from Ti 2^+ to Ti 4^+, and restoration of oxygen octahedral coordination in the interface region [2].

This study presents a method for selectively creating ionic bonds between perovskite oxides using electron beams. This approach opens new pathways for synthesizing artificial heterostructures beyond epitaxial constraints and for locally manipulating physical properties at their interfaces.

References:
[1] D. Lu et al., *Nature Materials* **15** (2016) 12
[2] G. Segantini et al., *Nano Letters* **24** (2024) 45