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Electronic and structural correlations at 2DEG oxide heterointerfaces[1]

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The formation of a two-dimensional electron gas (2DEG) at complex oxide interfaces is directly influenced by the rich electronic and structural characteristics of the bulk oxides, as well as new phenomena arising at the interface. We investigated how local correlations control oxide 2DEGs by inserting a single atomic layer of a rare-earth oxide (RO) [(R is lanthanum (La), praseodymium (Pr), neodymium (Nd), samarium (Sm), or yttrium (Y)] into an epitaxial $SrTiO_3$ matrix using pulsed-laser deposition with atomic layer control [1]. We find that structures with La, Pr, and Nd ions result in conducting 2DEGs at the inserted layer, whereas the structures with Sm or Y ions are insulating. Our local spectroscopic results, and our theoretical results, indicate that the interfacial conductivity is dependent on electronic and structural correlations that decay spatially into the $SrTiO_3$ matrix and are determined by the local rare-earth ion. We also find that at least the structural correlations play a role in the properties of the 2DEG at $LaAlO_3/SrTiO_3$ interfaces. We used different lattice constant single-crystal substrates to produce $LaAlO_3/SrTiO_3$ interfaces with controlled levels of biaxial epitaxial strain [2], finding that tensile-strained $SrTiO_3$ destroys the conducting 2DEG, while compressively strained $SrTiO_3$ retains the 2DEG, but with reduced carrier concentration. In addition, the critical $LaAlO_3$ overlayer thickness for 2DEG formation increases with $SrTiO_3$ compressive strain. Our first-principles calculations suggest that a strain-induced electric polarization in the $SrTiO_3$ layer, stabilized by the $LaAlO_3$ overlayer, is responsible for this behavior. This work was done in collaboration with H.W. Jang, C.W. Bark, D.A. Felker, T. Hernandez, Y. Wang, M.K. Niranjan, C.T. Nelson, Y. Zhang, D. Su, C.M. Folkman, S.H. Baek, S. Lee, K. Janicka, H. Zhou, Y. Zhu, X.Q. Pan, D.D. Fong, E.Y. Tsymbal, C. B. Eom. This work was supported by the National Science Foundation through grant DMR-0906443.

[1] H.W. Wang et al., Science **331**, 886 (2011).
[2] C.W. Bark et al., P. Natl Acad Sci USA **108**, 4720 (2011).

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