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Charge transfer induced modulation doping of two-dimensional electron gas at complex oxide interfaces

Y. Z. Chen, F. Trier, D. V. Christensen, S. Linderoth, and N. Pryds
Department of Energy Conversion and Storage, Technical University of Denmark, Risø Campus, 4000 Roskilde, Denmark
yunc@dtu.dk

The discovery of two-dimensional electron gases (2DEGs) at the interface between two insulating complex oxides, such as LaAlO$_3$ (LAO) or gamma-Al$_2$O$_3$ (GAO) epitaxially grown on SrTiO$_3$ (STO) $^{1,2}$, provides an opportunity for developing all-oxide electronic devices $^{3,4}$. However, large enhancement of the interfacial electron mobility remains a major and long-standing challenge for fundamental as well as applied research of complex oxides. Here, we report a 2DEG mobility enhancement of more than two orders of magnitude obtained by inserting a single unit cell (uc) buffer layer at the interface between disordered LaAlO$_3$ and crystalline SrTiO$_3$ created at room temperature. $^5$ The spacer layer suppresses strongly the formation of oxygen vacancies on the SrTiO$_3$ side and leads to an unexpected modulation-doping scheme of the complex oxide 2DEG via interface charge transfer. $^6$ This results in a very high 2DEG mobility exceeding 70 000 cm$^2$V$^{-1}$s$^{-1}$ at 2 K and low carrier density in the range of $10^{12}$ cm$^{-2}$. These findings open new avenues for oxide electronics.