Suppression of quasi-two dimensional electron gas in $LaAl_{1-x}Cr_xO_3/SrTiO_3$: Role of electronic reconstruction

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Abstract

RHEED controlled ultra thin films (~6 u. c.) of $LaAl_{1-x}Cr_xO_3$ ($0 \leq x \leq 1.0$) grown by pulsed laser on $SrTiO_3$ (100) single crystal substrate have been studied using transport and photoemission spectroscopy. Aim of this study is to shed more light on the origin of conducting and insulating interface in the case of $LaAlO_3/SrTiO_3$and $LaCrO_3/SrtiO_3$ heterostructures, respectively. Transport measurements show enhancement in sheet resistance and suppression of sheet electron density with the increase in Cr content. X-ray photoemission spectroscopy (XPS) and ultraviolet photoemission spectroscopy (UPS) measurements have been performed to understand the Cr concentration dependent metal-insulator electronic phase transition at the interface. Ti and Cr 2p XPS core level spectra clearly establishes the decrease/increase in Ti^{3+} / Cr^{2+} ion concentration with increasing Cr content in $LaAl_{1-x}Cr_xO_3$ films. UPS valence band spectra show continued suppression Ti 3d states and simultaneous opening of energy gap with increasing Cr concentration in the films. Our study confirms that polar catastrophe induced electronic reconstruction of Ti ions (Ti^{4+}/Ti^{3+}) drives the interface conductivity in Al rich films. On the other hand, for Cr rich films ($x \geq 0.6$), competing electronic reconstruction of Ti ions at interface and Cr ions in the film suppresses the polar catastrophe and results in insulating interface. Therefore, our study lead us to conclude that electronic reconstruction is the most important and universal mechanism in these oxide heterostructures, apart from the other possibilities such as interface chemical disorder and O defects.