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New Insights into the Creation of High-Mobility Two-Dimensional Electron Gas at Oxide Interfaces: Control of Interfacial Redox Reactions by an Electron Sink

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Redox reactions on the $SrTiO_3$ (STO) surface provide a new opportunity to create two-dimensional electron gas (2DEG) at all oxide interfaces by forming oxygen vacancies.[1] Herein, we report that an insulating buffer layer of $La_{1-x}Sr_xMnO_3$ (LSMO, $0\leq x\leq 1$), grown epitaxially on unit cell (uc) scale, can strongly suppress the formation of oxygen vacancies for typical metallic interfaces between STO and various insulating overlayers. Remarkably, for heterostructures with sizeable band-offsets, the LSMO buffer layer can result in modulation-doping[2] of the interfacial 2DEGs, where large enhancements in electron mobility as well as sharp metal-insulator transitions are achieved upon tuning the thickness of the buffer layer. Moreover, novel charge and orbital reconstruction at the modulation doped interface is also revealed by resonant X-ray reflectivity measurements, where the buffer layer play the role as an electron sink. On the other hand, for heterointerfaces with negligible band-offsets, the conduction is dominated by redox reactions and the carrier mobility is always lower than 1000 $cm^2V^{-1}s^{-1}$ at 2 K. The insertion of the electron sink layer turns out to be one of the most effective approaches to achieve high-mobility and low carrier density 2DEGs at oxide interfaces.

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[1] Chen, Y. Z. *et al. Nano Lett.* **11**, 3774 (2011).

[2] Chen, Y. Z. *et al. Nature Mater.* **14**, 801 (2015).