Handling the oxygen migration at oxide heterostructures

27 November 2018. NUS physicists have developed a methodology for tailoring the oxygen electromigration in buried interface of complex oxide materials and therefore realized the energy band reconstruction.

Oxide heterostructures, which are composed of layers of different oxide materials, exhibit unique physical properties at their interfaces which do not exist in their parent compounds. An example is the interface comprising an insulating film of lanthanum aluminate ($LaAlO_3$, abbreviated as LAO) on insulating strontium titanate single crystal ($SrTiO_3$, abbreviated as STO). This interface shows various emergent properties such as conducting, magnetism and two-dimensional superconductivity which are not observed in their bulk counterparts. It is found that the oxygen vacancies in STO play an important role in the emergent properties, especially for the interfaces synthesized at room temperature where the LAO over layer is amorphous. Room temperature synthesis of interface have the advantage of being compatible with established semiconductor fabrication process and is therefore vital for application exploration. Therefore, tailoring the number of oxygen vacancies at the interface would help to understand the underlying physics of novel properties and further explore potential device application.

A research team led by Prof ARIANDO from Department of Physics and Nanoscience and Nanotechnology Institute (NUSNNI) NanoCore, NUS implemented the electrolyte field effect to realize the oxygen vacancy control at the interface. In this experiment, the researchers used electrolyte as the dielectric material in the electric field effect device, the strong electric field caused by anion accumulation on LAO surface under the negative gate voltage drives the oxygen migration into oxygen-deficient STO, and therefore, change the vacancy concentration. More interestingly, they found that after the change of oxygen composition, the oxygen vacancy donor levels and interfacial band structure change accordingly, leading to the enhancement of electron mobility and the appearance of quantum oscillation of conductance. In previous experiment of electrolyte field effect, conducting surface degradation occurred due to the chemical reaction between sample surface and electrolyte, while in this experiment, the conducting channel is protected by the over layer, the oxygen migration is driven by pure electric field. This is the reason why the researchers could observe the mobility enhancement in their device.

Prof. Ariando said, “Our finding solves the controversy in the true mechanism of electrolyte field effect in complex oxides and opens a new avenue for constructing high-mobility oxide interfaces which can be synthesized at room temperature. The method also enables the design and fabrication of mesoscopic quantum devices potential for future oxide electronics.”

Reference:

Zeng SW, Yin XM, Herng TS, Han K, Huang Z, Zhang LC, Li CJ, Zhou WX, Wan DY, Yang P, Ding J, Wee ATS, Coey JMD, Venkatesan T, Rusydi A, Ariando, “Oxygen Electromigration and Energy Band Reconstruction Induced by Electrolyte Field Effect at Oxide Interfaces” PHYSICAL REVIEW LETTERS Volume: 121, Pages:146802 DOI: 10.1103/PhysRevLett.121.146802 Published: 2018.

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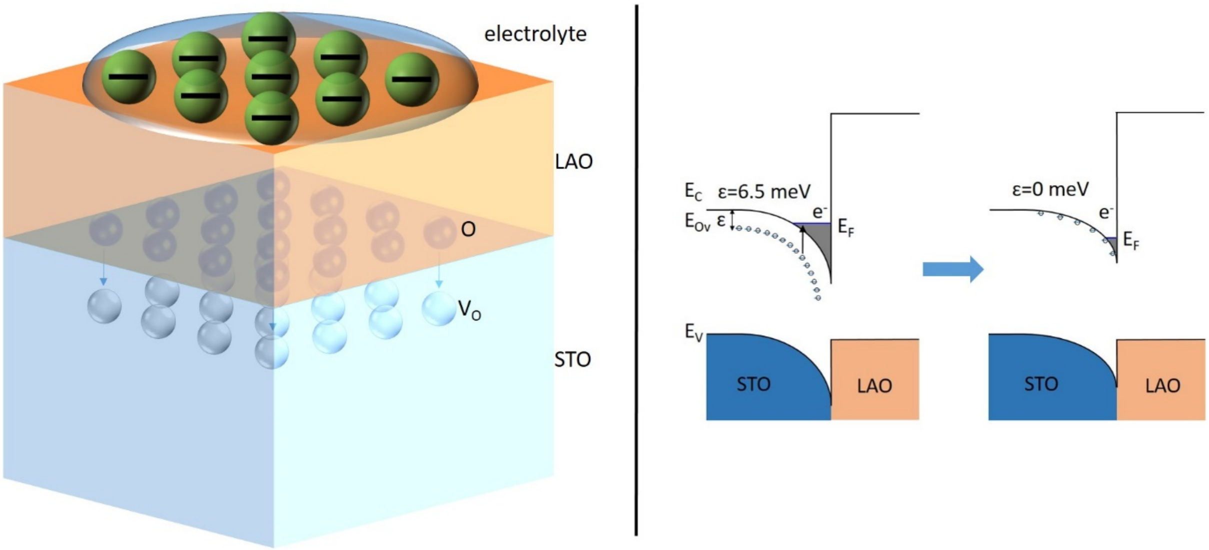

(Left) Figure shows a schematic of the operation of LAO/STO electrolyte field effect device. High electric field drives the oxygen (O) migration into STO to fill some of the vacancies (V_O). (Right) Change of interfacial energy band structures as a result of electrolyte field effect.