Proton Doping-Induced Resistance Modulation of $NdNiO_3$ Film under Electric Fields

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Resistive state change in strongly correlated-perovskite $R\mathrm{NiO_3}$ (R = rare earth elements) has the potential to enable novel electronic devices exploiting abrupt Mott phase transition. While the metal-insulator phase transition can be triggered by electrostatic or thermal excitation, ion doping via gas-phase-chemical reactions as an emerging field can completely reconstruct the electronic band structures resulting in giant resistivity modulation. In recent years, the vast resistivity modulation in the $R\mathrm{NiO_3}$ family has been successfully demonstrated through this chemical route. For example, proton-doped $SmNiO_3$ (SNO) thin film, where protons are dissociated from hydrogen molecules by utilizing Pt catalytic effect and then doped into the film, can lead to an ~10^8 of resistivity modulation at 300 K [1]. The colossal resistivity modulation is considered to be governed by proton motion in SNO, such as diffusion in the thin film. At the same time, the kinetics of such external control of proton diffusion, namely electric field, has not been clearly revealed.

In this work, electric-field-assisted hydrogenation and corresponding resistance modulation of $NdNiO_3$ (NNO) thin film resistors were systematically studied as a function of temperature and dc electric bias. Catalytic Pt electrodes serve as triple phase boundaries for hydrogen incorporation into a perovskite lattice. A kinetic model describing the relationship between resistance modulation and proton diffusion was proposed by considering the effect of the electric field during hydrogenation [2]. An electric field, in addition to thermal activation, is demonstrated to effectively control the proton distribution along its gradient with an efficiency of ~22% at 2×10^5 V/m. The combination of an electric field and gas-phase annealing is shown to enable the elegant control of the diffusional doping of complex oxides.

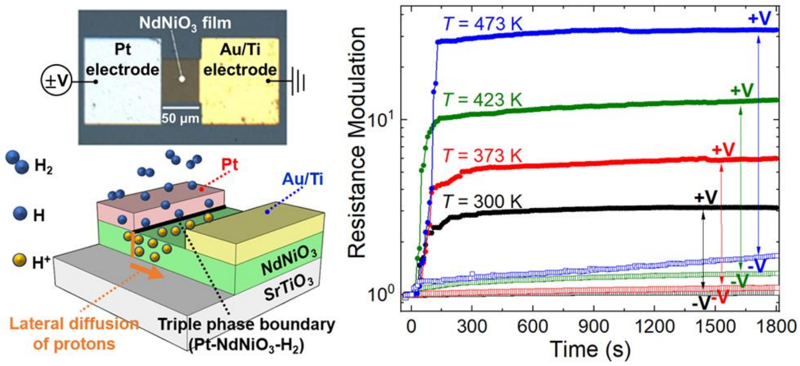

Figure 1. Optical microscopy image of two-terminal NNO film resistor with Pt-Au/Ti heteroelectrodes (top-left panel). Schematic illustration of evolution of proton concentration (bottom-left panel) and corresponding resistance modulation (right panel) under electric field-assisted hydrogenation.

[1] Shi, J.; et al. *Nat. Commun*. **2014,** *5*, 4860.

[2] Sidik, U.; et al. *ACS Appl. Mater. Interfaces* **2020**, *12*, 54955–54962