

Effect of Electric Field-Assisted Hydrogenation on NdNiO₃ Thin Film Resistor

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Perovskite-nickelates ($R\text{NiO}_3$, R = rare-earth elements) have attracted a considerable interest among researchers due to their sharp metal-insulator transition owing to the strongly correlated electronic effect. Their resistive switching behavior has the potential to construct high speed, densely scaled non-volatile memory and logic circuit devices. In recent years, a reversible and huge resistivity modulation through chemical reaction has been successfully demonstrated to this family of materials [1]. For example, proton-doped SmNiO_3 thin film, where protons dissociated from hydrogen molecules by utilizing Pt catalytic effect and then doped in to the thin film, can lead to colossal resistance increase at 300 K [2]. The giant resistance increase is considered to be governed by proton reaction/motion within the $R\text{NiO}_3$, such as diffusion within the thin film. In the hydrogenation process, while proton dopant would be diffused by thermal hopping and concentration gradient effect, electric field is also expected to be a driving force to diffuse the positively charged proton within thin film. However, this electric field effect has not been clearly revealed.

In this study, we prepared two terminals NdNiO₃ (NNO) thin film resistor with different electrodes (Pt and Au) and observed the effect of electric field-assisted proton diffusion during hydrogenation. **Figure 1(a)** shows optical microscope image of our NNO thin film resistor after hydrogenation with positively and negatively biased voltage to the Pt electrode (10V at 200 °C). It was confirmed that the transparent-doped region (proton-migrated length, ℓ_p) is expanded in positive bias Pt (+), whereas that is suppressed in negative bias Pt (-). This strongly indicated that electric field can effectively control hydrogenation, especially in diffusion process. **Figure 1(b)** and **(c)** show the resistance switching properties of our thin films during hydrogenation at various temperatures with polarity dependence. **Figure 1(b)** reveals that the resistance increase ratio (R_r) on thin film with Pt (+) is higher than that with Pt (-). **Figure 1(c)** shows a comparison between R_r and proton migrated-length (ℓ_p) with regard to polarity and temperature. We can see that both of R_r and ℓ_p of thin films with Pt (+) significantly increase with the increasing temperature, which is in contrast on thin films with Pt (-) where no noticeable change of R_r and ℓ_p . This implies that while the positive bias voltage and temperature can extend ℓ_p resulting in the rise of R_r , the negative bias voltage can suppress these increments by keeping the protons under the Pt electrode. We have successfully observed electric field-assisted hydrogenation effect, indicating a design of electric field-assisted proton migration device utilizing this phenomenon. In presentation, we will explain this phenomenon based on simulation model connecting time-dependent proton diffusion under electric field.

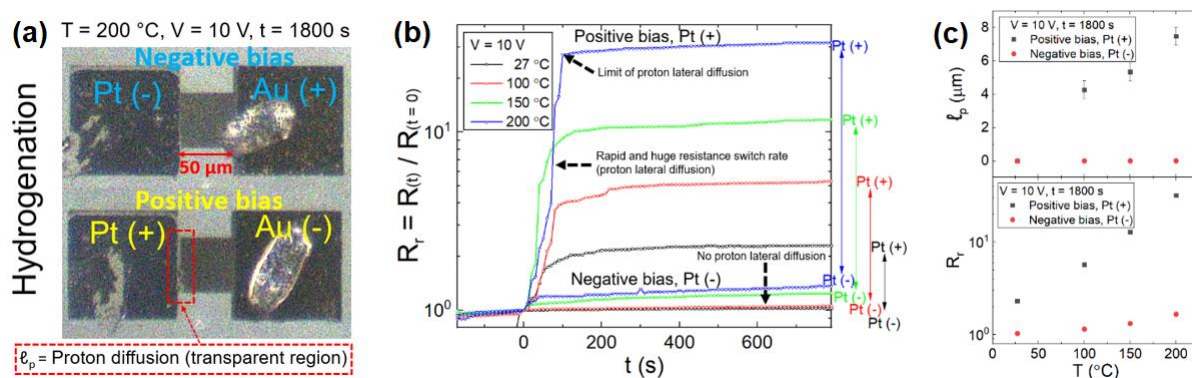


Figure 1. NNO thin film resistor: **(a)** Optical microscope image after hydrogenation, **(b)** Resistance increase ratio (R_r) vs time (t), and **(c)** resistance increase ratio (R_r) and proton migrated-length (ℓ_p) with polarity dependence measured at various temperatures (T)

References:

- [1] Chen, J., et al., Appl. Phys. Lett., 107(3), p.031905 (2015)
- [2] Shi, J., et.al., Nat. Commun., 5, p.4860 (2014)