Nanoscale dynamics of oxygen ions in $SrFeO_{2.5+\delta}$ epitaxial thin films

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A variety of functional properties in transition metal oxides are often underpinned by oxygen vacancies. While the oxygen vacancy concentration and arrangements are well-known to have strong influence on physical properties of oxides, the oxygen dynamics in oxides— including oxygen ion incorporation and movements during redox reactions—remain elusive.

To obtain insights to the oxygen dynamics, we focus on the oxygen nonstoichiometric iron-based oxide $SrFeO_{2.5+\delta}$. While the brownmillerite(BM)-structured $SrFeO_{2.5}$ is insulating, oxidizing it can lead to the perovskite(PV)-structured $SrFeO_{2.5+\delta}$ and increases its electrical conductivity. Importantly, the conducting property in $SrFeO_{2.5+\delta}$ strongly depends on the oxygen contents, which allows one to evaluate oxygen dynamics involving local redox reactions. In this study, we evaluate nanoscale oxygen dynamics in $SrFeO_{2.5+\delta}$ epitaxial thin films by investigating their structures and local conductions associated with redox reactions by X-ray diffraction (XRD) and conductive atomic force microscopy (c-AFM) [1].

Figure 1 shows topography (top) and c-AFM (bottom) images for the as-grown BM-structured $SrFeO_{2.5}$ film and the $SrFeO_{2.5+\delta}$ film air-annealed at 500 ºC. The oxidation-induced BM-to-PV structural change was confirmed by XRD measurements. We found that the local electrical conduction is enhanced in the annealed $SrFeO_{2.5+\delta}$ film. Analysis of the c-AFM images revealed that the local conduction is increased on the higher terraces near the outer step edges, indicating that oxygen ions are preferably incorporated and diffuse into the films. These results highlight the importance of the nanoscale oxygen dynamics in redox reactions in $SrFeO_{2.5}$ films. In this presentation, we will also present that the local conductions in $SrFeO_{2.5}$ films can be reversibly controlled by electric-field-induced redox reactions at room temperature.

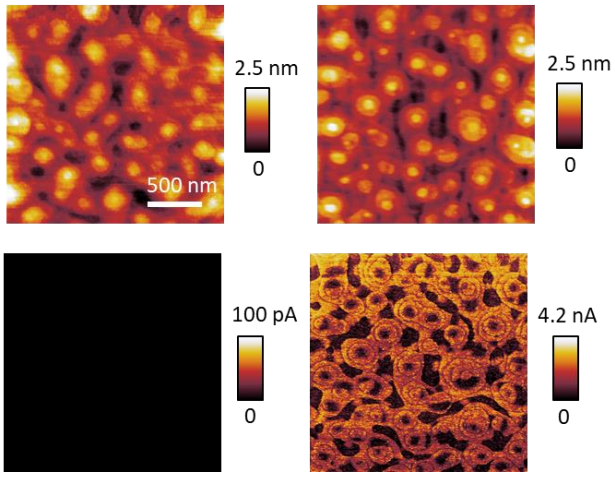

Figure 1.Local electrical conduction induced by oxidation during air-annealing. Topography (top) and c-AFM (bottom) images for (a) as-grown and annealed films at (b) 500 ºC.

[1] Y. Heo, et al., Appl. Phys. Lett. 113, 221904 (2018).