Experimental report

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Council: 4/2023

Title: Revealing the oxide substrate rolein the switching mechanisms through oxygen diffusion deriven by electric field

Research area: Physics

This proposal is a resubmission of 5-54-382

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Samples: Pd
SiO2
SrTiO3
CO
Sr2RuO4
Fe3O4/SrTiO3
SRO
Nb-STO

Instrument	Requested days	Allocated days	From	To
D17	7	4	25/08/2023	27/08/2023
			01/03/2024	05/03/2024

Abstract:

Controlling the oxide interfaces is the key towards controlling the switching phenomenon and thus realizing functional devices. We found that oxide substrates can take active part in the redox process at the interface and may be even used to tune properties. Hence, our next goal is to control the switching phenomenon at Fe3O4 films by controlling the oxygen diffusion through interfaces. We have characterized our samples using different lab techniques, e.g. XRR, XRD, SQUID and GISAXS. Using SQUID, we observe the disappearance of Verwey transition, the characteristic temperature for Fe3O4, when applying a positive voltage. This indicates a change of oxygen content in the Fe3O4 phase to the insulator gamma-Fe2O3 phase. Thus, our next step is to measure in-situ the magnetic depth profiling during applied electric field using polarized neutron reflectivity.

Experiment report: Revealing the oxide substrate rolein the switching mechanisms through oxygen diffusion deriven by electric field

Redox resistive switching is an important topic due to its potential applications in spintronic devices and neuromorphic computing. Transition metal oxides, such as iron oxides, have been actively studied for their ability to switch magnetic and electrical states by tuning their oxygen content.
In particular, we are investigating the effects of applying an electric field on the switching behavior of Fe_3O_4 films. Our previous work on Fe_3O_4 films grown on STO substrates revealed an interface layer composed of γ-Fe_2O_4[1]. Using neutron reflectometry (NR), we aimed to measure the magnetization profile and the oxygen diffusion gradient in the Fe_3O_4 film under different conditions.

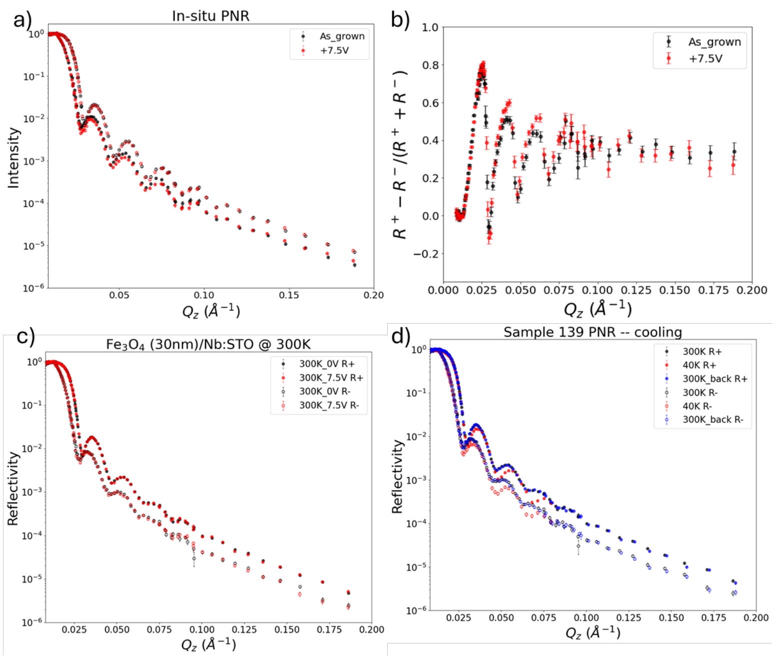

Figure 1: (a) NR measurements of sample 1 at 300K under applied voltage; (b) Corresponding Scattering Length Density (SLD) data for sample 1; (c) Room temperature NR measurements of sample 2 with applied voltage; (d) NR measurements for sample 2 at 300K and 40K.

We conducted NR on two Fe_3O_4/Nb:STO samples. The first sample was measured at room temperature (RT), and we then cooled it down while applying a voltage. However, the connection broke during the experiment, so we warmed it up, reconnected, and continued the measurements at room temperature. The results are shown in Figure 1(a), with the associated SLD (Scattering Length Density) data shown in Figure 1(b).
To better understand the behavior, we used a second sample. We first measured the sample at RT with 0V and 7.5V applied as shown in 1(c), but no significant difference was observed. We then cooled the sample without applying any voltage and observed a change in the scattering profile between RT and 40K as shown in 1(d). At low temperatures, we also observed faceting effects on the detector, which is due to the phase transition of STO. We then cooled the sample while applying a voltage, but no significant change in behavior was observed due to the electric field.
In conclusion, while the first sample showed a change induced by the electric field, the second sample did not exhibit significant differences under the same conditions. This suggests that we need to identify an optimal sample for studying electric field effects in Fe_3O_4. However, the cooling NR measurements revealed important effects from both the STO phase transition, which induces strain, and the Verwey transition, which can help us better understand the interface behavior at low temperatures. This study gives us useful insights into how oxide substrates affect the switching mechanisms in complex oxide heterostructures, providing a solid foundation for future work on oxide-based applications.

Reference

[1] M. H. Hamed, et.al., ACS Appl. Mater. Interfaces, 11 (7), 2019.