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Magnetic properties in $Sr_{1-x}La_xRu_{1-x}Fe_xO_3$ thin film

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1. Introduction

The Mamchik et al. measured the magnetotransport behavior and ferromagnetism in $Sr_{1-x}La_xRu_{1-x}Fe_xO_3$ (SLRFO) polycrystalline material.[1] They observed spin glass behavior and high negative magnetoresistance in spin-frustrated SLRFO polycrystalline material. Their results accompanied by grain boundary and a disorder in the material. Gupta et al. studied the effect of grain boundary on the magnetoresistance behavior of LCMO bulk polycrystalline materials. They showed that domain boundaries have a major role in spin dependent scattering in LCMO ploy-crystal samples and the value of MR in LCMO epitaxial thin films is less as compared to bulk polycrystalline samples.

In our earlier report, we had shown by using epitaxial strain, we could stabilize single crystalline thin film of Sr(Ru,Fe)O_3 thin films without co-doping in Sr site and we had tried to address the 'intrinsic' aspect of 'self-spin valve'.[2] However we changed two things together, co-doping vs. single doping and polycrystal vs. epitaxial thin film. Now we want to focus on only one change from the Mamchik's work; polycrystal vs epi thin film. In the current study, we made single crystalline epitaxial thin films of $Sr_{1-x}La_xRu_{1-x}Fe_xO$(x= 0.00, 0.05, 0.10, 0.20, 0.30) on $SrTiO_3$ (001) substrates.

2. Experimental

For the current study, $LaFeO_3$ doped $SrRuO_3$ epitaxial thin films Sr1-xLaxRu1-xFexO3(x= 0.05, 0.10, 0.20, 0.30) on STO (001) substrate were grown by pulsed laser deposition, using KrF excimer Laser (35 mJ/cm^2, 4Hz). The substrate temperature was maintained around 750°C during thin film growth. Two different oxygen partial pressures were used during the film deposition. SLRFO 5 and 10% films were deposited on 175 mTorr whereas SLRFO 20% and 30% films were deposited on 250 mTorr oxygen partial pressure. As we know oxygen partial pressure has the key role in determining the quality of thin films. This oxygen partial pressure is higher than that for the earlier oxygen deficient films in our previous study.[2] The thickness of films have been characterized by field emission transmission electron microscope (FESEM) and found to be about 60 nm. Surface morphology and lattice parameters were used to evaluate the film quality. Crystal structure was characterized by using high-resolution X-ray diffraction. Surface morphology of films was analyzed by atomic force microscopy. Magnetic measurements were carried out by using a superconducting quantum interface device Vibrating sample magnetometer (SQUID-VSM). In order to investigate the magnetoresistance (MR), we have used a standard four point hall bar geometry for all thin films. A magnetic field up to 9 T was applied parallel to the applied current. By applying magnetic field sweep 9 T, the sample resistivity (Rxx) decreased giving rise to negative magnetoresistance. The temperature dependence resistance and field dependence resistance of all compositions were measured by using a cryogen-free cryostat and dual channel source measure unit (Keithley).

3. Results and Conclusion

All the films showed excellent *c*-axis orientation with the STO (001) substrate. The change of the calculated *c*-axis lattice constant remains the same within ±0.003 Å. The reciprocal space mapping showed that SLRFO has grown coherently with the in-plane lattice constant values as same as those of the underlying STO (001) substrate. Zero field resistivity values of the SLRFO films were measured and compared with that for Ru doped film, SLRO bulk crystal. In comparison between SRFO with higher oxygen vacancy and SRFO with lower oxygen vacancy, higher oxygen vacancy in the film gives pronounced effects on the resistivity at low-temperature while high-temperature resistivity does not change much. The Co-doping of La3+ at Sr2+ site together with Fe3+ doping at Ru4+ site was reported to be useful to make single phase sample in poly-crystal. The Co-doping in SRO thin film increased resistivity much more than single Fe doping in SRO thin film while the latter accompanies with oxygen vacancy problem. The disorder affecting the increase of resistivity is stronger for co-doping shown in SLRFO than single doping with oxygen vacancy in the SRFO. Also making thin films of SLRFO, we could minimize the contribution of grain boundary and can compare MR with bulk magnetic measurement. We have observed a large negative magnetoresistance (~35%) in SLRFO epitaxial thin films grown on STO (001) substrates. With increasing LFO doping concentration, decreasing Tc and increasing resistivity of the thin film was observed. It was found that metal insulator transition persists in the SLRFO epitaxial thin film. Upon application of external magnetic field sweep up to 9 T the film resistivity decreased giving rise to a large negative magnetoresistance which was stronger in low temperature (down to 10 K). It was also noticed that the absolute value of MR increased with increase in doping concentration from x = 0.05 % to 0.30%.

4. References

[1] A. Mamchik, et. al., Phy. Rev. B. 70, 104409 (2004).

[2] K. R. N. Toreh, et. al., J. Alloys Compd. 657, 224 (2016).