# Magneto-resistance in doped $SrRuO_3$ thin film

Chang Uk JUNG[1*] and Umasankar Dash[1]
[1]Department of Physics and Oxide Research Centre, Hankuk University of Foreign Studies, Yongin, Gyeonggi 449-791, Korea
[*]cu-jung@hufs.ac.kr

## 1. Introduction

The ferromagnetic and conducting perovsktie of SrRuO3 have been paid a significant attention due to their potential for various applications.[1] In particular, SrRuO3 is used as the bottom electrode in devices due to its good conductivity and low lattice mismatch with perovskite oxide substrate. Recent discovery of large negetive magnetoresistance (MR) in $(Sr_{1-x}La_x)(Ru_{1-x}Fe_x)O_3$ polycrystalline sample offers numerous possible applications in magnetic industry such as data storage, non-volatile memory, and sensing applications.[2] However, these polycrystalline samples suffered from A- site disorder problem and co-doping of La3+ was necessary to stabilize them. Recently, we have shown that high quality Fe-doped $SrRuO_3$ without A- site co-doping can be stabilized using epitaxial strain during thin film growth.[3] But the obtained maximum MR value ~14% in our Fe doped $SrRuO_3$ epitaxial thin film was substantially less as compared to 55% that of co-doped $(Sr_{1-x}La_x)(Ru_{1-x}Fe_x)O_3$ polycrystalline samples. We particularly noticed that our Fe doped $SrRuO_3$ samples with intentionally reduced oxygen vacancies were metallic, while large MR was observed in semiconducting $(Sr_{1-x}La_x)(Ru_{1-x}Fe_x)O_3$ polycrystalline samples. So, we measured MR of our previously reported Fe doped $SrRuO_3$ deposited at a lower oxygen partial pressure and possessing higher number of oxygen vacancy and we successfully corelate the oxygen vacancy to MR. [4] In addition, we also report a very high negative MR of ~36.4% observed in semiconducting $SrRu_{0.7}Fe_{0.3}O_{3-d}$ epitaxial thin films. This MR value for high oxygen vacancy thin film of $SrRu_{0.7}Fe_{0.3}O_{3-d}$ is more than two times larger than the MR for low oxygen vacancy thin film of $SrRu_{0.9}Fe_{0.1}O_{3-d}$.

## 2. Experimental

For the current study, we have used three set of samples, (1) We have used the existing MR and structural analysis for the low oxygen vacancy thin film [3], (2) we measured MR for the high oxygen vacancy thin film used in our previous report [4] and (3) we fabricated a new SRFO thin film with very high oxygen vacancy. These $SrRu_{1-x}Fe_xO_{3-d}$ (x = 0.10, 0.20, and 0.30) thin films with different oxygen vacancy were grown on STO substrates under different oxygen partial pressure by using pulsed laser deposition. The laser power and substrate temperature was maintained at 35 mJ and ~7500C at a constant frequency of 4Hz. The thin films were deposited at oxygen partial pressure of 100 mTorr and 180 mtorr, so they are expected to show different oxygen vacancy. The crystal structure was characterized by high resolution x-ray diffraction (HR-XRD). Surface morphology was examined by atomic force microscopy (AFM). Magnetoresistance was measured by using a set of cryostats (Physical Property Measurement System by Quantum Design and CMag Vari9 by Cryomagnetics Inc.) and a dual channel source measure unit. (Keithley 2612A standard measurement unit.)

## 3. Results

The main results of our study are as follows. For x = 0.10 and x = 0.20 Fe doped $SrRuO_3$ thin films the HR-XRD peaks shifts towards lower 2θ angel with increase in Fe doping concentration as well as oxygen vacancy, implying that both the lattice constant and unit cell volume. However, for x=0.30, the peak of the thin film shifts towards right as compared to x=0.20, implying that the lattice constant decreased. This Fe doping induced change in the lattice constant parameters of SRFO thin films has been reported to be well explained in terms of possible substitution of Fe3+ ion rather than Fe4+ion at Ru4+sites. When the MR trend of x = 0.10 and x = 0.20 thin films were considered, the MR value increases with increase in oxygen vacancy for semiconducting thin films, while it decreases with increase in oxygen vacancy for metallic thin films. In this context a larger MR is expected for a thin film having more oxygen vacancy and showing semiconducting behaviour. For this purpose, we prepared semiconducting $SrRu_{0.7}Fe_{0.3}O_{3-0.12}$ thin films with higher oxygen vacancy compared the MR for a series of $SrRu_{1-x}Fe_xO_{3-d}$ films grown at lower oxygen partial pressure. As predicted, the MR for $SrRu_{0.7}Fe_{0.3}O_{3-0.12}$ thin films value increased more than two times as compared to MR value of $SrRu_{0.8}Fe_{0.2}O_{3-0.09}$ thin film.

## 4. Conclusion

The $SrRu_{1-x}Fe_xO_{3-d}$ perovskites thin films (x = 0.10, 0.20, and 0.30) with various amount of oxygen vacancy were deposited on STO(100) substrates. Without applied magnetic field, the films showed metal-insulator transition as Fe doping increased. For low doping case of x = 0.10, magnetoresistance was higher for films with lower oxygen deficiency while magnetoresistance was higher for films with higher oxygen deficiency for higher doping of x = 0.20. The magnetoresistance approached upto ~ 40 % for $SrRu_{0.7}Fe_{0.3}O_{3-0.012.}$ These results were compared with the magnetoresistance studies for polycrystal of $(Sr_{1-x}La_x)(Ru_{1-x}Fe_x)O_3$ samples. These results highlight the crucial role of oxygen stoichiometry in determining the MR in SRFO thin films.

## 5. References


[1] G. Koster, et. al, Rev. Mod. Phys. 84, 253 (2012).

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

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

[4] B. W. Lee. et. al., J. Korean Phy. Soc. 59, 322 (2011).