The Effect of Plasma Treatment on the Transport Properties of Magnetic $SrRuO_3$ Thin Films

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1. Introduction

In the world of nano science technology, $SrRuO_3$ is known as one of the most promising materials used as the bottom electrode. $SrRuO_3$ exhibited an excellent conducting properties even at room temperature. However, at the ultrathin layer $SrRuO_3$ film showed metal-insulator transition which is studied recently.[1,2] The studies in the metal-insulator transition not only restricted in ultrathin $SrRuO_3$ films. The oxygen stoichiometry, substrate properties, and annealing process also have various effect in the conducting properties of $SrRuO_3$.[3] In this work, we reported that the disorder due to external treatment can also change the conducting properties of $SrRuO_3$. The change of conductivity was closely related to the structural properties of $SrRuO_3$ films. The expansion of $SrRuO_3$ lattice constant was regarded to the oxygen vacancy concentration in the plasma-treated $SrRuO_3$ thin films.

2. Experimental

25 nm-thickness of $SrRuO_3$ film was grown on $SrTiO_3$ (001) substrate using pulsed laser deposition with a KrF excimer laser. The temperature and oxygen partial pressure was maintained at 750^oC and 100 mTorr, respectively. The structure and film orientation of $SrRuO_3$ were characterized using high-resolution XRD. After film deposition, the film was exposed in the plasma ambient in a conventional RF plasma chamber. To generate O_2 plasma we used O_2 gas, while H_2 gas to create the H2 plasma. The plasma-treated film was measured using high-resolution XRD to see the effect of plasma treatment in the structural change of $SrRuO_3$ thin films.

3. Results

The main result of our experiment was shown in the figure 1. In the Fig. 1(a), we found that the conductivity of $SrRuO_3$ thin film was decreased in the O_2 plasma-treated $SrRuO_3$ thin film (SRO25-O). Meanwhile, the conductivity of H_2 plasma-treated $SrRuO_3$ thin film was drastically decreased showing semiconductor properties. Having looked closer to the low temperature region, we also revealed that the transport mechanism could be explained using the Anderson transition method which used the Mott-type variable-range-hopping.[5]

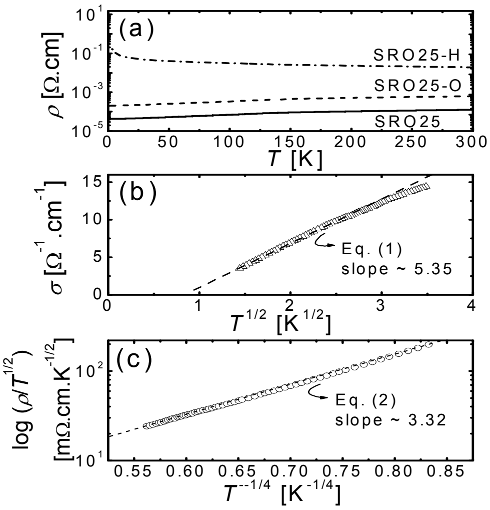

Figure 1 (a) Temperature dependence of resistivity for SRO25, SRO25-O, and SRO25-H films; (b) electrical conductivity of the SRO25-H fitted using the two-fluid model[4], and (c) electrical conductivity of SRO25-H, fitted using the Mott-type variable range-hopping conduction (Anderson insulator) model.[5]

4. Conclusion

The Anderson transition method can be used to explain our H_2 plasma-treated $SrRuO_3$ thin films. In the low temperature region of resistivity Mott-type variable-range-hopping showed the 3D hopping process and multi-phonon processes. Even though the source of disorder generating the metal-insulator transition was quite different from the other experiment using Ti-doped $SrRuO_3$, both experiment showed a clear linear relationship and the values of the fitting parameter were quite similar in order of magnitude.

5. Reference

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