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Swift heavy ion irradiation effect on structural properties for epitaxial $Ba(Fe_{0.5}Mn_{0.5})O_{3-\delta}$ thin films

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1 Introduction

We have ever studied novel magneto-dielectric Ba-based perovskite oxides without using toxicant heavy elements [1, 2]. We have revealed so far that single crystalline $Ba(Fe_{0.5}Mn_{0.5})O_{3-\delta}$ (BFMO) thin films synthesized on (001)$SrTiO_3$(STO) are ferromagnetic insulators at room temperature. It has also been reported that the amount of oxygen deficiencies of the BFMO thin films plays a dominant role in determining these natures of the films. Hence, the precise control of the oxygen amount in the films should be indispensable to design such a class of materials. However, the previous experiments have shown that it is quite difficult to control the total oxygen amount in the films quantitatively. Here, it should be noticed that the swift heavy ion irradiation possibly becomes a potential method for the quantitative control of the oxygen vacancies of oxides through the high density electronic excitation. In the present report, we discuss the changes in the structural and magnetic properties of BFMO films due to the irradiation with the 200 MeV Xe^{14+} ion.

2 Experiment

BFMO thin films with a thickness of 60 nm were synthesized on (001)STO single crystal substrates by a PLD technique. The deposition was performed in a vacuum at the pressure of $1.0x10^{-5}$ Pa. The oxygen gas was introduced into the film during the subsequent cooling at the pressure of 10 mTorr. The sample without introducing oxygen (named as 0 mTorr film) was also synthesized for reference. Then, four samples were irradiated with 200 MeV Xe^{14+} ions by using a high energy ion accelerator at JAEA-Tokai. The irradiation was performed at room temperature and the ion fluences were $1x10^{10}$, $3x10^{10}$, $1x10^{11}$ and $3x10^{11}$ /cm^2 for the four samples. Structural characterizations of the films were investigated by x-ray diffraction (XRD). The magnetic properties were measured by SQUID magnetometer. The valence state of the Fe and Mn ions was evaluated by XPS analysis by using soft X-ray radiation at KEK-PF.

3 Results and Discussion

The (001) epitaxial grown BFMO thin film with a pseudo tetragonal perovskite crystal structure were successfully synthesized. Figure 1 shows the XRD narrow-scanned spectra for the sample before and after 200 MeV Xe ion irradiation to the fluence of $3x10^{11}$ /cm^2. For comparison, these figures also show the spectra for the 0 mTorr film. The (00L) BFMO diffraction peaks for the irradiated sample, however, apparently sift toward the low-angle side, suggesting that the lattice of the BFMO films are expanded by the ion irradiation. As can be seen in the figure, the XRD spectrum for the 0 mTorr sample also exhibits a similar tendency.

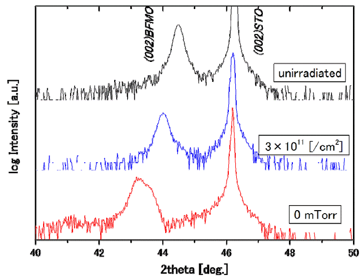

Fig. 1: XRD scans for the BFMO films.

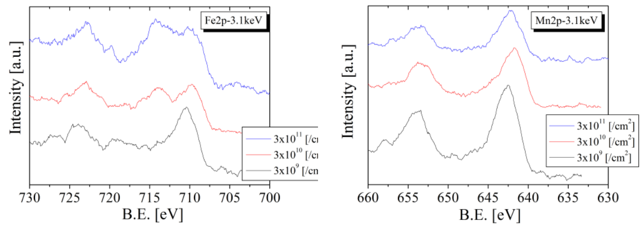

Fig. 2: $2p_{2/3}$ and $2p_{1/2}$ core level XPS spectra for Mn and Fe ions for the irradiated BFMO films.

Figures 2 show $2p_{2/3}$ and $2p_{1/2}$ core level XPS spectra for Mn and Fe ions. AS is clearly in the figure, the peak of the Fe spectra significantly shifted toward the higher energy side with increasing in the ion irradiation fluence, while the peak position of the Mn little changed. This tendency is quite similar to our previous work for the BFMO thin films having oxygen deficiencies. Hence, it can be speculated that the swift heavy ion irradiation effectively displaces the oxygen atoms and increase the amount of oxygen deficiency in the films.

References

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References

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