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Growth and Properties of Multilayered Ba- and Sr-Ferrites' Films

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Abstract. Thin films of c-axis oriented Ba- and Sr-hexaferrits (BaM and SrM) were prepared by reactive evaporation method without any post heat treatments. Subsequently growth of BaM/SrM multilayered films was tried and the sidebands in XRD clearly appeared. According to magnetization measurements all films had the perpendicular magnetic anisotropy. However the M_S for BaM film was only 55% of that for the bulk. A broad background in Mössbauer spectrum for the BaM suggested the fluctuating magnetic moments. Though the M_S for SrM film was improved it had some inplane magnetization components. To combine the advantages of BaM and SrM individual films, the BaM/SrM multilayered film exhibited good magnetic properties: The M_S was recovered to about 80% of the bulk value and the inplane magnetization components disappeared in both the magnetization curves and the Mössbauer spectrum.

1. INTRODUCTION

Thin films of c-axis oriented Ba- and Sr-hexaferrites (BaM and SrM) are of great interest in their technological applications to magnetic recording and microwave devices [1]. Both have a magnetoplumbite structure with a large magnetocrystalline anisotropy along the c-axis. The anisotropy constants (K_1) of BaM and SrM for bulks are 3.3×10^5 and 3.6×10^5 J/m^3, and their saturation magnetizations (M_S) are 380 and 365 G, respectively [2]. However magnetic properties of thin films are influenced by many factors like crystallinity, stoichiometry and strains of the films [3].
Reactive evaporation is a powerful technique to prepare well-crystallized and multilayered oxide films with controlled stoichiometry, by modifying the evaporation conditions such as evaporation sources, deposition rate and oxygen pressure. Since the lattice mismatch between BaM and SrM is only 0.4 %, well-crystallized but slightly strained BaM/SrM multilayered films are expected to form. We report here the structural and magnetic properties of c-axis oriented BaM, SrM and BaM/SrM multilayered films deposited on sapphire (α-Al_2O_3).

2. EXPERIMENTAL

BaM/SrM films were prepared on α-Al_2O_3(0001) single-crystalline substrates by using reactive evaporation system. The system had three evaporation sources; two for Fe and Ba were heated by electron beams and one for Sr was by a crucible heater. After the chamber was evacuated to 2×10^{-5} Torr, the substrate temperature was kept at 800°C and oxygen gas was introduced into the chamber to the pressure of 2×10^{-4} Torr. Oxygen plasma was generated by rf power supply of 200W. The ratio between Ba (or Sr) and Fe deposition rate was controlled to 1:10 by quartz thickness monitors and the total deposition rate was fixed to about 1.0Å/s. These were the conditions that the growth of well-crystallized BaM and SrM films was confirmed in our system. Sample films were characterized by x-ray diffraction (XRD) method with Cu Kα, magnetization measurement using a vibrating sample magnetometer (VSM), and conversion electron Mössbauer spectroscopy (CEMS). The thicknesses of the deposited films ranged up to 2000 Å.

3. RESULTS AND DISCUSSION

3.1 BaM and SrM films

XRD patterns for both BaM and SrM films clearly show the growth with good c-axis orientation on the substrate. However the pattern for BaM (Fig.1 (a)) is a little broader than that for SrM (Fig.1(b)). According to the bulk phase diagrams of BaO-Fe_2O_3 and SrO-Fe_2O_3 systems, liquid phase appears above 1315°C and 1195°C, respectively [4]. Mobility of atoms on the substrate should influence the crystallinity of the films. During the deposition impinging atoms onto the substrate diffuse along the surface and subsequently condense into the crystal. Lower eutectic temperature for SrO-Fe_2O_3 suggests the larger mobility of

Sr than Ba. Moreover the lattice mismatch between SrM and α-Al_2O_3 is 7.0 %, while the one between BaM and α-Al_2O_3 is 7.1 %. Thus the SrM film seems to have better crystallinity than the BaM film.
Magnetization curves of c-axis oriented BaM and SrM films measured by VSM indicate the perpendicular magnetic anisotropy as expected from the magnetocrystalline anisotropy of the bulks. However the M_S of 210 G for the BaM film is considerably smaller not only than that of the bulk, but also than that of 280 G for the SrM film. Smaller M_S for BaM supports the XRD results of the poor crystallinity of the film. The easy axis coercivity of $H_C\perp$= 2.7 kOe for the SrM film is larger than that of $H_C\perp$= 1.9 kOe for the BaM film. While the hard axis coercivities of $H_C//$ for SrM and BaM are 1.9 and 0.1 kOe, respectively. The SrM film has some components with the inplane magnetization. If SrM has the negative magnetostriction constant ($\lambda\perp$) as that for BaM [5], the inplane lattice contraction due to the lattice matching with α-Al_2O_3 induces the inplane magnetic anisotropy.
A CEMS spectrum for the BaM film (Fig.2 (a)) is a typical Mössbauer pattern of BaM with small intensities in the second and fifth peaks of the sextets, though it is overlaid with a broad backgroud component. A broad background suggests the distributions in the magnetic hyperfine fields due to the poor crystallized region in the film. The small intensity ratio in the second and fifth peaks reflects the magnetization direction parallel to the γ-ray incidence, *i.e.* perpendicular magnetization axis against the film plane. While the spectrum for the SrM film (Fig.2 (b)) has a smooth backgroud with somewhat larger intensities in the second and fifth peaks. Though the film has the good crystallinity it has the inplane magnetic components parallel to the film plane. These are consistent with both the XRD and the magnetization measurements discussed above.

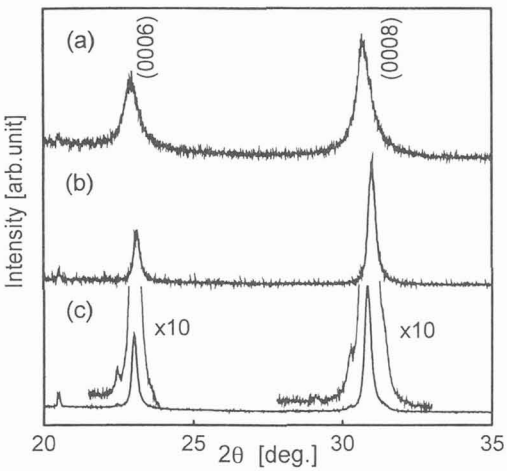

Figure 1: X-ray diffraction patterns for (a) BaM, (b) SrM, and (c) BaM/SrM multilayered films on α-Al_2O_3(0001).

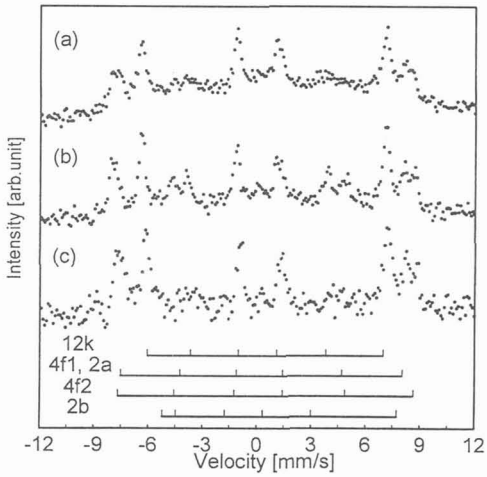

Figure 2: Room temperature Mössbauer spectra for (a) BaM, (b) SrM, and (c) BaM/SrM multilayered films.

3.2 BaM/SrM multilayered film

Fig.1 (c) shows a typical XRD pattern for BaM/SrM multilayered films. The film was designed as [BaM(80Å)/SrM(80Å)]8, consisting of 80Å of BaM and 80Å of SrM repeated 8 times. In spite of the high substrate temperature of 800°C, small sidebands appears just beside the (000*L*) lines when the individual BaM and SrM layers are thicker than 80Å. A modulation period calculated from the sideband positions of this pattern is about 150Å which is nearly consistent with the designed value. The multilayered films clearly have the magnetic anisotropy perpendicular to the film plane, too. The M_S of 290 G is considerably improved than those of both BaM and SrM individual films. The measured M_S is about 80% of the bulk value of $Ba_{0.5}Sr_{0.5}M$. The easy axis coercivity is $H_C\perp$= 2.5 kOe, while the hard axis coercivities is $H_C//$=0.1 kOe. A typical CEMS spectrum for the multilayered films (Fig.2 (c)) shows a similar pattern to those for BaM and SrM films. Besides, the second and fifth peaks of the sextets almost vanish and the pattern has smooth background. The crystallinity and the perpendicular magnetic anisotropy are improved to form the multilayered BaM/SrM.

Acknowledgments

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