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The Crystallographic and Magnetic Properties of Oriented Strontium Ferrite Films

논 문
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Hyo-Duk Nam*, Eng-Chan Kim**, Sung-Hyun Yoon***

Abstract

Crystallographic and magnetic properties of oriented Sr ferrite ($SrFe_{12}O_{19}$) films sputtered with the different deposition conditions on Si(111) substrate have been studied by x-ray diffraction, conversion electron Mössbauer spectroscopy and vibrating sample magnetometer. Sputtered strontium ferrite films upon annealing at high temperatures show different textures depending on the deposition parameters.

It is noted that by changing the deposition parameters the c-axis orientation of $SrFe_{12}O_{19}$ on Si(111) can be tailored to vary from parallel plane to normal to the film plane.

It is shown that the conversion electron Mössbauer spectra for films are well consistent with values obtained for bulk $SrFe_{12}O_{19}$ ferrite.

Key Words(중요용어) : Sputtering deposition, Polycrystalline $SrFe_{12}O_{19}$ films, Deposition parameter, Conversion Electron Mössbauer

I. Introduction

In recent years, M-type hexagonal ferrite ($BaFe_{12}O_{19}$ and $SrFe_{12}O_{19}$) films have been investigated due to their large potential applications[1~8]. The films with perpendicular anisotropy are studied for applications in perpendicular recording and magneto-optic recording media. Whereas, films with in-plane anisotropy are investigated for their application as longitudinal recording media.

Therefore, the main research interest has been to deposit these films with c-axis oriented either normal or parallel to the film plane[6,9]. It was reported that M-type strontium ferrite (SrM) films can be sputter deposited on amorphous fused quartz substrates with c-axis normal to the film plane[6]. It was shown that the films prepared at low rf power were crystallized with c-axis normal to the film plane after annealing. On the other hand, the films prepared at high rf power were reported to crystallize with random orientation. To investigate whether such dependence of the film texture on deposition condition is characteristic of the substrates used or not, we deposited $SrFe_{12}O_{19}$ films on the Si(111) substrate. The purpose of this research is to show that the film with both c-axis oriented normal or parallel to the film plane can be deposited by changing the deposition condition.

II. Experiment

Films were prepared by rf diode sputtering on the Si (111) substrate in a Leybold Z400 system A disk cut from a commercial $SrFe_{12}O_{19}$ ferrite was used as a target. The sputtering gas was a mixture of 75 % argon and 15 % oxygen. Oxy-gen to argon ratio (R) in the sputtering gas was kept at 15%.

* : 영남대학교 전기전자공학부
(경상북도 경산시 대동 214-1, 전화 : 053-810-2493, Fax : 053-814-5713 E-mail : hdnam@ynucc.yeungnam.ac.kr)
** : 영남대학교 물리학과
*** : 군산대학교 물리학과
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the total gas pressure was 6×10^{-3}mbar. The distance between target and substrate was kept at 50 ㎜. Sputtering rates were 1.2 ㎚/sec at P = 60 W, 3.6 ㎚/sec at P = 230 W, and 4.5 ㎚/sec at P = 330 W, respectively. For annealing, the film was introduced into a furnace which is maintained at 800℃. The annealing was carried out at 800℃ for three hours followed by furnace cooling. For the conversion electron M ssbauer study, films were enriched with ^{57}Fe by keeping small amount of enriched Fe_2O_3 on the SrM target during sputtering. Films with thickness of ~ 2000 Å were used in this study.

The target and film composition were determined by Inductively Coupled Plasma analysis. The atomic ratio of Sr : Fe in the target was 1 : 12 and was varied between 1 : 12 to 1 : 12.2 for the film.

Measurements of magnetic properties were carried out using a vibrating sample magnetometer (VSM) and a torque magnetometer in the field of 15 kOe.

Ⅱ. Results and discussion

As-deposited films were amorphous. These films crystallized upon annealing at 800℃.

Though 'as-deposited' were X-ray amorphous and were not magnetic, these 'as-deposited' films when annealed, showed different textures depending on the deposition conditions as if these deposition conditions leave some signature in the films which eventually decides the texture of these films. It was found that the films prepared at low rf power when annealed at temperatures ≥ 800℃ showed perpendicular anisotropy while the films prepared with high rf power after annealing showed in plane anisotropy.

Fig. 1 shows the X-ray diffraction (XRD) patterns for three films. As seen in this figure, samples prepared at the rf power (P) of 60 W show prominent (00 l) lines, indicating a c-axis orientation normal to the film plane. The sample with P=230W shows all the prominent peaks of SrM, indicating the absence of any preferred orientation.

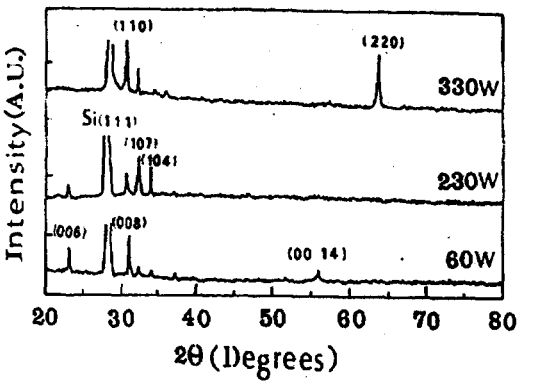

Fig. 1. X-ray diffraction patterns for $SrFe_{12}O_{19}$ films deposited at different powers at room temperature.

On the other hand, the sample with P=330 W shows strong (110) and (220) peaks, indicating a c-axis orientation in the film plane. These results show that the c-axis orientation can be tailored to very from in plane to normal to film plane by changing the deposition conditions.

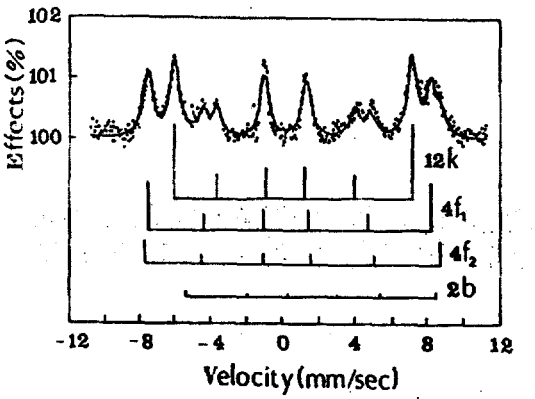

Fig. 2. Conversion electron Mössbauer spectrum for the $SrFe_{12}O_{19}$ film deposited at P = 60 W.

Fig. 2 shows the conversion electron Mössbauer spectrum obtained at room temperature for the sample with P=60 W. The spectrum was fitted using a least square method to four six line patterns corresponding to 12k, $4f_1$, 2a, $4f_2$, and 2b Fe sites under the well-known restraint[10], which are valid when the quadrupole interaction is much weaker than the hyperfine interaction.

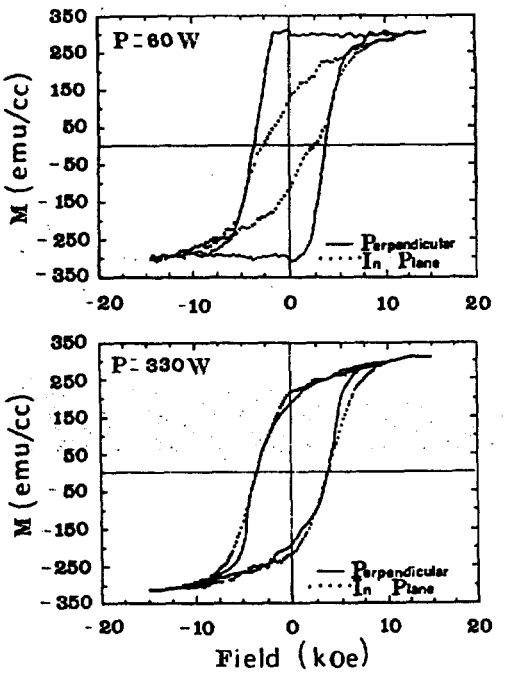

Fig. 3. In plane and perpendicular M-H loops of $SrFe_{12}O_{19}$ films deposited at two different rf powers.

The figure shows the fitted spectrum along with contribution from four subspectra, which have been offsetted for clarity. Relative intensities of patterns corresponding to 12k, $4f_1$, 2a, $4f_2$, and 2b Fe sites matched very well with values obtained matched for the bulk SrM[11]. The intensity ratio of the second to the third lines of subspectra was 0.9. Since Mössbauer spectra were recorded with γ-rays normal to the film plane, the low value of ratio shows that there is an easy direction of magnetization normal to the film plane, indicating a good c-axis orientation perpen dicular to the plane. For the sample with P=330 W, this ratio was 2.8 showing a change in orientation.

Fig. 3 shows parallel and perpendicular M-H loops for the films prepared at 60 and 330 W rf powers. The perpenicular loop for the sample with P =60 W is rectangular with a remanence ratio of 1. This confirms that the film has an easy axis (c-axis) normal to the plane. A fairly open symbol in plane loop with a remanence ratio of 0.4 indicates that fraction of the film is not oriented. This was also indicated by the presence of some XRD peaks other than (00 l). The sample with P=330 W shows nearly rectangular loops both with perpendicular and in plane configuration with remanece ratios of 0.64 and 0.83, respectively.

Loops measured along the parallel and perpendicular to the film plane were similar, indicating that there is no preferential axis within the film plane. There is a long tail in the hysterisis loop before reaching saturation as was observed by Sui and Kryder[9] in $BaFe_{12}O_{19}$ ferrite films with c-axis orientation in the film plane.

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