The Korean Journal of Ceramics, 6[4] 405-407 (2000)

Evaluation of Spin Direction in Ferrite-Plated Films by Fe^{57} Conversion Electron Mossbauer Spectroscopy

Fumio Shirasaki, Yoshitaka Kitamoto, Shusuke Kantake and Masanori Abe

Department of Physical Electronics, Tokyo Institute of Technology O-okayama, Meguro-ku, Tokyo 152-8552, Japan

(Received September 23, 1998)

Polycrystalline films of Ni- and Co-ferrites films are prepared from aqueous solution at 90°C by ferrite plating, which are subjected to Fe^{57} conversion electron Mossbauer spectroscopy in backscatter mode. The average angle of Fe spins relative to the film plane is evaluated as 18 degree and 82 degree for the Ni- and Co-ferrite films, respectively, indicating a prominent magnetic anisotropy parallel and perpendicular to the film plane. It was also verified by the magnetization measurements.

Key words: Ferrite plating, Mossbauer spectroscopy, Magnetic anisotropy, Co-ferrite, Ni-ferrite

I. Introduction

We[1)] have investigated the feasibility of ferrite films to be applied to perpendicular magnetic recording media. Co-ferrite films may be used for recording layers and Ni-Zn ferrite films for back layers which increase recording efficiency. In this study we investigated the magnetic anisotropy, or spin direction, in Co-ferrite films and Ni-ferrite films by means of Fe^{57} conversion electron Mössbauer spectroscopy (CEMS).[2)] The ferrite films were prepared by ferrite plating,[3)] a chemical method which facilitates fabrication of crystalline ferrite films of spinel structure from an aqueous solution at low temperatures less than 100°C.

II. Experimental

Films of Ni- and Co-ferrites were prepared by spin-spray ferrite plating method on glass substrates (76×26×1 mm^3 in size) at 90°C. A reaction solution (pH=4~4.5) of $FeCl_2$+ $NiCl_2$ (or $FeCl_2$+$CoCl_2$) and an oxidizing solution (pH= 7~7.5) of $NaNO_2$+CH_3COONH_4 (a pH buffer) were simultaneously spayed on a spinning substrate for preparing the Ni (or Co) - ferrite film. The thicknesses of the films were evaluated by SEM observation of their cross sections. The CEMS spectra were taken using 3.7 GBq of Co^{57} as a source and detecting 7.3 keV K-conversion and Auger electrons which are back-scattered from surface (depth <~1500A) of the ferrite films.[2)] As shown in Fig. 1 the sample is contained in a proportional counter having an anode wire applied with a positive high voltage. The anode wire captures the conversion electrons, generating electric pulses. Because we do not need to transmit γ-rays through the sample as in case of conventional transmission Mössbauer spectroscopy, we can perform CEMS for films on thick substrates which forbid transmission of γ-rays; we need not take off (or make thin) the substrates to transmit γ-rays. Therefore CEMS is an advantageous tool for investigating magnetic properties of films deposited on thick substrates as in this study. Magnetic and crystallographic properties of the films were investigated by a vibrating sample magnetometer and an X-ray diffractometer using CuKα radiation, respectively. All the measurements were performed at room temperature.

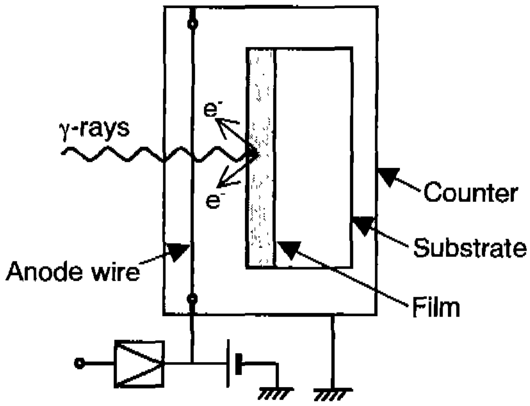

Fig. 1. CEMS apparatus.

III. Results and Discussion

The films are polycrystalline with single phase spinel structure, having no preferred crystallographic orientation. They are ~300 nm in thickness.

Fig. 2(a) shows the Mössbauer spectrum obtained for the Ni-ferrite film, which is composed of a couple of hyperfine split sextets. One is attributed to Fe^{3+} and the other to $Fe^{2.5+}$ (a mixed valence state generated by fast exchange of electrons between the Fe^{2+} and Fe^{3+} ions on the octahedral sites of spinel) similar to that observed in magnetite. Fig. 2(b)

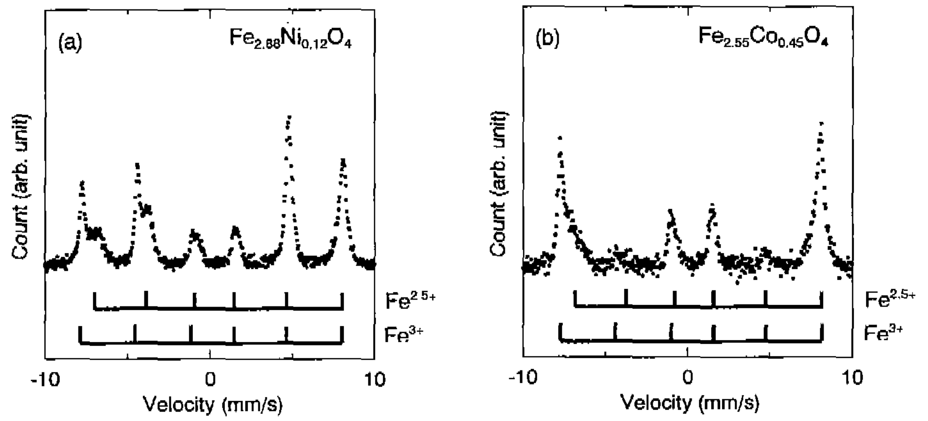

Fig. 2. Mössbauer spectra for the (a) Ni-ferrite and (b) Co-ferrite filsms.

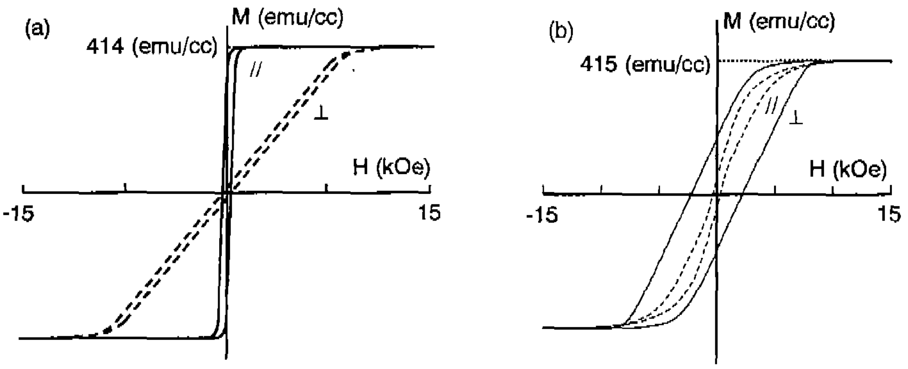

Fig. 3. Magnetization curves for the (a) Ni-ferrite (b) Co-ferrite films, under external magnetic field parallel (//) and perpendicular (⊥) to film plane.

shows the spectrum for the Co-ferrite film, which is composed of a couple of sextets due to Fe^{3+} and $Fe^{2.5+}$ similar as in the Ni-ferrite film. But intensities of the second and the fifth lines are decreased much as compared to the spectrum for the Ni-ferrite film (Fig. 2(a)), indicating the difference in the direction of the spins in the two samples.

In order to estimate the spin direction, let us define an average angle θ of the spins relative to the film plane as,

$$\tan\bar{\theta} = \bar{S}_{\perp} / \bar{S}_{//} \quad (1)$$

Here $\bar{S}_{\perp}$ and $\bar{S}_{//}$ are average spin components perpendicular and parallel to the film plane, respectively. In terms of $\bar{\theta}$ the ratio of areas, S_1~S_6, for the six lines in each sextet is expressed

$$S_1:S_2:S_3:S_4:S_5:S_6 = 3(1+\cos^2\theta):4\sin^2\theta$$
$$:(1+\cos^2\theta):(1+\cos^2\theta):4\sin^2\theta:3(1+\cos^2\theta) \quad (2)$$

Combining Eqs. (1) and (2), we obtain

$$\tan\bar{\theta} = (S_2+S_5)/(S_3+S_4) \quad (3)$$

which is applicable when Si is the sum of the i-th lines of the couple of the sextets.

Using Eq. (3) we obtained $\bar{\theta}$ =18° for the Ni-ferrite film. Since this value is far from 90° and rather near to 0°, the spins are roughly aligned parallel to the film plane. In a similar way for the Co-ferrite film we obtained $\bar{\theta}$ =82°, fairly close to 90°, indicating that the spins are nearly aligned perpendicular to the film plane.

Because the Ni- and Co-ferrites have a Neel type linear ferrimagnetic structure, our result indicates a prominent in-plane and a perpendicular magnetic anisotropy existing in the Ni- and Co-ferrite films, respectively. This is supported by the results of the magnetic measurements shown in Fig. 3. The magnetization curves measured for the Ni-ferrite film applying external field parallel and perpendicular to the film plane exhibit typical features for soft magnetic films having in-plane anisotropy; the magnetization being easily saturated along the film plane as compared to perpendicular to the film plane. The magnetization curves for the Co-ferrite film, on the other hand, exhibit a prominent perpendicular anisotropy; being more easily saturated and having stronger coercive force when magnetized perpendicular to the film plane than when magnetized parallel to the film plane.

Because Ni-ferrite has very weak magnetic anisotropy, our Ni-ferrite film exhibits the in-plane anisotropy due to demagnetizing field. In contrast Co-ferrite has strong magnetic anisotropy with easy axis along (111) axis. Since our film has no preferced orientation, the prominent perpendicular magnetic anisotropy overcoming the demagnetizing field should be ascribed to inverse magnetostriction effect which may be caused by residual internal stress associated with the columnar structure of the film.[4]

IV. Conclusion

By CEMS measurements on the samples of Ni- and Co-ferrite films as plated on the thick glass substrate, the average angle of spins from film plane was evaluated. We obtained $\bar{\theta}=18^\circ$ and 82° for the Ni- and Co-ferrite films, respectively, indicating that they have prominent magnetic anisotropy in and perpendicular to the film plane. This was supported by the results of the magnetic measurements for the films.

References

1. Y. Kitamoto, S. Kantake and M. Abe, "Ferrite-Plating Thin films for Perpendicular Recording Media," *J. Magn. Soc. Jpn.*, **21**(S2), 81-84 (1997).
2. Y. Yonekura, T. Toriyama, J. Itoh and K. Hisatake, "Depth Selective Conversion Electron Mossbauer Spectroscopy by Use of a Proportional Counter," *Hyperfine Interactions*, **15/16**, 1005-1008 (1983).
3. M. Abe, T. Itoh and Y. Tamaura, "Magnetic and Biomagnetic Films Obtained by Ferrite Plating in Aqucous Solution," *Thin Solid Films*, **216**, 155-161 (1992).
4. Y. Kitamoto and M. Abe, "Internal Stress in Ferrite Plated Thin Films," *JOURNAL DE PHYSIQUE IV FRANCE*, **7**, C1-595-596 (1997).