Magneto-Optical Properties of Bi-YIG Particles Dispersed in a Plastic Binder

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Abstract - Garnet fine particles of $Bi_{1.8}Y_{1.2}Fe_5O_{12}$ (Bi-YIG) were prepared by coprecipitation and annealing processes. The annealing was carried out at 650 °C for 4 h. The obtained particles were identified as garnet by X-ray diffraction. The magnetic inks were made for various Bi-YIG/binder ratios, and were coated on glass and plastic substrates. The volume ratios of Bi-YIG particles were from 0.05 to 0.70 in the coated films. The size of the Bi-YIG particles was about 50 nm. The Faraday rotation spectra of the coated films shifted to longer wavelength with decreasing particle content in the films. The maximum value of the figure of merit of the coated Bi-YIG films was 2.2, whereas that value for the sputtered film having about same composition was 2.5.

1 INTRODUCTION

Thin films of bismuth substituted yttrium iron garnet (Bi-YIG) have a considerable potential for magneto-optical (MO) devices working in the visible wavelength region as well as in the inflared region. Until now Bi-YIG films have normally been prepared by sputtering with substrates heated higher than 500 °C[1]. Therefore, the inexpensive and large size plastic sheets can not be used as substrates. We can solve this thermal problem by employing a coating technique in the film preparation process. Bi-YIG particles have been prepared by coprecipitation, sol-gel, and pyrolysis methods[1,2]. Some coated films were reported for MO recording media[3,4]. Recently Fujii *et al*[5,6] reported some calculations and measurements of Faraday rotation spectra for the films contain dispersed ferromagnetic particles. We already reported the possibility that the Bi-YIG coated films could be applied to devices working in the visible wavelength region to display recorded magnetic images[7,8,9].

In this report we prepare fine Bi-YIG particles by coprecipitation and annealing processes, and examine the relation between the magneto-optical properties of the dispersed particles and the volume fraction of the particles in the binder.

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2 PREPARATION OF Bi-YIG FINE PARTICLES

Fine Bi-YIG particles were prepared by the preparation process shown in Fig.1[8,9]. First aqueous solutions of Bi, Y and Fe nitrates were mixed with the ratio of the composition of $Bi_{1.8}Y_{1.2}Fe_5O_{12}$. Then the solution was mixed with an NH_4OH aqueous solution at room temperature. The concentration of the alkaline solution was adjusted so that the *p*H of the mixed solution was 10.0 at the end of the coprecipitation reaction. The slurry obtained was washed, filtered and dried at 100 °C for 8 h. Then the coprecipitate was heated in air at 650 °C for 4 h to form fine garnet particles. The contents of the cations in the coprecipitate were analyzed

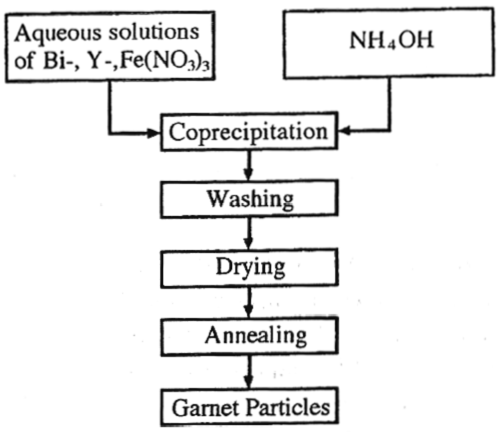

Fig.1 Preparation process of Bi-YIG particles by coprecipitation and annealing.

by inductively coupled plasma spectrometry. The crystal phases of the particles were examined by X-ray diffraction analysis with a Cu-Kα source.

3 PREPARATION OF Bi-YIG COATED FILMS

The Bi-YIG particles were mixed with an organic binder such as epo-teck 396 (Epoxy Technology Co.) and cyclohexanon and milled with a Pulverisette P7 milling machine (Fritsch Co.) for 30 h. It was then coated on a Corning 7059 glass substrate using a spin coater. The thickness of the films was adjusted by the speed of disk rotation. Films were prepared for various volume ratios (x) of Bi-YIG particles in the coated films in the range from 0.05 to 0.70.

The magnetic properties of the coated films were measured with a vibrating sample magnetometer (VSM) at room temperature. The Faraday rotation spectra of the coated films were measured by the polarization modulation method. The optical measurements were carried out in the visible wavelength region. The Bi-YIG particles dispersed in the films were observed with a scanning electron microscope (SEM) and an atomic force microscope (AFM).

4 RESULTS AND DISCUSSION

4.1 Magnetic properties of Bi-YIG particles

Figure 2 shows the X-ray diffraction pattern of the Bi-YIG particles. All the peaks were assigned to the garnet structure. The saturation magnetization of the Bi-YIG particles was 16 emu/g at room temperature.

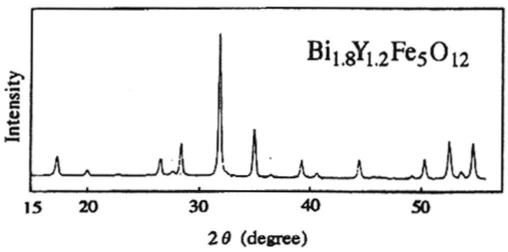

Fig.2 X-ray diffraction pattern of Bi-YIG particles.

4.2 Structure of Bi-YIG coated films

Figure 3 shows the surface of the Bi-YIG coated films observed by SEM. The size of the dispersed particles is about 50 nm, and is almost equal for the various particle volume ratio x. The surface of the films became rough when x increased more than 0.7. Transparent films were obtained in the range of x from 0.05 to 0.53. Figure 4 is the AFM image of the film for $x = 0.4$ showing more details of the particles in the coated film. It is also noted that the particles are observed

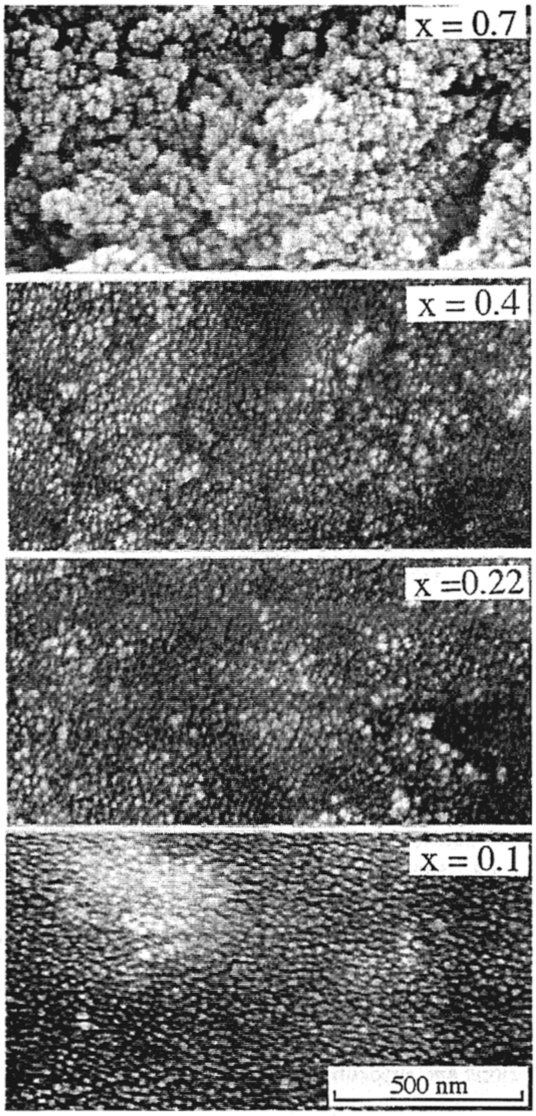

Fig.3 SEM images of the Bi-YIG coated films.

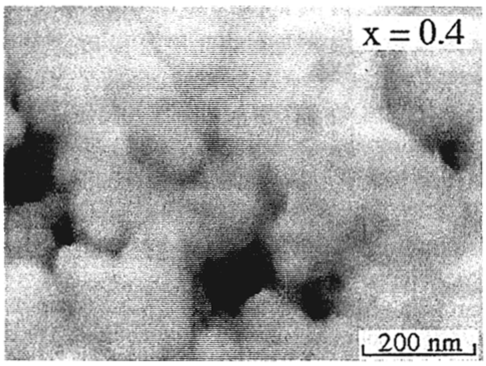

Fig.4 AFM image of the Bi-YIG coated film.

with a uniform size. The mean size of the particles is smaller than the wavelength of visible light.

4.3 Display of magnetic pattern by coated films

The coated film was evaluated by displaying a magnetic pattern through the MO effect. Figure 5 shows an optical arrangement and magneto-optical contrast obtained with an x = 0.4 coated film. The magnets were arranged in a checkerboard pattern as shown in the figure. The magneto-optical contrasts were observed with the analyzer angles of ± 2 degrees from the cross Nicol condition[7].

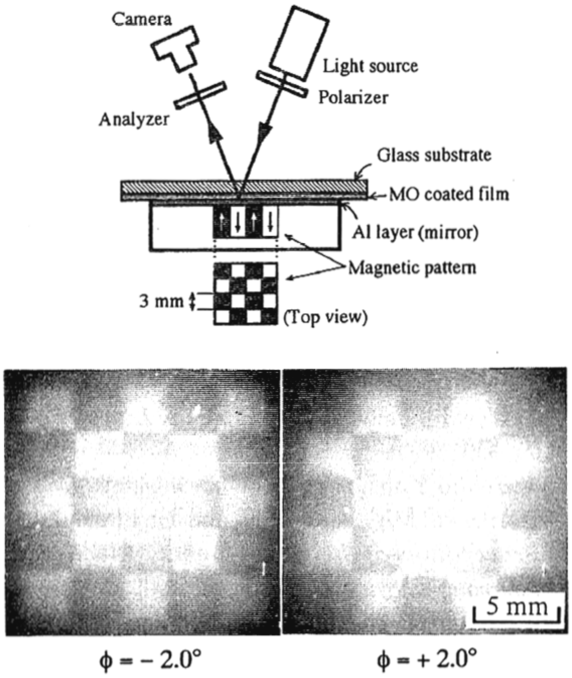

Fig.5 Schematic diagram of the optical configuration used for the observation of magneto-optical contrasts ; ϕ : offset angle of analyzer.

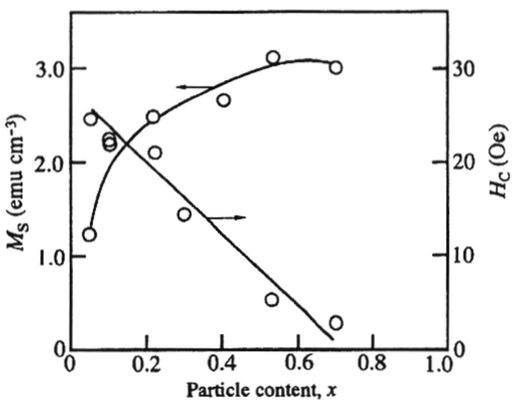

Fig.6 Saturation magnetization and coercive force of the films as a function of particle content x .

4.4 Magnetic and Magneto-Optical properties of coated films

The saturation magnetization (M_S) and coercive force (H_C) of the coated films are shown in Figure 6. The measurements were made in the perpendicular configuration with the maximum applied field of 2.5 kOe. The H_C decreased linearly with increasing x, the relation is the same as that reported by Shimizu *et al*[12]. The M_S increased with x.

Figure 7 shows the Faraday rotation spectra of the coated films for various x. The peaks of the curves shift to longer wavelength points when x decreases. This result suggests that the coated films can be adjusted by particle content to have their maximum sensitivities in the light source of the devices.

The saturation magnetization M_S and the Faraday rotation θ_F of the films were divided by x and were plotted in Fig. 8. The $M_{S,P}$ and $\theta_{F,P}$ in the figure indicate the values per particle volumes in the films. The $M_{S,P}$ decreases with x when x is less than 0.4, however, the $\theta_{F,P}$ increases with x in the same range. It is presumed that these variations in the $M_{S,P}$ and $\theta_{F,P}$ are caused by the change in the magnetic interactions between Bi-YIG particles and binder.

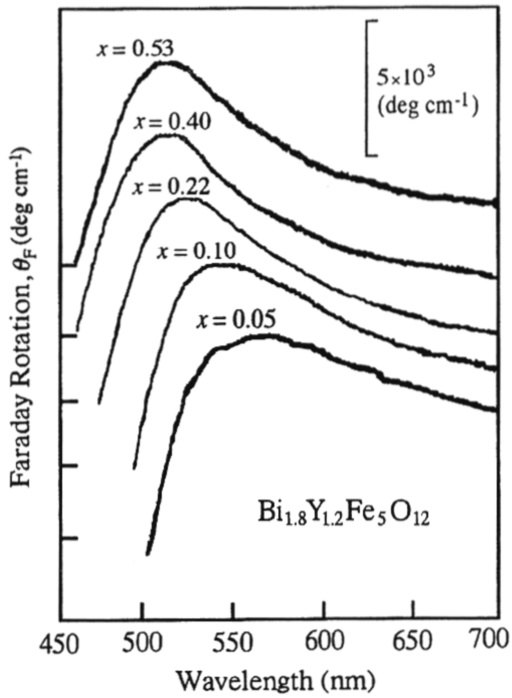

Fig.7 Faraday rotation spectra of the Bi-YIG coated films.

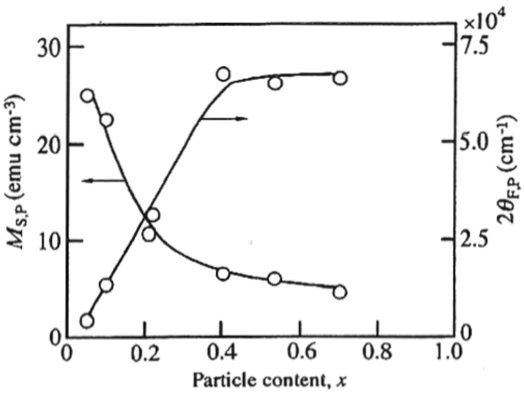

Fig.8 Saturation magnetization and Faraday rotation expressed in units per particle volume in the films.

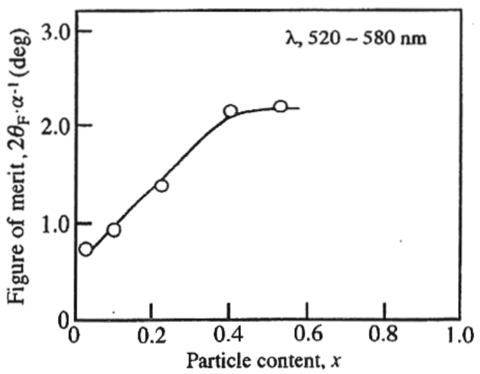

Fig.9 The figure of merit of the Bi-YIG coated films in the visivle wavelength region.

Figure 9 shows the figure of merit of the coated films in the visible wavelength region. The figure of merit of the films is comparable to sputtered Bi-YIG films in the region of x from 0.4 to 0.6[13, 14].

5 CONCLUSIONS

In order to develop large and economical media working in the visible wavelength region, fine Bi-YIG particles were prepared by coprecipitation and annealing processes. The particles were coated with a plastic binder on glass and plastic sheets. The magneto-optical properties were measured in the visible wavelength region. The following results were obtained:

1) Transparent coated MO sheets can be prepared when the content of the Bi-YIG particles is less than 0.7.
2) The figure of merit of the coated sheets in the visible wavelength region is comparable with conventional sputtered polycrystal Bi-YIG films containing about same amount of Bi ions. A clear magneto-optical image was obtained using the coated sheet.
3) It was found that the magnetic and magneto-optic properties of the films varied when the content of the Bi-YIG particles in the films changed.

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