Proceedings of the First Magneto-Electronics International Symposium, 1994.

Bi-YIG COATED MAGNETO-OPTICAL THIN FILMS

Teruyoshi Hirano, Norikazu Kawai*, Eiju Komuro*, Tatsuru Namikawa* and Yohtaro Yamazaki*

Toppan Printing Co., Ltd., Takanodai-minami, Sugito, Saitama 345, Japan
*Tokyo Insistute of Technology, Nagatsuta, Midori-ku, Yokohama 227, Japan

Abstract-Garnet fine particles are prepared by coprecipitation. The saturation magnetization of the particles increases as the annealing temperature increases. Almost all X-ray diffraction peaks from the particles annealed at 700 °C for 1h are assigned to garnet. The prepared particles are classified in order to remove the aggregated large particles which lower the transparency of the film. Faraday rotation of the particles which are dispersed into methylene iodide is confirmed under a polarization microscope. The Faraday rotation of the coated films are shown as a function of wavelength. A magnetic field pattern was displayed using a prepared coated film.

KEYWORDS : Bi-YIG, coprecipitation, Faraday rotation, coated thin film

I. INTRODUCTION

Thin films of Bi substituted yttrium iron garnet (Bi-YIG) are applicable to magneto-optical disks and magneto-optical display devices. In the preparation of Bi-YIG thin films by sputtering methods, ceramic crystal or glass substrates are required because of the high preparation temperature. As the temperature is normally more than 500 °C, it is difficult to use the plastic substrates. Recently garnet fine particles can be obtained by chemical methods [1], [2]. It is possible to avoid the thermal requirement by adopting the coating method for Bi-YIG fine particles [3]. Therefore, garnet fine particles are considered to be a promising material for thin film applications [3], [4].

We prepare Bi-YIG fine particles by a coprecipitation method, and discuss their structural and magnetic properties. Faraday rotation of the film coated of the particles is measured in the visible wavelength region.

II. EXPERIMENTAL

Figure 1 shows the preparation process of Bi-YIG particles by coprecipitation [5]. First, aqueous solutions of nitrates of Bi, Y and Fe with the ratio of cations corresponding to the composition of $Bi_{1.6}Y_{1.4}Fe_5O_{12}$ were prepared and mixed at room temperature with an alkaline solution of NH_4OH. After the coprecipitation reaction, the pH of the solution affects the composition and the saturation magnetization of the particles. The relation between the composition and the saturation magnetization of the particles and the pH of the solution is indicated in Fig. 2. In the range of the pH over 8.7, the ratio of the cations in the particles was the same as that of the nitrate solution. In this paper, the pH of the solution was fixed to 10.7. Then the obtained slurry was washed with water to remove the alkaline ions, filtered and dried at 100 °C for 1.5 h. Then the coprecipitate was annealed in air at Ta=500 °C ~ 700 °C for 1 h or 4 h to crystallize (Ta: annealing temperature).

The composition of the coprecipitates was analyzed by inductively coupled plasma spectroscopy. The shape and the size of the particles were investigated using a transmission electron microscope

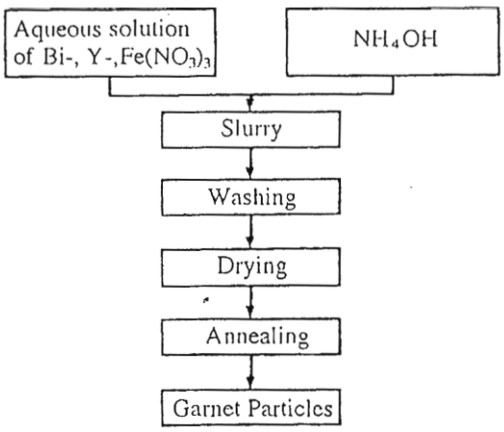

Fig. 1 Preparation of garnet fine particles by coprecipitation.

(TEM) and the crystal structure of the particles was examined by X-ray diffraction. Magnetic properties were measured using a vibrating sample magnetometer at room temperature.

Classification of the particles was conducted as follows. Bi-YIG particles (2.0 g) annealed at 600 °C for 1 h were dispersed in water (100 ml) by using an ultrasonic cleaner for 10 min and then stood for 30 min. After the large particles settled, the fine particles in the water were collected with a magnet.

The coated magneto-optical thin films prepared as follows. To coat the particles on a glass substrate, first, the particles, organic binder and cyclohaxanone were mixed. Then it was milled for 10h and coated on the substrate using a spin coater. The film thickness was adjusted by the speed of rotation of the spin coater. A homogeneous film was obtained.

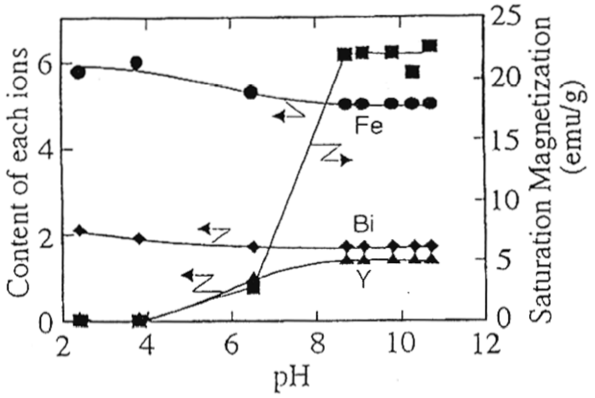

Fig. 2 Content of each ions and saturation magnetization of the particles as a function of pH of the solution.

III. RESULTS AND DISCUSSION

A. Magnetic Properties

Figure 3 shows the saturation magnetization of the particles as a function of the annealing temperature for both annealing periods. For annealing period of 1h, magnetization appears at Ta=580 °C, whereas for 4h, the magnetization appears at Ta=570 °C.

X-ray diffraction patterns of the particles annealed for 4h at various temperatures from 500 °C to 700 °C are shown in Fig. 4. At 550 °C, no peaks were detected. Garnet peaks appear at 600 °C, but some unidentified peaks are also present. Then, at 700 °C, the unidentified peaks become negligibly small and almost all peaks are assigned to garnet.

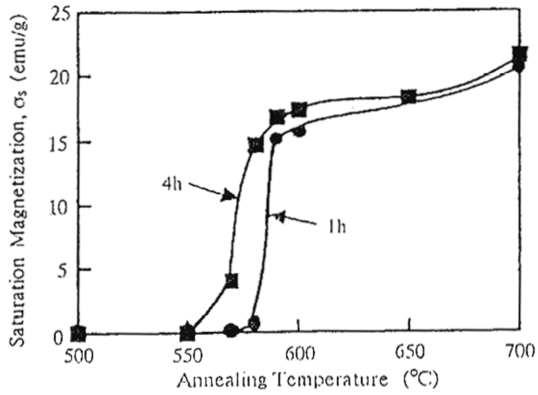

Fig. 3 Saturation magnetization of preparation particles vs. annealing temperature for different annealing periods.

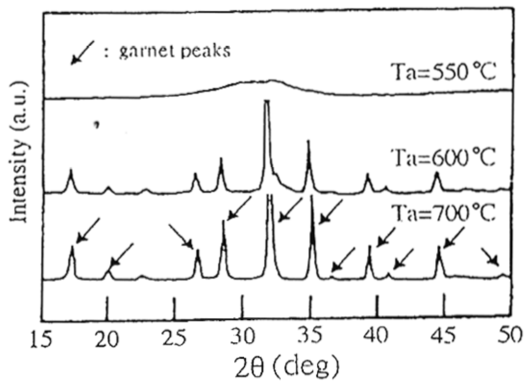

Fig. 4 X-ray diffraction patterns of the particles for various annealing temperature.

The particles annealed for 1h show the same tendency as those annealed for 4h in regard to X-ray diffraction.

Figure 5 shows TEM micrographs of the particles annealed for 4h at various temperatures from 500 °C to 700 °C. The magnetization is not detected in the particles annealed at 500 °C and 550 °C.

Some particles, in the powder samples synthesized at 570 °C for 1h, are found to show considerably large magneto-optical effect.

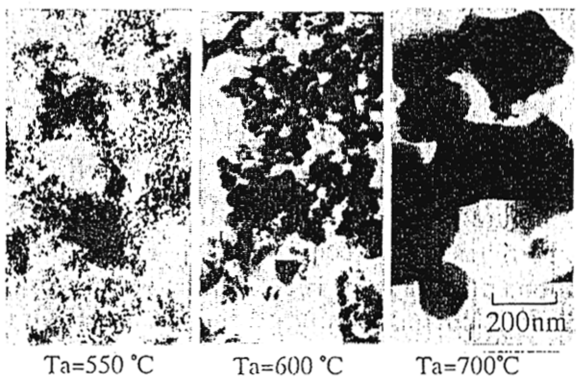

Fig. 5 TEM micrographs of annealed Bi-YIG particles.

B. Classification

Table 1 shows the effect of the classification process on the saturation magnetization and coercive force of the particles. Although the saturation magnetization hardly changes by the process, the coercive force lowers to half of the initial value after the classification.

Figure 6 shows TEM micrographs of the particles before and after classification. The small fine particles, which result in lower coercive force, are collected after the classification. However, the aggregated large particles composed of the small particles are removed by the classification process.

Table 1 Effect of Classification Magnetization and Coercive Force

	Before classification	After classification
Magnetization σ_s (emu/g)	12	11
Coercivity Hc (Oe)	20	10

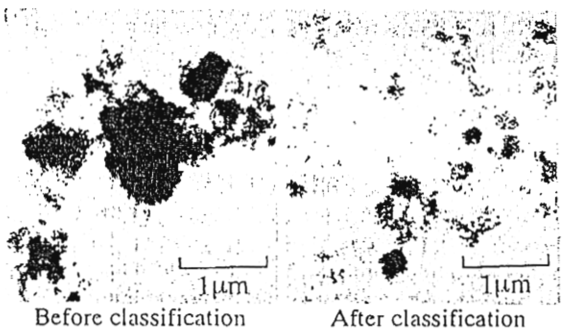

Fig. 6 TEM micrographs of annealed Bi-YIG particles, before and after classification.

C. Observation of the particles

Images of the particles annealed at 700 °C for 1h dispersed in methylene iodide are shown in Fig. 7. The photos were taken using a polarization microscope, under opposite magnetic fields. The analyzer was fixed at five degrees from crossed Nicol condition. Methylene iodide was used as a dispersion medium because of its high refractive index. The particles which the arrows point to in Fig. 7a are bright while those in Fig. 7b are dark. This result

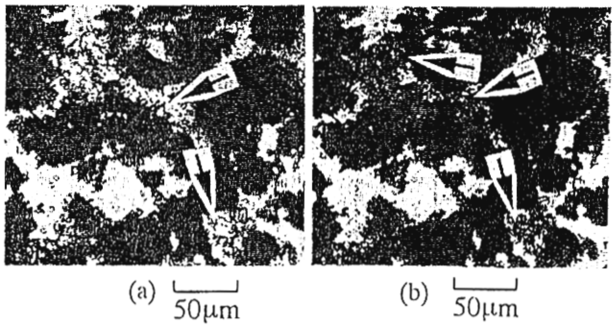

Fig. 7 Images obtained with annealed Bi-YIG particles, immersed in methylene iodide under obverse (a) and reverse (b) magnetic fields.

suggests that some of the synthesized particles rotate the plane of visible wavelength light.

D. Faraday rotation of coated film

Figure 8 shows the Faraday rotation of the film coated of the particles having the composition of $Bi_{1.8}Y_{1.2}Fe_5O_{12}$ at 1000rpm as a function of wavelength. The thickness of the film was about 630nm. In the region of the wavelength from 420nm to 570nm, the coated film showed Faraday rotation.

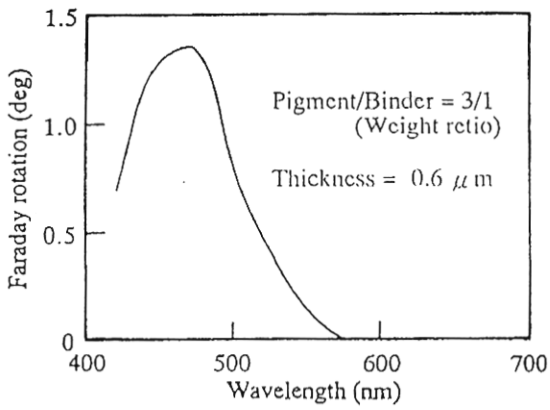

Fig. 8 Faraday rotation of the film prepared by spin coating at 1000rpm as a function of wavelength.

E. Optical Read Out of Magnetic Pattern

A Bi-YIG coated film was placed on a mirror which was placed on a magnet. The magnet was magnetized with a checkered pattern show in Fig.9. The optical arrangement is also shown in Fig.9. The angles of the analyzer were ± 2 degrees from crossed Nicol condition for the read out experiment. Fig. 10 shows the read out patterns obtained with the reflected light.

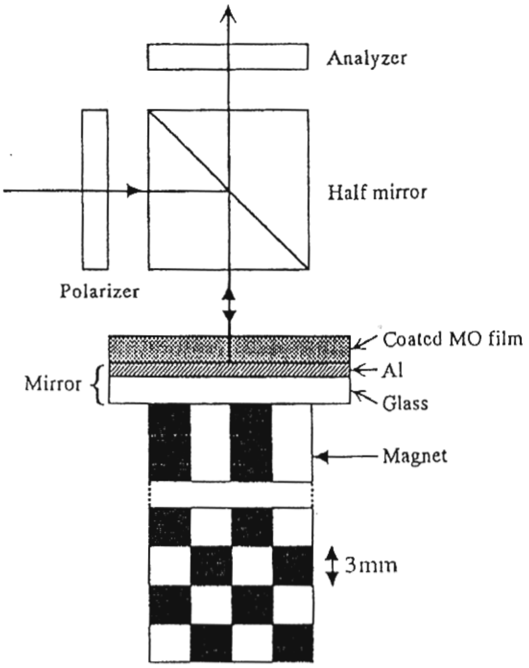

Fig.9 Optical system for the read out of magnetic pattern.

We can confirm that the prepared coated film reads out the magnetic pattern of the magnet by using a visible light. It is also noted that the read out is carried out with an optic arrangement of reflection configuration which is more suitable for optical devices than that of transmission configuration.

IV. CONCLUSIONS

Bi-YIG fine particles were prepared by coprecipitation and anneal process in order to study their structural, magnetic and magneto-optical properties. From the results of saturation magnetization and X-ray diffraction patterns of the particles, it was found that garnet phase appears over 550 °C, and pure garnet phase is formed at 700 °C. Classification of the prepared particles was conducted in order to collect smaller particles. The coercive force lowers to half of the initial value after the classification. Faraday rotation of the particles was confirmed using a polarization microscope. A MO film was prepared by coating the particles. The film showed Faraday rotation in the region of wavelength from 420nm to 570nm. The coated MO film showed magnetic field pattern with reflected light. Thus, Bi-YIG fine particles prepared by coprecipitation process have the possibility to be applied to display devices working in the visible wavelength region.

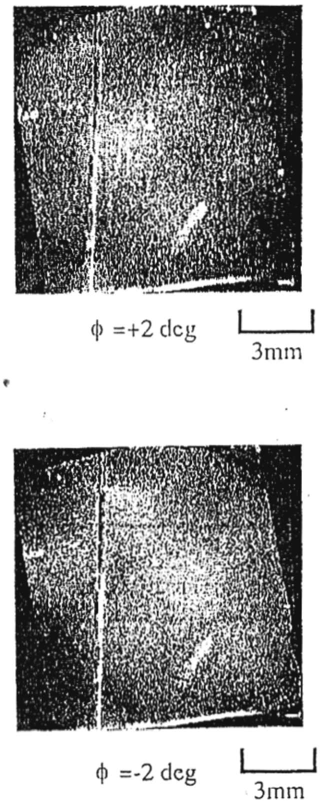

Fig. 10 Bi-YIG coated films showing a magnetic field pattern with reflected light.

REFERENCES

[1] M. Gomi, Serada and M. Abe, "fine particles of Bi- and Ce- substituted iron garnet prepared by coprecipitation," *Proceedings of The Sixth International conference on Ferrites,* 999 (1992).
[2] K. Odagawa, K. Nakagawa and A. Itoh, "Effects of heat treatment conditions and impurity doping on garnet films for M-O recording prepared by pyrolysis," *IEEE Trans. Magn.*, vol. **26**, 1721 (1990).
[3] T. Fujimoto, Y. Kumura, M. Gomi and M. Abe, "Particulate films for magneto-optical recording III and IV," *J. Magn. Soc. Jpn.*, vol. **15**, Sppl. S1, 263 and 267 (1991).
[4] K. Nakagawa and A. Itoh, "Microstructure and crystallization mechanism of Bi-substituted garnet films for M-O recording prepared by pyrolysis and sputtering," *J. Magn. Soc. Jpn.*, vol. **17**, Sppl. S1, 278 (1993).
[5] N. Kawai, T. Hirano, E. Komuro, T. Namikawa and Y. Yamazaki, "Preparation of Bi substituted YIG particles by coprecipitation," *DENKI KAGAKU,* vol. **62**, 348 (1994).