PREPARATION OF Bi-YIG PARTICLES FOR DISPLAY DEVICES

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***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 ℃ for 1h are assigned to garnet. The prepared particles are classified in order to remove the aggregated large particles which are considered to prevent passing of light. The coercive force lowers to half of the initial value after the classification. Faraday rotation of the particles which are dispersed into methylene iodide is confirmed under a polarization microscope. Faraday rotation of the film coated of the particles are shown as a function of wavelength.**

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

Fig. 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℃ for 1.5 h. Then the coprecipitate was annealed in air at Ta=500 ℃~700 ℃ for 1 h or 4 h to crystallize (Ta: annealing temperature).

Classification of the particles was conducted as follows. Bi-YIG particles (2.0 g) annealed at 600 ℃ 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 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 (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.

III. Results and Discussion

A. Magnetic Properties

Fig. 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 ℃, whereas for 4h, the magnetization appears at Ta=570 ℃.

X-ray diffraction patterns of the particles annealed for 4h at

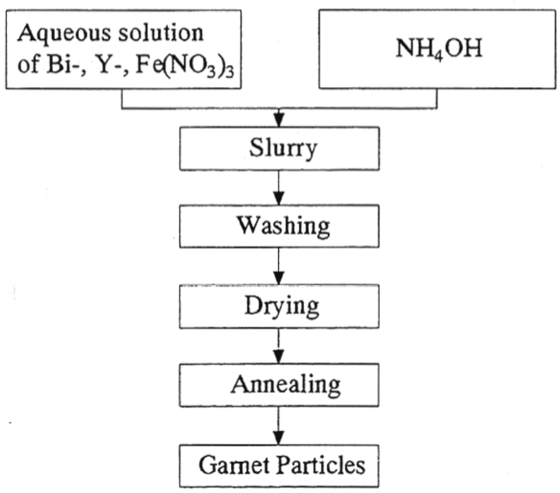

Fig. 1 Preparation of garnet fine particles by coprecipitation.

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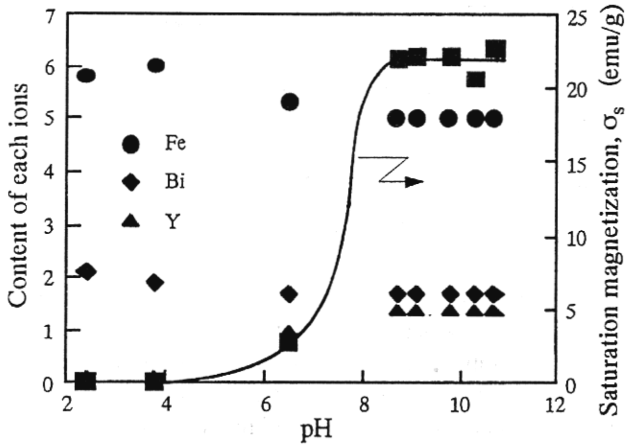


Fig. 2 Content of each ions and saturation magnetization of the particles as a function of pH of the solution.

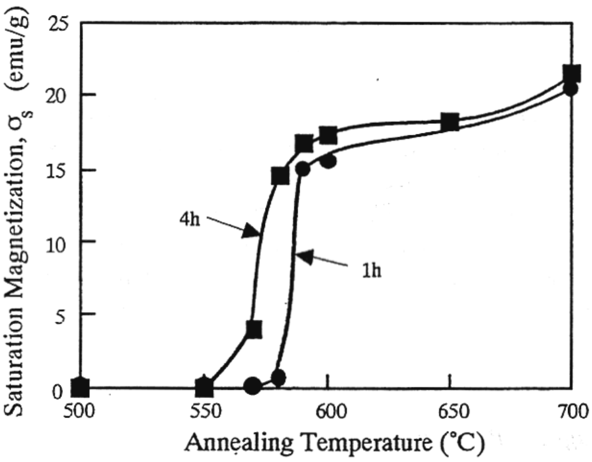


Fig. 3 Saturation magnetization of preparation particles vs. annealing temperature for different annealing periods.

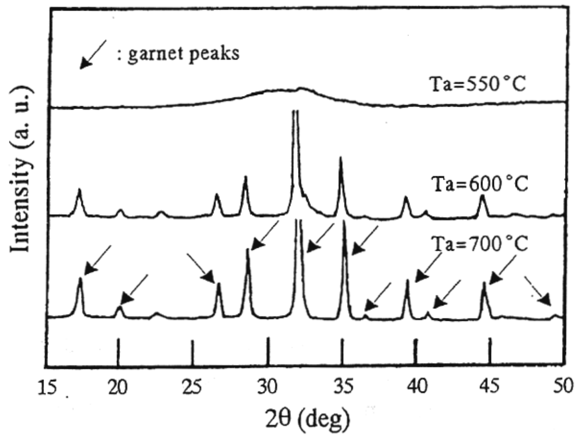


Fig. 4 X-ray diffraction patterns of the particles for various annealing temperature.

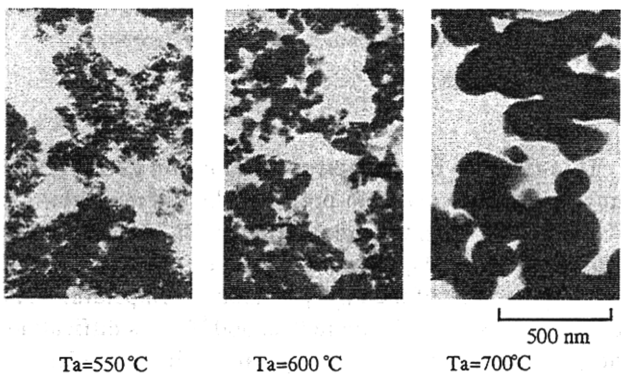


Fig. 5 TEM micrographs of annealed Bi-YIG particles

various temperatures from 500 ℃ to 700 ℃ are shown in Fig. 4. At 550 ℃, no peaks were detected. Garnet peaks appear at 600 ℃, but some unidentified peaks are also present. Then, at 700 ℃, the unidentified peaks become negligibly small and almost all peaks are assigned to garnet. The particles annealed for 1h show the same tendency as those annealed for 4h in regard to X-ray diffraction.

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

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

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.

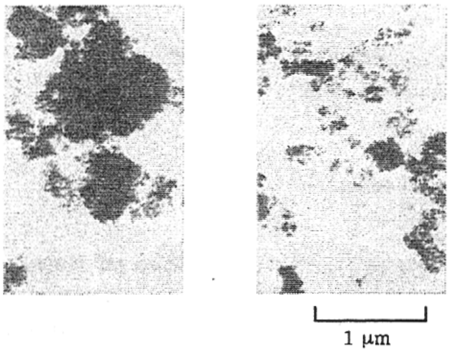
Fig. 6 shows TEM micrographs of the particles before and after classification. The small fine particles, which result in lower coercive force, are collected after the classification. However, the aggregated large particles composed of the small particles are removed by the classification process.

TABLE I
EFFECT OF CLASSIFICATION ON MAGNETIZATION AND COERCIVE FORCE

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

C. Observation of the particles

Images of the particles annealed at 700 ℃ for 1h dispersed



Before classification After classification

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

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

D. Faraday rotation of coated film

To coat the 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. 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.

IV. Conclusions

Bi-YIG fine particles were prepared by coprecipitation and an annealing process in order to study their structural, magnetic and magneto-optical properties. From the data of the saturation magnetization and X-ray diffraction patterns of the particles, garnet phase appears over 550 ℃, and the pure garnet phase is formed at 700 ℃. Classification of the prepared particles is 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 which were dispersed into methylene iodide was observed under a polarization microscope, and their magneto-optical effect was confirmed. The film coated of the particles showed Faraday rotation in the region of wavelength from 420nm to 570nm.

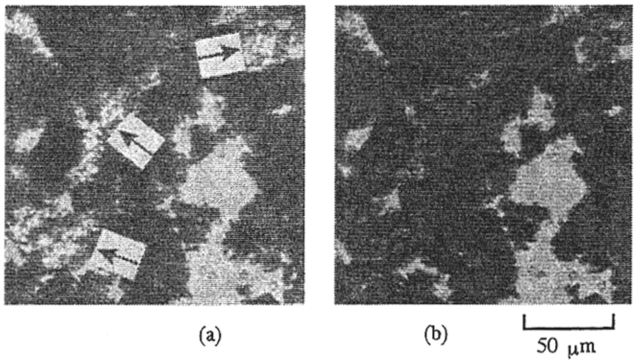


Fig. 7 Images obtained with annealed Bi-YIG particles, immersed in methylene iodide under obverse (a) and reverse (b) magnetic fields.

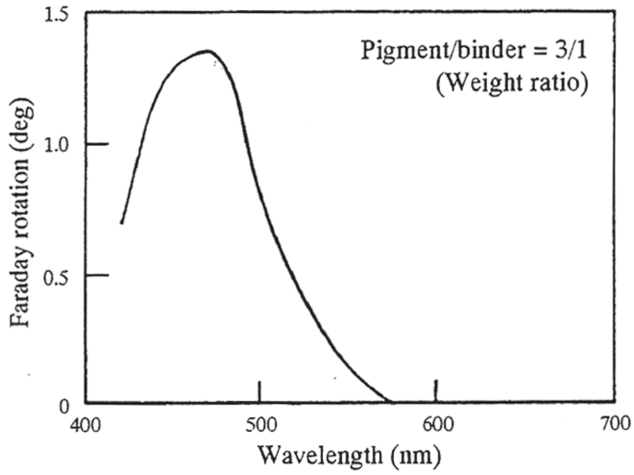


Fig. 8 Faraday rotation of the film prepared by spin coating at 1000rpm as a function of wavelength.

Thus, Bi-YIG fine particles prepared by a coprecipitation process have the possibility to be applied to devices working in the visible wavelength region.

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