—Communication—

Estimation of Bi Content in Bi-YIG Particles Prepared by Coprecipitation and Annealing

Yoshiyuki KAWANO, Teruyoshi HIRANO†, Tatsuru NAMIKAWA and Yohtaro YAMAZAKI*

Received March 27, 1995 ; Accepted May 8, 1995

1 INTRODUCTION

Fine particles of Bi substituted yttrium iron garnet (Bi-YIG) have large Faraday rotation in the visible wavelengh region. Coated thin films of Bi-YIG particles can be easily prepared and are expected to be applied to information display devices[1]. Strocka, et al.[2] reported an empirical formula for the calculation of lattice constants of garnet crystals and that the lattice constant of Bi-YIG increased linearly with increasing Bi content. However the study did not include particlate materials. In this study, the lattice constants of Bi-YIG particles prepared by coprecipitation and annealing are measured for various Bi contents in the starting materials of nitrate solutions. The maximum substitution in the Bi-YIG phase in the prepared particles is discussed for various annealing temperatures.

2 EXPERIMENTAL

Aqueous nitrate solutions of Bi, Y and Fe(III) which had the composition of $Bi_xY_{(3-x)}Fe_5$, $0 \leqq x \leqq 2.5$ were prepared. The solutions were mixed with an NH_4OH solution and coprecipitation reaction proceeded at room temperature. After the reaction, the *p*H of the solution was 10. Then the alkaline ions in the coprecipitates were removed by washing with water, and filtered and dried at 300°C for 1h. Then 0.5g of dried coprecipitate was thermally treated to crystallize at 600°C, 650°C, 700°C and 750°C for 1h. Saturation magnetization (M_s) was measured by using a vibrating sample magnetometer at room temperature. The lattice constant of the particles was measured by the internal standard method using a high purity Si powder.

3 RESULTS AND DISCUSSION

Figure 1 shows the lattice constant (a_0) and M_s of the particles annealed at each temperature as a function of Bi content (x) in nitrate solutions. Dotted lines show the relation between a_0 of Bi-YIG and substituted Bi content given by Geller[3] as:

$$a_0 = 12.3754 + 0.0828\,x_s \qquad (1)$$

where x_s represents the Bi substitution in the garnet phase. XRD was measured for all the samples. No second phases were observed in the range of x from 1.5 to 1.8 for the annealing temperature of 650°C. The single phase regions for 700°C and 750°C were $1.2 \leqq x \leqq 1.7$, $0.5 \leqq x \leqq 1.6$, respectively. The open circles in Fig. 1 indicate single phase samples. The relationship between the lattice constants of these garnet single phase particles and Bi content in the nitrate solutions for various annealing temperatures was obtained as Eq. (2) by the least square method.

$$a_0 = 12.3482 + 0.0826\,x \qquad (2)$$

Solid circles in Fig. 1 indicate the multi-phase samples. The slope of Eq. (2) is almost the same as Eq. (1). Garnet phase was not observed in the samples annealed at 600°C for $x \leqq 1.3$. The lattice constant of the samples annealed at 600°C fits Eq. (1). The M_s for the samples of 600°C shows a maximum value at $x = 1.7$. The M_s for the samples of 650°C decreases as the ratio of $Bi_2Fe_4O_9$ phase increases in the Bi content of $1.9 \leqq x$. The lattice constant and M_s for the samples of 700°C begin to decrease when $Bi_2Fe_4O_9$ phase is observed in the particles at x =1.8. For the samples of 750°C, the second phase

Department of Electronic Chemistry, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology (4259 Nagatsuta, Midori-ku, Yokohama 226, Japan)
† Technical Research Institute, Toppan Printing Co., Ltd. (4-2-3 Takanodai-minami, Sugito-machi, Kitakatsushika-gun, Saitama 345, Japan)
Key Words : Bi-YIG Particle, Lattice Constant, Substituted Bi Content

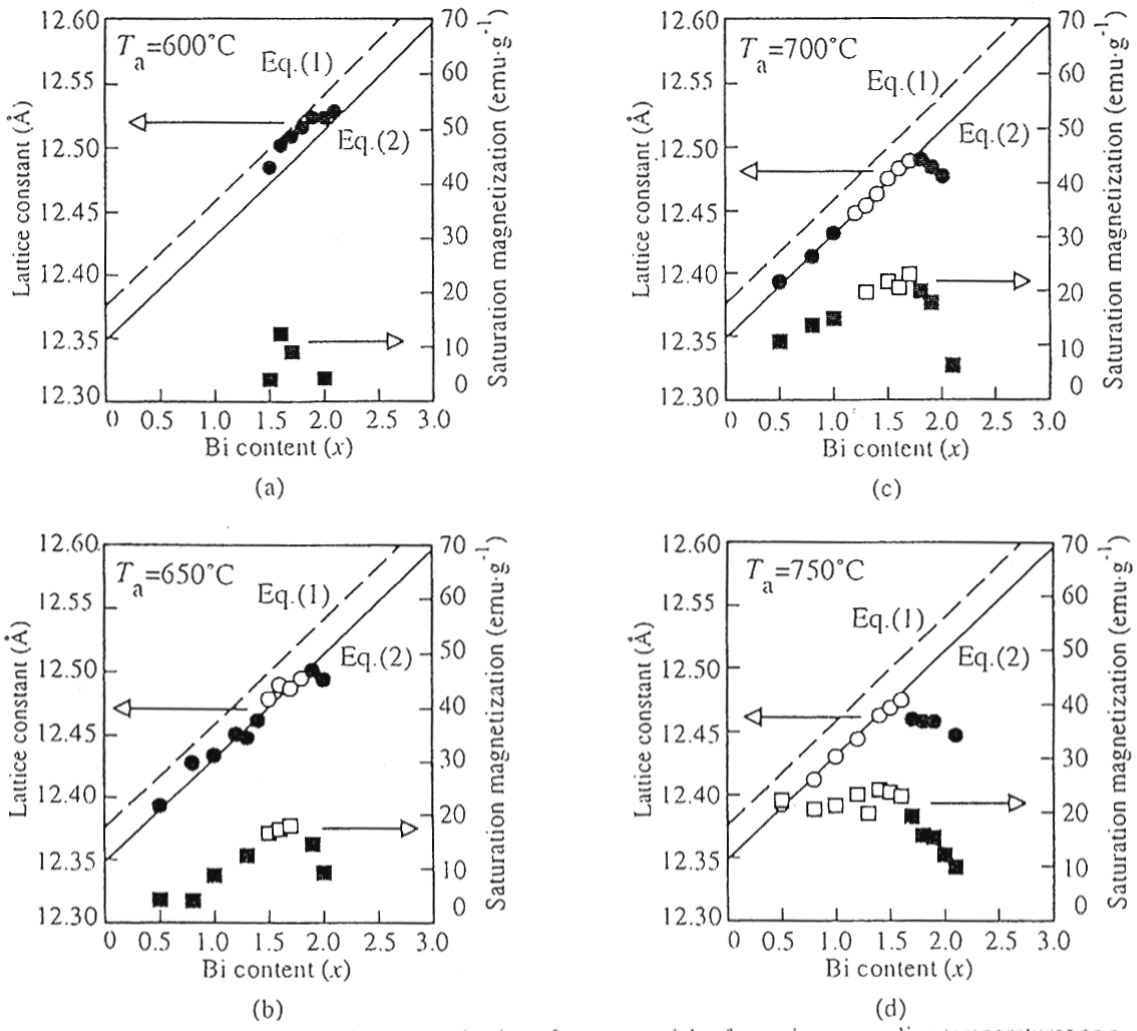

Fig. 1 Lattice constant and saturation magnetization of garnet particles for various annealing temperatures as a function of Bi content in the nitrate solution. T_a is annealing temperature. The open marks (○, □) and solid marks (●, ■) represent garnet single phase samples and multi-phase samples, respectively.

appeared at x = 1.7. An estimation of the limit of the Bi substitution for this preparation process is presented. The maximum value of lattice constant for the garnet single phase particles prepared in this experiment is 12.4950Å in Fig. 1(b). Then we obtain the limit of the Bi substitution is 1.5 from the value of lattice constant and Eq. (1).

4 CONCLUTIONS

A linear relationship between the lattice constant of the garnet phase and the Bi content in the starting materials of nitrate solutions was obtained and the coefficient was determined for the preparation of Bi-YIG fine particles by coprecipitation and heat treatment. The maximum lattice constants of the garnet phases formed in the prepared particles for various annealing temperature were determined. From the result, It was clarified that more Bi containing particles were prepared at lower annealing temperatures. The limit of the Bi substitution for YIG particles prepared by coprecipitation and heat treatment was also determined.

REFERENCES

1) N. Kawai, E. Komuro, T. Namikawa, Y. Yamazaki and T. Hirano, *IEEE Trans. Magn.*, 30, 4446 (1994).
2) B. Strocka, P. Holst and W. Tolksdorf, *Philips J. Res.*, 33, 186 (1978).
3) S. Geller, H. J. Williams, G. P. Espinosa, R. C. Sherwood and M. A. Gillelo, *Appl. Phys. Lett.* 3, 21 (1963).