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MAGNETO-OPTICAL PROPERTIES OF Mg-DOPED Bi-YIG SPUTTERED FILMS

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Abstract- Magnetic and magneto-optical properties of polycrystalline $Bi_2YMg_xFe_{5-x}O_{12}$ have been investigated. Amorphous films deposited by the sputtering were annealed in air at 650°C for 4h to be polycrystalline films. When Mg content was less than x = 0.52, garnet structure was stably formed. The Faraday rotation of the films at 520 nm decreased linearly with increasing x. Absorption coefficient also reduced monotonously. As a result, the figure of merit was improved in the visible wavelength region and had a maximum value of 5.36 degrees at x = 0.36.
KEYWORDS: Mg, Bi, YIG, FARADAY ROTATION, ABSORPTION COEFFICIENT, FIGURE OF MERIT

I. INTRODUCTION

Bismuth substituted yttrium iron garnet (Bi-YIG) is highly attractive material for magneto-optical media, because it exhibits a large Faraday rotation[1]. In the visible wavelength region, however, Bi-YIG films have substantial absorption caused by Fe^{3+} ions[2]. Therefore it is possible to improve figure of merit by means of reducing the absorption in this wavelength region. In this paper, we discuss the effects of Mg^{2+} ions in Mg-doped Bi-YIG sputtered films on the magnetic and magneto-optical properties of the films.

II. EXPERIMENTAL

Mg-doped Bi-YIG films were prepared on Corning #0317 glass substrates by rf-sputtering under the conditions given in Table I. Targets were prepared first by mixing of Bi_2O_3, Y_2O_3, Fe_2O_3 and MgO, and they were fired at 800°C for 4h and ground with a mill. Then it was pressed at 200kg/cm^2 to form a disk. The amorphous films deposited by the sputtering were annealed in air at 650°C for 4h to be polycrystalline films. The phases in the annealed films were analyzed through X-ray diffraction with Cu-Kα. The film thickness was measured with a surface step analyzer (Sloan DEKTAK 3030). The saturation magnetization (M_s) was measured with a VSM. The magnetic field was applied up to 2kOe. Faraday rotation (θ_F) was measured by the polarization modulation method. The absorption coefficient (α) was measured by a spectro-photometer.

Table I Sputtering conditions

Sputter gas	Ar, 6.7 Pa
Substrate	Corning #0317 glass
Substrate temperature	400°C
rf power density	2.5 W/cm^2
Deposition rate	5.0 nm/min
Target-substrate distance	40 mm

III. RESULTS AND DISCUSSION

The relation between the target compositions of $Bi_2YMg_xFe_{5-x}O_{12}$ and film compositions are given in Table II. The film compositions were determined by ICP measurements, assuming that the total number of the cations (Bi^{3+}, Y^{3+}, Mg^{2+}, and Fe^{3+}) was 8. The amounts of bismuth ion were slightly deficient in the films than those in the targets. Yttrium contents were a little more in the films than those in the targets. The contents of both Mg and Fe ions in the films were almost the same as those in the targets. As there was not large difference between the compositions of targets and films, we use the compositions of the films in the following discussion.

Table II Compositions of targets and films ($Bi_2YMg_xFe_{5-x}O_{12}$)

Sample No.	Target		Film			
	Mg	Fe	Bi	Y	Mg	Fe
1	0.0	5.0	1.93	1.08	0.00	4.99
2	0.3	4.7	1.86	1.30	0.36	4.48
3	0.5	4.5	1.87	1.16	0.52	4.45
4	0.7	4.3	1.82	1.18	0.73	4.27
5	1.0	4.0	2.11	1.07	0.98	3.85

Figure 1 shows the X-ray diffraction patterns of annealed films. Each pattern shows garnet structure. As the Mg content increases, all garnet peaks become broad and weak. Other peaks are also observed at 2θ = 23.1 and 46.9 degrees for the sample No.5 which contains the largest amount of Mg ions.

Figure 2 shows the variation of M_s of the films as a function of Mg content. M_s keeps the values more than 100 emu/cm^3 until x= 0.52, and then linearly decreases. It gives only 60 emu/cm^3 at x= 0.98.

From both results of X-ray diffraction patterns and M_s, it is considered that the garnet phase can not be stable in the films which contain large amount of Mg ions.

The Faraday rotation of the films at 520nm is plotted in Fig. 3 as a function of Mg content . θ_F considerably decreases from 17.6 deg/cm to 5.6 deg/cm. It is noted that M_s is almost constant from x = 0.0 to 0.52, while θ_F decreases linearly in this range. This is explained as follows. Faraday rotation in Bi-YIG crystal is generally attributed to the Bi^{3+} ions in dodecahedral site[3]. When Mg^{2+} ions are doped in Bi-YIG, Mg^{2+} tends to occupy dodecahedral site[4]. Then θ_F decreases in proportion to the amount of the substituted Bi^{3+} ions in dodecahedral site.

The absorption coefficients of the films at 520nm are shown in Fig. 4. As x increases, α decreases monotonously from 3.47 cm^{-1} to 1.80 cm^{-1}. This means that Bi-YIG films containing Mg^{2+} reduce the absorption largely in the visible wavelength region. This also takes place in Ca doped Bi-YIG films[5].

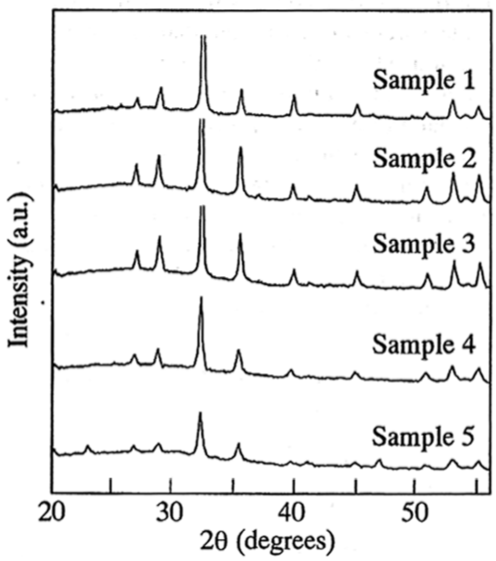

Fig. 1 X-ray diffraction patterns of Mg-doped Bi-YIG films.

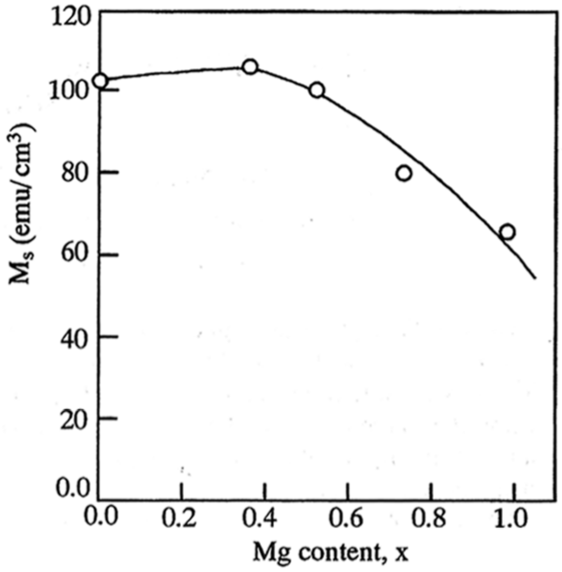

Fig. 2 Saturation magnetization (M_s) of the films as a function of Mg content.

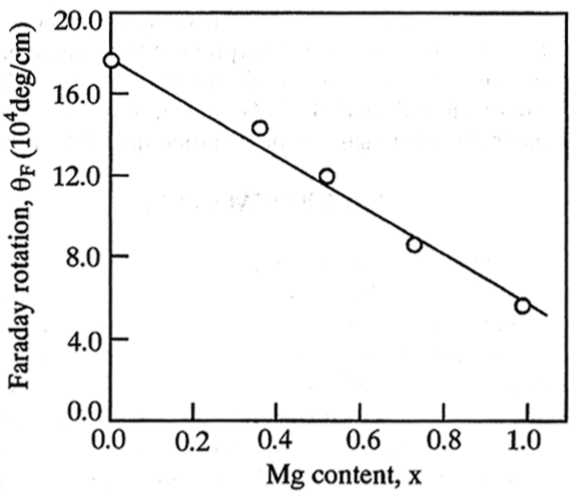

Fig. 3 Faraday rotation of the films at 520nm as a function of Mg content.

The relation between the figure of merit (θ_F/α) at 520nm and x are shown in Fig. 5. θ_F/α keeps high values until x= 0.52, then it decreases sharply with increasing Mg content. In this study we obtained the maximum θ_F/α value of 5.36 degrees at x= 0.36.

IV. CONCLUSIONS

Polycrystalline Bi-YIG films containing large amount of Mg ions ($Bi_2YMg_xFe_{5-x}O_{12}$) were prepared by rf-sputtering, and their magnetic and magneto-optical properties were investigated. In the wide range of Mg concentrations, garnet phases were formed. However, the M_s of the films suddenly decreased for the Mg content more than x = 0.52. It is concluded that the garnet phase is not stable when the films contain more Mg ions than x = 0.52. Faraday rotation decreases linearly with increasing x. It is presumed that Mg^{2+} substitute Bi^{3+} at the dodecahedral site in the garnet structure. The absorption coefficient at 520nm also decreases monotonously with x. As a result, the figure of merit has a maximum at x = 0.36. Mg substitution in Bi-YIG films is effective to improve the figure of merit of the films in the visible wavelength region.

V. REFERENCES

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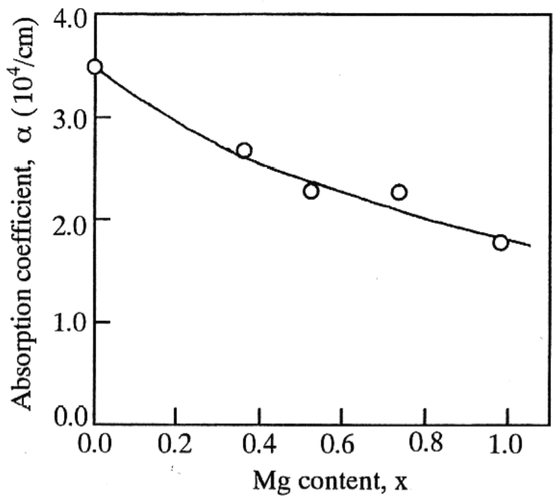

Fig. 4 Absorption coefficient of the films at 520nm as a function of Mg content.

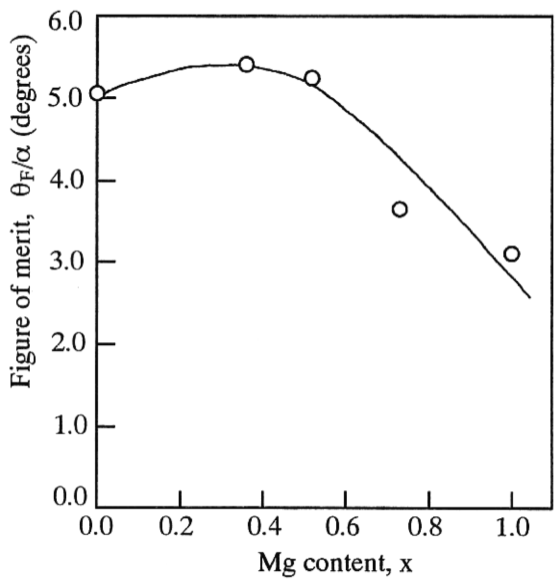

Fig. 5 Figure of merit of the films at 520nm as a function of Mg content.