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Crystal structure and magnetic characteristics of $(YBiGd)_3Fe_4Ga_1O_{12}$ garnet film fabricated on glass substrates by metal organic decomposition method

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Abstract: Garnet films of the composition: $(YBiGd)_3Fe_4Ga_1O_{12}$ and $Y_{3-x}Bi_xFe_{3.8}Ga_{1.2}O_{12}$ were fabricated on glass substrates by metal organic decomposition (MOD) method. In all films, all the diffraction lines observed by X-ray diffraction method were identified as the garnet phase. The magnetostriction of the $(YBiGd)_3Fe_4Ga_1O_{12}$ garnet film was larger than that of the $Y_{3-x}Bi_xFe_{3.8}Ga_{1.2}O_{12}$ garnet film by substitution of Gd.

1. Introduction

$Y_3Fe_5O_{12}$ (YIG) based garnets are important materials for making a new low power consumption device using a spin wave (magnon), because they have high electrical resistivity and low damping contents of precession. The garnets can be easily tuned their magnetic characteristics by substitution. If *c*-site in the garnet is substituted by rare earth elements, the magnetostriction of garnet is changed [2]. Y and Fe in YIG were partially substituted by Bi, Ga and Gd to control its magnetic characteristics, respectively. In this research, crystal structure and magnetic properties of $Y_{1.5}Bi_1Gd_{0.5}Fe_4Ga_1O_{12}$ and $Y_{2.7}Bi_{0.3}Fe_{3.8}Ga_{1.2}O_{12}$ garnet films fabricated on glass substrates by metal organic decomposition (MOD) method [1] were investigated.

2. Experimental procedure

Two different MOD solutions were used for $Y_{1.5}Bi_1Gd_{0.5}Fe_4Ga_1O_{12}$ (YBiGd-garnet) and $Y_{2.7}Bi_{0.3}Fe_{3.8}Ga_{1.2}O_{12}$ (YBi-garnet). The solutions were spin-coated on a glass substrate (Corning: EAGLE-XG) and followed by drying at 100 ℃ for 10 minutes to evaporate organic solvent and pre-annealing at 450 ℃ for 10 minutes to decompose and volatilize organic matter. This process was repeated 4 times. The films were post-annealed at 750 ℃ for 3 hours for oxidization and crystallization. The film thicknesses are expected to be 160 nm. The garnet films on glass substrate must be polycrystalline. The crystal structures were analyzed by X-ray diffraction (XRD) with Cu-*K*α line. Magnetic hysteresis curves were measured by vibrating sample magnetometer (VSM) with applying the magnetic field parallel to the film plane and normal to the film plane for estimating magnetic anisotropy of the garnet film.

3. Results and discussion

XRD patterns of YBiGd- and YBi-garnet films on glass substrates are shown in Fig. 1. In all the films, each observed diffraction line was identified as the garnet phase. Crystallinity of the YBiGd-garnet film was worse than that of YBi-garnet film by substitution of Gd for Y.

Magnetic hysteresis curves of the YBiGd- and YBi-garnet films on glass substrates measured at room temperature by VSM are shown in Fig. 2. Saturation

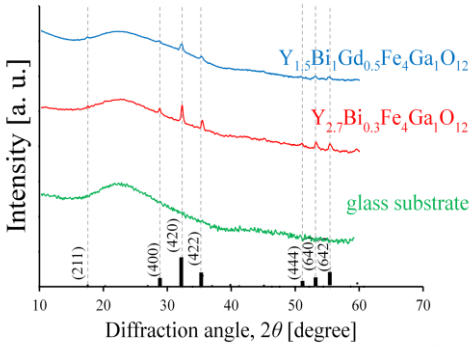

Fig. 1 XRD patterns of $Y_{1.5}Bi_1Gd_{0.5}Fe_4Ga_1O_{12}$ garnet film and $Y_{2.7}Bi_{0.3}Fe_{3.8}Ga_{1.2}O_{12}$ garnet film on glass substrates.

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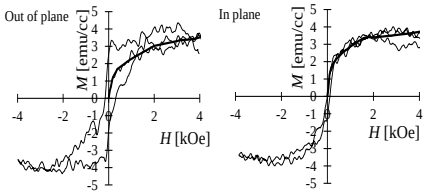
magnetization M_s of the YBi-garnet film is as same as that of the film grown by liquid phase epitaxy (LPE) method [3]. Uniaxial magnetic anisotropy constant K_u was calculated from effective uniaxial magnetic energy K_u^{eff} and demagnetization energy, as shown in Eq. (1).

$$K_u = K_u^{eff} + 2\pi {M_s}^2 \quad (1)$$

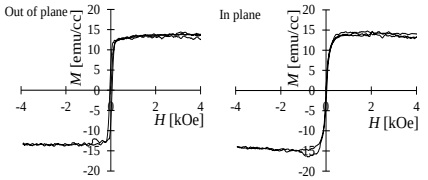
where, K_u^{eff} was calculated by subtraction from magnetizing energy of out-of-plane direction E_{out} to that of in-plane direction E_{in} from Fig. 2. Under the consumption that the K_u is caused by only magnetostriction, magnetostriction coefficient λ_s of the films was calculated by Eq. (2) [4],

$$K_u = -\lambda_s \frac{E_f}{1-\nu_f}[(\alpha_f - \alpha_s)\Delta T] \quad (2)$$

where, E_f is Young's modulus of film, ν_f is Poisson's ratio of film, α_f and α_s are expansion coefficient of the film and substrate, and ΔT is a difference between growth temperature and room temperature. We evaluated λ_s of the films using YIG parameters [4, 5]. Magnetostriction coefficient λ_s of YBi-garnet film was lager in negative direction than YBiGd- garnet film. It is consistent with the report [1] that Magnetostriction coefficient λ_s become larger in positive direction because of substitution of Gd by MOD method. Even though it was expected that Magnetostriction coefficient λ_s of YBiGd-garnet is negative direction, Magnetostriction coefficient λ_s of YBiGd-garnet was positive direction. The difference is caused by calculation method using the initial magnetization curve.



(a) $Y_{1.5}Bi_1Gd_{0.5}Fe_4Ga_1O_{12}$ film



(b) $Y_{2.7}Bi_{0.3}Fe_{3.8}Ga_{1.2}O_{12}$ film

Fig. 2 Magnetic hysteresis curves of (a)$Y_{1.5}Bi_1Gd_{0.5}Fe_4Ga_1O_{12}$ garnet film and (b)$Y_{2.7}Bi_{0.3}Fe_{3.8}Ga_{1.2}O_{12}$ garnet film on glass substrate measured at room temperature by VSM.

Table 1 Magnetic parameters of $Y_{1.5}Bi_1$-$Gd_{0.5}Fe_4Ga_1O_{12}$ and $Y_{2.7}Bi_{0.3}Fe_{3.8}Ga_{1.2}O_{12}$ garnet films

	YBiGd	YBi
M_s [emu/cc]	3.7	13.8
K_u^{eff} [erg/cc]	-0.8×10^3	-0.6×10^3
K_u [erg/cc]	-0.7×10^3	0.6×10^3
λ_s	0.5×10^{-7}	-0.4×10^{-7}

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