Preparation and Characterization of Bi substituted gadolinium iron garnet (Bi:GdIG) on glass substrates by MOD method with GdIG buffer layer

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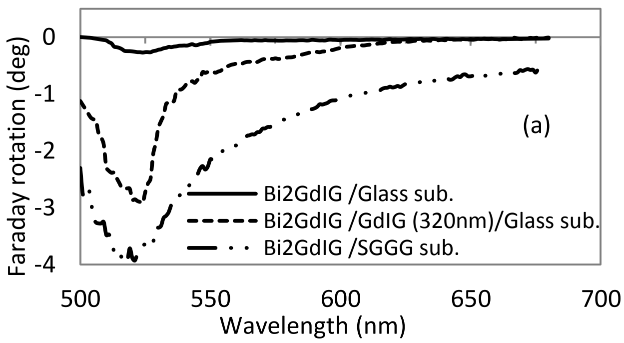
Bi-substituted rare-earth iron garnets (Bi:RIG) have large Faraday rotation (FR) with high transparency in the visible to near infrared region[1], which made them suitable for various applications. Bi:RIG have been used for magneto-optical device elements such as in magnetoplasmonic structure[2], optical isolators[3], circulators[4], and magnet photonic crystals (MPCs) used in magneto-optic spatial light modulators (MOSLMs)[5]. Among them, bismuth substituted gadolinium iron garnet (Bi:GdIG) is one of the ferrimagnetic rate-earth iron garnets showing perpendicular magnetic anisotropy[6]. There are several methods to prepare the Bi:GdIG thin films such as a laser ablation, RF magnetron sputtering. Metal organic decomposition (MOD) method is a promising one to prepare magnetic garnet film, because it is a simple fabrication method which is composed of spin coating of the MOD solution and annealing, and guarantees high uniformity in chemical composition and purity combined with chemical stability[7]. In order to use Bi:GdIG thin films in waveguide optical isolators and MOSLMs, it is required that Bi:GdIG thin films are prepared on glass substrates. However, it is not easy to fabricate Bi:GdIG thin films on glass substrates because of the differences in crystal structure and thermal expansion coefficient between Bi:GdIG and glass substrate.

We fabricated $Bi_2Gd_1Fe_5O_{12}$ (Bi:GdIG) thin films on glass substrates by the MOD method with GdIG buffer layer, and compared the FR and crystalline properties by X-ray diffraction (XRD). We fixed the thickness $d_{\mathrm{Bi:GdIG}}$ and fabrication conditions for Bi:GdIG thin films ($d_{\mathrm{Bi:GdIG}}$ =115 nm, and annealed at 620°C for 2 hours under air at atmospheric pressure). We changed the GdIG buffer layer thickness from 0 to 880 nm, by increasing the spin-coating times of the GdIG layer (0 to 10 times). The GdIG buffer layers were annealed at 650°C for 2 hours. For comparison, we prepared a Bi:GdIG single crystal film on (111) $(GdCa)_3(GaMgZr)_5O_{12}$ (SGGG) single crystal substrate. The film thicknesses of the all the layers were estimated from the measured optical reflectivity spectra. Fig.1(a) shows the FR spectra of the Bi:GdIG thin films with and without GdIG buffer layers on glass substrates, and Bi:GdIG thin film on a SGGG substrate. The Bi:GdIG sample with 320 nm-thick GdIG buffer layer (spin coating time = 4) shows FR of 2.8 deg. at a wavelength λ = 522 nm, which is 10 times larger than FR of the sample without GdIG buffer layer, and 70 % of the FR of the single crystal Bi:GdIG film on SGGG substrate (4 deg.). Fig. 1(b) shows the GdIG buffer layer thickness (spin-coating time) dependence of the maximum FR. Max FR showed maximum at the spin-coating time of 4. When the spin-coating time is 2, the GdIG layer is amorphous, and do not work as the buffer layer. When the spin-coating time are larger than 6, max FR decreased. From XRD characterizations, we found that Gd_2O_3 phase are more dominant than the $Gd_3Fe_5O_{12}$ phase when the spin-coating time is larger than 6, leading to lower FR. In conclusion, we have fabricated $Bi_2Gd_1Fe_5O_{12}$ thin films on glass substrates by the MOD method with the GdIG buffer layer. The optimized film showed 70 % of the FR of the single crystalline $Bi_2Gd_1Fe_5O_{12}$, which is promising for application in optical waveguide devices and MOSLMs.



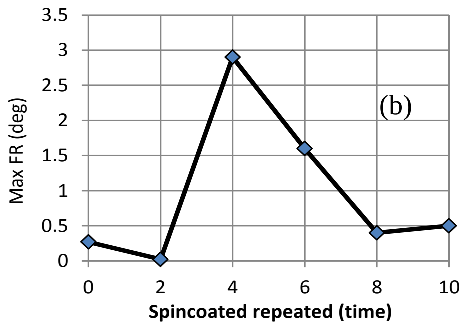


Fig 1 (a) Faraday rotation spectra of Bi:GdIG samples on glass with / without GdIG buffer layer, and (111) SGGG single crystal substrate, (b) Maximum FR of Bi:GdIG on various GdIG buffer layer thicknesses (spin coating times = 0 to 10).

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