Effect of target composition on the barium hexaferrite (0001) thin films

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Barium hexaferrite ($BaFe_{12}O_{19}$; BaM) is a magnetic oxide with the magnetoplumbite structure which has a hexagonal close-packed (hcp) oxygen frame-work structure [1]. In our previous report, the BaM(0001) thin films grown by using stoichiometric ($BaFe_{12}O_{19}$) target shows lower saturation magnetization (M_s)[2]. The reason for lower M_s is due to change in the composition ratio (Ba:Fe) in the deposited thin films. For applied purposes, the high quality thin film growth technique is required to achieve large magnetization comparable to the bulk. Nevertheless to say, fundamental physical properties of a film are strongly dependent on chemical composition if the film is alloy or compound. In the present study, BaM thin films were investigated by changing target composition to observe the effect on the magnetic properties.

The barium hexaferrite (BaM) (0001) epitaxial thin films were deposited on an α-Al_2O_3(0001) substrate by radio frequency (RF) magnetron sputtering. Barium-rich ($BaFe_{10}O_x$) target with a diameter of 68 mm was used. The flow rate of Ar was 10 sccm; total pressure inside the sputtering chamber was maintained at 0.41 Pa. Before the deposition, the substrate was annealed under vacuum at the growth temperature of 800 ℃ for 1 hour. The RF power of the sputtering process was set at 50 W. The BaM(0001) thin films of 23.5, 54.7, 73.6, 104, and 140 nm thicknesses were deposited. The BaM(0001) thin films were post-annealed in the atmosphere at 1000 ℃ for 10 minutes.

Figure 1(a)-(f) Shows typical θ-2θ XRD patterns of a sapphire substrate and BaM thin films of different thicknesses after post-annealing. The dominant reflection peaks are (006), (008) and (0014), which indicate excellent *c*-axis orientation. However, at a higher thickness of 140 nm, BaM thin film shows the additional peaks supposedly assigned as (105), (207), and (315) with very low intensity. It is also found that the value of the lattice parameter *c* of the BaM thin films deviates from its bulk value 23.18 Å [ICDD PDF 01-084-0757] are shown in Fig. 1(g). In all samples of BaM(0001) thin films using the position of (008) bragg peak, the obtained value remains in the range of 23.1 to 23.18 Å. This indicates the crystallites of the thin films are under some strain. The BaM(0001) thin film of thickness 104 nm shows saturation magnetization (out-of-plane) of 379 emu/cm^3, which is comparable to that of the bulk value of M_s = 380 emu/cm^3 [1]. Although the M_s in the case of stoichiometric target thin films remains almost constant (~300 emu/cm^3) for all films [2]. The increased M_s suggest that the strong dependence on the target composition. On the other hand effective uniaxial magnetic anisotropy ($K_u^{eff.}$) shows the similar trend in both cases.

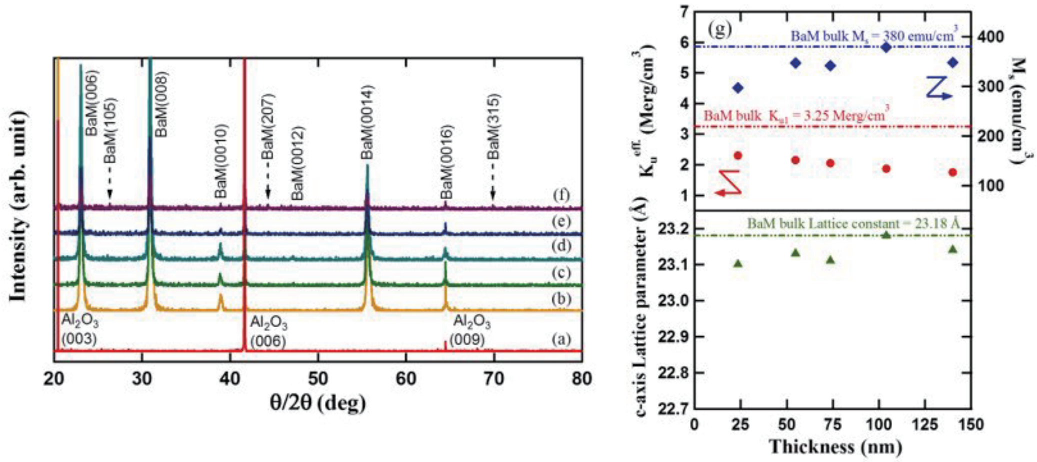

Fig. 1(a) XRD patterns of a sapphire substrate, (b-f) XRD patterns of BaM thin films with thickness of 23.5, 54.7, 73.6, 104 and 140 nm after post-annealing, (g) Plot of saturation magnetization (M_s) (out-of-plane), effective uniaxial anisotropy ($K_u^{eff.}$) and c-axis lattice parameter of BaM(0001) vs different thickness.

Reference
1) B. D. Cullity and C. D. Graham, Introduction to Magnetic Materials (Wiley, New York, 2009).
2) Y. Ikeda et al, The 64rd JSAP Spring Meeting, **14p** (2017) P10-52.