MAGNETIC PROPERTIES OF EPITAXIAL BARIUM HEXAFERRITE (0001) THIN FILMS DEPOSITED BY RADIO FREQUENCY MAGNETRON SPUTTERING

R. PATEL*[1], Y. IKEDA[1], H. ONADA[1], T. TAINOSHO[1], Y. HISAMATSU[1], S. SHARMIN[1], E. KITA[1, 2], and H. YANAGIHARA[1]

1) Division of Applied Physics, Graduate School of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Ibaraki 305-8573, Japan

2) National Institute of Technology Ibaraki College, Hitachinaka, Ibaraki 312-8508, Japan

Barium hexaferrite epitaxial thin films is a potential candidate for microwave devices and data storage application, due to its uniaxial magnetic anisotropy, moderate saturation magnetization, high curie temperature, and low microwave losses [1-5]. Previous studies showed that the barium hexaferrite thick films with buffer layer grown by liquid phase epitaxy, pulsed laser deposition, and radio frequency sputtering methods have the lower saturation magnetization and squareness ratio [5-8]. Therefore, the high quality thin film growth technique to achieve large magnetization comparable to the bulk is required for the above purpose. Thus, the purpose of this research is to understand the effect of thickness and composition on magnetic behavior of the barium hexaferrite (0001) thin films.

The epitaxial growth of barium hexaferrite (0001) thin films was performed with two different target composition (stoichiometric: $BaFe_{12}O_{19}$, and barium rich: $BaFe_{10}O_x$) on an α-Al_2O_3 (0001) substrate via radio frequency (RF) magnetron sputtering. Hereafter, we refer the samples grown with the stoichiometric target as BaM1(0001) and with the Ba-rich target as BaM2(0001). The flow rate of Ar was 10 sccm; total pressure inside the sputtering chamber was maintained at 0.4-0.5 Pa. The RF power of the stoichiometric and barium rich target was set at 100 W and 50 W. The barium hexaferrite (0001) thin films were post annealed in atmosphere at 1000 °C for 10 minute. The BaM1(0001) thin films of 25, 53, 83, 100, and 135 nm thicknesses were deposited, similar thicknesses is also deposited with BaM2(0001) thin films.

The RHEED image after deposition indicates the epitaxial growth of barium hexaferrite thin films. The XRD was used to characterize the structural properties for all samples. The dominant reflection peaks are (006), (008) and (0014), which indicate excellent c-axis orientation. It is found that the value of the lattice constant c of the barium hexaferrite deviates from its bulk value 23.2 Å [ICDD PDF 01-084-0757]. In all samples of BaM1(0001) thin films using the position of (008) bragg peak, the obtained value is lower in the range of 23.0 to 23.1 Å, but in case of BaM2(0001) thin films for all sample, the obtained value range from 23.1 to 23.2 Å. This indicates the crystallites of the thin films are under some strain.

The magnetic properties of BaM1(0001) and BaM2(0001) thin films deposited on α-Al_2O_3 (0001) substrate are shown in fig 1(a-b). The barium hexaferrite (0001) thin films grown under the optimal conditions exhibit magnetic anisotropy with the easy axis of magnetization perpendicular to the films with a high squareness ratio of 0.7. The BaM1(0001) thin film of thickness 101 nm shows saturation magnetization M_s (out-of-plane) of 304 emu/cm^3, while the BaM2(0001) thin film (thickness 104 nm) shows M_s (out-of-plane) of 379 emu/cm^3, which is comparably equal to the bulk value of $BaFe_{12}O_{19}$ (380 emu/cm^3)[2].While the effective uniaxial magnetic anisotropy K_u^{eff} of the BaM1(0001) thin film of 25 nm is $K_u^{eff} = 3.12 \times 10^6$ erg/cm^3. On the other hand, BaM2(0001) thin film of 23.5 nm is $K_u^{eff} = 2.3 \times 10^6$ erg/cm^3. Although the saturation magnetization in case of BaM1(0001) thin films is almost constant for all film thickness, the magnetic anisotropy constant decreases with increasing film thickness and becomes almost constant over 100 nm. But in case of BaM2(0001) thin films, the saturation magnetization get closer to the bulk value with increasing the film thickness.

Rutherford backscattered spectroscopy (RBS) was performed to evaluate the composition of the BaM1(0001) thin film of 100 nm. The experimentally obtained ratio of BaM1(0001) thin film is off-

s1530111@u.tsukuba.ac.jp

stoichiometric Ba:Fe = 1:9, suggesting that some defects exists in the obtained hexaferrite films. The crystal structure of barium hexaferrite is close-packed layers form with four fundamental blocks, S, S*, R and R*, among which the S* and R* blocks can be obtained simply through the rotation of the S, and R blocks respectively, by 180° with respect to the c axis. A pair of S and R or S* and R* conserves charge neutrality and Ba ions occupies in R (or R*) block. Therefore, an off-stoichiometric M-type hexaferrite may involve the other oxide block such as T-block. The estimated T-block is about 23%, which affects neither magnetization nor magnetic anisotropy. The rest of S R S* R* block influence the M_S and $\boldsymbol{K_u^{eff}}$, which is 292 emu/cm^3 and 2.46 Merg/cm^3 and it is close to the experimental value. Therefore, such reduction of M_s and $\boldsymbol{K_u^{eff}}$ in BaM1(0001) thin films could be explained by an existence of T-block.

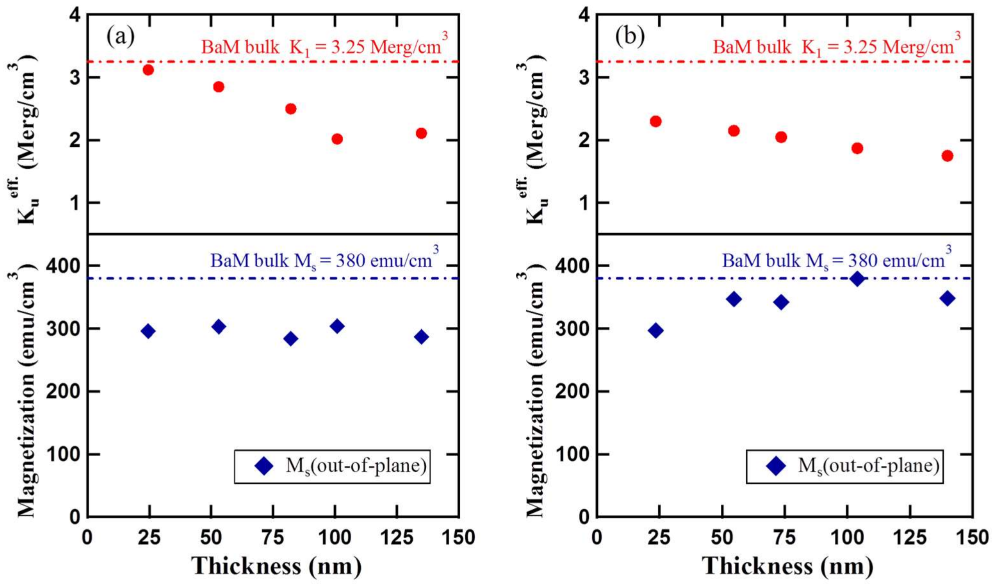

Fig. 1(a-b) Plot of saturation magnetization (out-of-plane) and effective uniaxial magnetic anisotropy (K_u^{eff}) of BaM1(0001) and BaM2(0001) thin films vs different thicknesses.

References

1. B. T. Shirk, W. R. Buessem, Temperature dependence of M_S and K_1 of $BaFe_{12}O_{19}$ and $SrFe_{12}O_{19}$ single crystals, J. Appl. Phys. 40, 3 (1969).
2. R. O. Handley, Modern Magnetic Materials (Wiley, New York, 2000).
3. L. Zhang, X. D. Su, Y. Chen, Q. F. Li, and V. G. Harris, Radio-frequency magnetron sputter-deposited barium hexa-ferrite films on Pt-coated Si substrates suitable for microwave applications, Scripta Mater. 63, 492–495 (2010).
4. R. D. Weir, Carl W. Nelson, Vertical-Magnetic-Recording medium with barium ferrite magnetic layer, United States Patent 6110557, 29 (2000).
5. S. D. Yoon and C. Vittoria, Thick M-type barium hexaferrite films grown on garnet substrates, J. Appl. Phys., 96, 4 (2004).
6. X. H. Liu, M. H. Hong ,W. D. Song , G. X. Chen, H. M. J. Lam, J. P. Wang, T. C. Chong, Barium ferrite ($BaFe_{12}O_{19}$) thin films prepared by pulsed laser deposition on MgO buffered Si substrates, Appl. Phys. A 80, 611–614 (2005).
7. H. Xu, W. Zhang, B. Peng, W. Zhang, Properties of barium hexa-ferrite thin films dependent on sputtering pressure, Appl. Surf. Sci. 257, 2689–2693 (2011).
8. Z. Chen, A. Yang, K. Mahalingam, K. L. Averett, J. Gao, G. J. Brown, C. Vittoria, and V. G. Harris, Structure, magnetic, and microwave properties of thick Ba-hexaferrite films epitaxially grown on GaN/Al2O3 substrates, Appl. Phys. Lett. 96, 242502 (2010).