LARGE NEGATIVE UNIAXIAL MAGNETIC ANISOTROPY OF COBALT FERRITE THIN FILMS

T. TAINOSHO, J. INOUE, S. SHARMIN, and H. YANAGIHARA
Univ. of Tsukuba, Tsukuba, Japan, s1630108@u.tsukuba.ac.jp

I. INTRODUCTION

Cobalt ferrite (CFO) is known as a magnetic material that possess large magneto-elastic coupling and therefore, uniaxial magnetic anisotropy can be introduced in a form of epitaxial films through magnetoelastic effect. Indeed, a CFO thin film on MgO(001) substrate showed extremely large uniaxial magnetic anisotropy energy K_u ($\simeq$ 1.4 MJ/m^3) [1]. In the phenomenological understanding of magnetoelastic effect, K_u is simply proportional to strain tensor. However, the linear relationship must be failed if the strain is large enough. In fact, from the view point of the recent electron theory [2], K_u seems to be saturated at highly distorted regime. At this moment, applicability of the phenomenological model regarding large strain is not clear for CFO. In this study, we investigated K_u of epitaxial CFO thin films with large distortion and compared it to the electron theory.

II. EXPERIMENT

CFO thin films (thickness :12.9 ~ 81.6 nm) were deposited on $MgAl_2O_4$(001) substrates by a reactive RF magnetron sputtering technique. The substrates were annealed at 773 K in a vacuum chamber. FeCo (3:1 atm ratio) was used as a sputtering target. Ar and O_2 mixed gas was flown as process gas at a rate of 30.0 sccm (~0.5 Pa) and 6.0 sccm (~0.1 Pa), respectively. The substrates were kept at 773 K and being rotated during the deposition. To change the amount of strain, several CFO thin films with different thickness (12.9 ~ 81.6 nm) were prepared. The surface structure of the films was characterized by reflection high-energy electron diffraction (RHEED). X-ray diffraction measurements were performed to examine both in-plane and out-of-plane lattice constants (*a* and *c*). MH-curves and magneto-torque curves were measured at 300 K.

III. RESULTS AND DISCUSSION

The RHEED pattern showed streaks typical for spinel structure suggesting an epitaxial growth of CFO. From Bragg positions of CFO(800) and (004) by XRD measurements, the in-plane and out-of-plane lattice constants were estimated to be 0.821 ~ 0.831 nm and 0.845 ~ 0.855 nm , respectively. In-plane MH-curves showed saturation magnetization comparable to that of a bulk. On the other hand, we could not saturate out-of-plane MH-curves due to its large anisotropy field. We measured torque curves to evaluate K_u, and saw-tooth-like curves (figure 1) were observed, indicating large magnetic anisotropy field exists. K_u was estimated to be -5.8 ~ -3.1 MJ/m^3 by Miyajima analysis. Figure 2 shows K_u vs χ ($\equiv c/a$ -1) plots. The linear relation between K_u and χ was confirmed despite the large strain. Assuming that the data plot passes through an origin, the magnetoelastic coefficient B_1 was estimated to be $0.131(\pm 0.019)$ GJ/m^3. This value is consistent to the bulk value (0.14 GJ/m^3) calculated from the elastic moduli C_{11} = 273 GPa, C_{12} =106 GPa, and magnetostiction constant λ_{100} = -590. We have succeeded in demonstrating that the phenomenological model of magnetoelastic theory for CFO is obviously valid for the strain of $\chi \simeq 0.04$, at least.

Takeshi Tainosho
E-mail: s1630108@u.tsukuba.ac.jp
tel: +81-29-853-5243

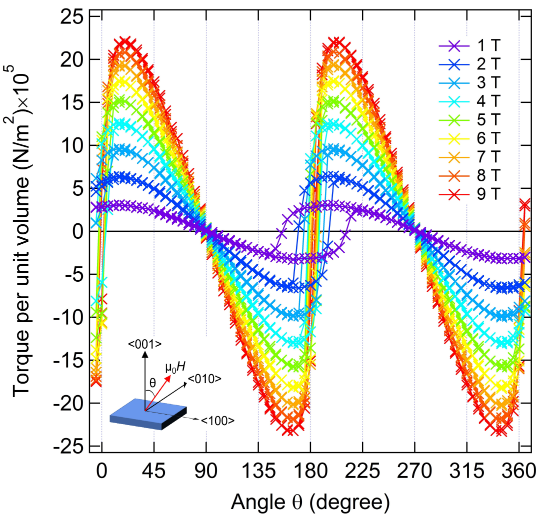

Fig.1 The torque curve of CFO (45 nm)/MAO. θ represents the angle between magnetic field vector and <001> direction of the film.

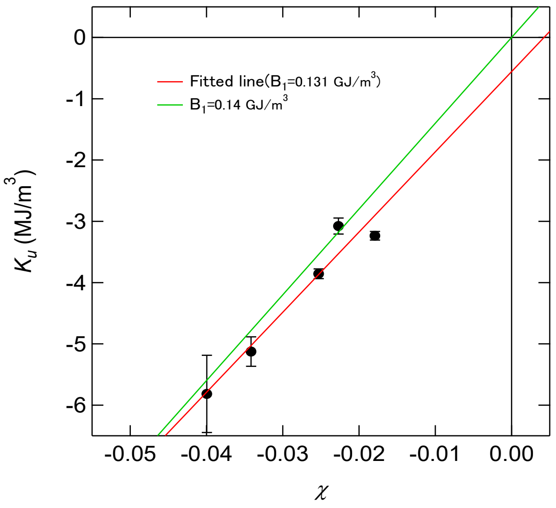

Fig.2 K_u vs χ plots. The fitting line is drawn by red one, and the green line indicates simple product $B_1\chi$ as B_1 = 0.14 GJ/m^3.

REFERENCES

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