Layer thickness and underlayer dependence of perpendicular magnetic anisotropy in Cu_2Sb-type (Mn-Cr)AlGe films

IMR, Tohoku Univ. [1], CSRN, Tohoku Univ. [2], JST-CREST [3], CSIS, Tohoku Univ. [4],

°Takahide Kubota[1,2], Keita Ito[1,2], Rie Y. Umetsu[1,2,4], Masaki Mizuguchi[1,2,3,*], Koki Takanashi[1,2,4]

E-mail: takahide.kubota@tohoku.ac.jp

The Cu_2Sb-type MnAlGe and (Mn-Cr)AlGe are materials showing uniaxial magnetocrystalline anisotropy and relatively small saturation magnetization, M_s, (~ 300 emu/cm^3) [1,2], which are attractive for application of the current induced magnetization switching phenomena. Previously we reported magnetic properties of (001)-textured MnAlGe and (Mn-Cr)AlGe films showing perpendicular magnetization fabricated onto thermally oxidized silicon (Si, SiO_2) substrates for a layer thickness of 100 nm [3]. Although the compatibility with silicon substrates and the relatively large perpendicular magnetic anisotropy energy, K_u are attractive, the reduction of layer thickness is necessary for application. Thus, in this work, the layer thickness dependence of perpendicular magnetic anisotropy was investigated.

The samples were fabricated using a magnetron sputtering machine. The stacking structure was as follows: Si, SiO_2 sub. | underlayers | MnAlGe or (Mn-Cr)AlGe t | MgO 1.5 nm | Ta 5 nm, where t is the layer thickness changing from 5 to 30 nm. For the underlayers, "no underlayer" or Ta 5 nm | CoFeBTa 1 nm | MgO 1.5 nm was used, for which SiO_2 of the substrate and the MgO layer acted as templates, respectively. The samples were annealed using a vacuum furnace. The annealing temperature was changed from 300 – 500 °C. The K_u and magnetic dead layer thickness, t_{dead}, are summarized for optimum annealing temperatures which are 300 °C for MnAlGe films with the MgO template, and 400 °C for MnAlGe with the SiO_2 template and (Mn-Cr)AlGe films with the MgO templates. The t_{dead} was 1.7 nm for the MnAlGe films onto the SiO_2 template, while those for the MgO template films were approximately twice larger. From cross-sectional transmission electron microscope images, the oxidization of the (Mn-Cr)AlGe layer was found at the MgO interfaces, which was an origin for the magnetic dead layer. The values of K_u in 10-nm-thick samples are of the same order as those reported for the 100-nm-thick film samples in ref. [3], while the K_u decreased for the 5-nm-thick samples. Details will be discussed in the presentation including other annealing temperatures and as-deposited samples.

Table I Summary of K_u and t_{dead} for the samples with optimum annealing temperatures.

Material	Template	t_{dead} (nm)	K_u (10^6 erg/cm^3)	
			t: 5 nm	t: 10 nm
MnAlGe	SiO_2	1.7	1.1	2.8
MnAlGe	MgO	2.9	2.1	3.2
(Mn-Cr)AlGe	MgO	3.5	1.4	5.8

[1] K. Shibata *et al.*, JPSJ **35**, 448 (1973).

[2] T. Kubota *et al.*, APEX **12**, 103002 (2019).

* Presently at Graduate School of Engineering, Nagoya Univ., and JST-CREST.