Optimization of Fabrication Temperature to Obtain L1_0-Ordered MnAl Thin Films with High Perpendicular Magnetic Anisotropy and Small Roughness

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Magnetic tunnel junction with perpendicularly magnetized ferromagnetic materials (*p*-MTJs) has great potential to realize the ultra-high-density STT–MRAM. The switching current density (J_{co}) in STT-MRAM is directly related to saturation magnetization (M_s) and Gilbert damping constant (α) of the ferromagnetic free layer of MTJs [1]. In order to achieve high thermal stability and low switching current density in *p*-MTJs, ferromagnetic materials with large perpendicular magnetic anisotropy energy (K_u), small M_s and low α are required. Here, we focus on a $L1_0$-MnAl alloy, which exhibits small M_s and high K_u [2,3]. In our previous works, we obtained large K_u in $L1_0$-MnAl films prepared at high substrate temperature [4]. However, high substrate temperature can cause increasing roughness of the films and atomic diffusion between the MnAl films and their buffer layers. In this work, we systematically investigated substrate and annealing temperature dependences of structural and magnetic properties in the MnAl thin films to achieve both high K_u and small surface roughness.

The film stacking structure was MgO(001)-sub./CrRu(40)/Mn-Al(50)/Ta(5)(in nm). All the films were prepared by a magnetron sputtering system. The Mn-Al alloy target composition was $Mn_{46}Al_{54}$.The substrate temperature (T_s) during deposition was varied from 200°C to 400°C and the post-annealing temperature (T_a) was varied from 200°C to 500°C. The crystal structure of MnAl(50nm) films was investigated by an X-ray diffraction (XRD). The magnetic properties and surface morphology of the films were measured by vibrating sample magnetometer (VSM) , superconductive quantum interference device (SQUID) and atomic force microscopy (AFM).

We confirmed that CrRu buffer layers had good structural property and very smooth surface morphology after annealing at 650°C. In the XRD patterns, (001) and (002) peaks of $L1_0$-MnAl were observed.The result indicates that both $L1_0$-ordered and (001)-oriented MnAl films were successfully fabricated. The peak intensity of $L1_0$-MnAl was improved with increasing both substrate and annealing temperature. However, surface roughness drastically increased above T_s=300°C.We systematically investigated annealing temperature dependence of magnetic properties in MnAl films prepared with T_s = 250°C. As a result, K_u showed a maximum at T_a = 350°C as shown in Fig. 1, and finally obtained a $L1_0$-ordered MnAl film with high K_u of 13.0 Merg/cc, relatively low M_s of 497 emu/cc and small roughness (R_a) of 0.3 nm in the condition of T_s= 250°C and T_a =350°C. The optimized MnAl film will be greatly useful to realize the high-density STT-MRAM.

This work was part of a research and development project for ICT key technology to realize future societies supported by MEXT, the Center for Spintronics Research Network (CSRN).

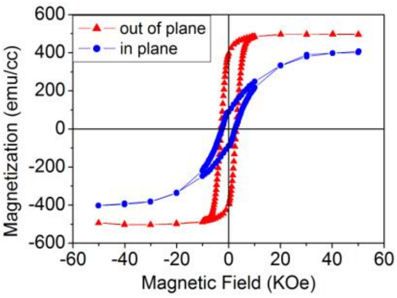

Fig. 1 MH curves in MnAl films with T_s=250°C and T_a=350°C

References

[1] J. C. Slonczewski, J. Magn. Magn.Mater.**159**, L1 (1996)
[2] A. Sakuma, J. Phys. Soc. Jpn., 63, 1422 (1994).
[3] J. H. Park*et al.*, J. Appl. Phys., 107, 09A731 (2010).
[4]M.Oogane, K. Watanabe *et al.*, Jpn. J. App. Phys., **56**, 0802A2(2017)