Perpendicularly magnetized $L1_0$-MnAl thin films for STT-MRAM

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A spin transfer torque type magnetic random access memory (STT-MRAM) has attracted considerable interest. Magnetic tunnel junctions (MTJs) using perpendicularly magnetized materials have great potential, which can developultra-high–density STT–MRAM. Switching current density (J_{c0}) 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, $L1_0$-MnAl is a promising candidate of perpendicularly magnetized materials which satisfies the requirements for STT-MRAM [2]. However, its magnetic properties are sensitive to its crystalline structure, that is, $L1_0$ order is necessary to obtain high K_u. In our previous works, it is expected the crystalline structure was improved by adding Co into MnAl [3]. In this work, we fabricated MnAl and $(Mn_{1-x}Co_x)_{0.5}Al_{0.5}$ films on MgO single crystal substrate having a high K_u, small M_s and α.

The film stacking structure was MgO(001)-sub./CrRu(40)/$(Mn_{1-X}Co_X)_{0.5}Al_{0.5}$(*d*), Mn-Al(*d*)/Ta(5)(in nm). All the films were prepared by a magnetron sputtering system. 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 400°C. The crystal structure of $(Mn_{1-x}Co_x)_{0.5}Al_{0.5}$ films were investigated by an X-ray diffraction (XRD). The magnetic properties and surface morphology of the films were measured by super-conductivity quantum interference device (SQUID), vibrating sample magnetometer (VSM) and atomic force microscope (AFM).

After the deposition of CrRu buffer layers, films were annealed at 650°C. A good structural property and very smooth surface morphology were exhibited. (001) and (002) peaks in XRD patterns for MnAl (50nm) films were observed at T_s = 350°C. The peak intensities of MnAl were improved with increasing post annealing temperature. Both $L1_0$-ordered and highly (001)-oriented MnAl films were successfully fabricated. Magnetization curves are shown in Fig. 1.Bold line indicates the perpendicular and thin line indicates the in plane magnetic field directions. The value of K_u for MnAl film was 1.2×10^7 erg/cc, small saturation magnetization, M_s of 518 emu/cc were observed at substrate temperature of 350°C .

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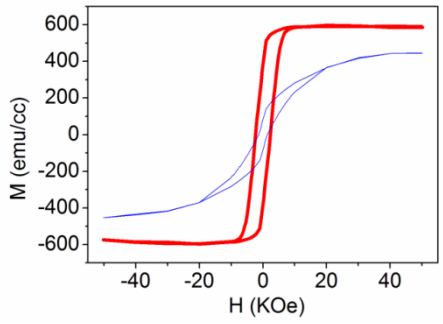

Fig. 1 The *M-H* curve for MnAl with T_s = 350°C.Bold and thin lines indicate perpendicular and in-plane directions of magnetic field.