THE EFFECT OF TIO_2 VOLUME FRACTION ON THE MICROSTRUCTURE AND MAGNETIC PROPERTIES OF MnAl THIN FILM

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Abstract - The effect of TiO_2 doping on MnAl films are systematically studied. The MnAl:TiO_2 thin films were prepared by co-sputtering using MnAl and TiO_2 target at a growth temperature of 300°C. DC sputtering was used for MnAl while RF sputtering was used for the case of TiO_2.The magnetic and structural properties of MnAl:TiO_2 films were also studied. The incorporation of TiO_2 into MnAl have significant change on the structure and magnetic properties of MnAl films. With the incorporation of above 7.5% TiO_2, the □-phase is completely destroyed. The perpendicular coercivity of MnAl:TiO_2 films was found to change with TiO_2 content, and obtained maximum at 5%. The change in roughness of MnAl:TiO_2 films were also observed. The roughness of MnAl:TiO_2 thin films increases with the incorporation of the TiO_2 and then decreases with the increase of TiO_2 content.

Keywords - Epitaxial growth, buffer layer, □-phase, magnetic anisotropy constant.

I. INTRODUCTION

Ferromagnetic material of L10 class are attractive for its potential applications in spintronic devices such as spin-RAM, high power oscillator, spin light-emitting diodes, spin field-effect transistors etc. [1-4]. Millimeter waves are recently detected in perpendicular magneto tunnel junction (MTJ) using L10 materials [5]. Low damping constant is also reported in perpendicularly magnetized L10 class material [6-7]. Therefore, the utility of perpendicular MTJ of L10 class material is promising in future anticipated spin RAM and STT-RAM devices. Among the various L10materials, MnAl have a great potential in showing a high performance in STT-MRAMs because of their high perpendicular magnetic anisotropy (Ku), small magnetic damping constant (α), and small magnetization (Ms). [8] Doping oxides or other material into L10 class material might change the ordering kinetics and magnetic properties [9]. The effect of doping of TiO2 on the microstructure and magnetic properties of L10 CoPt and FePt films is reported [10, 11]. In those cases, the doping of TiO_2 plays an important role in controlling the microstructure to achieve well isolated smaller grain size and magnetic properties of the films. In the literature, there are very few reports of microstructure of the MnAl film with the doping of TiO_2. Therefore, the study of magnetic and structural properties of MnAl:TiO_2 films are investigated with the variation of TiO_2 content.

II. EXPERIMENTAL

The MnAl:TiO_2 were prepared by co-sputtering of MnAl and TiO_2 target. The Ar pressure during deposition was 0.2 Pa. DC sputtering was used for MnAl while RF sputtering was used for the case of TiO_2. The films were deposited on 50 nm CrRu buffered MgO(100) substrate. The growth temperature was kept constant at T_S=300°C while the volume fraction of TiO_2 was controlled by changing the RF power. The volume of MnAl was kept constant in order to compare the magnetic properties. Finally, 4 nm Ta layer was deposited in order to avoid oxidation. The substrates were cleaned by acetone, ethyl alcohol and deionized water. It was noted that the substrate was flushed at 500□C to clean the surface before deposition. Magnetic measurements were done using VSM. The structure of the films was studied by a Bruker X-ray Diffractometer. The surface morphology was studied by atomic force microscopy (AFM).

III. RESULTS AND DISCUSSION

The out-of-plane and in-plane M-H loop measured by VSM is shown in fig. 1. It is observed that there is a significant change in hystereis loop with the doping of TiO_2. The loop illustrates that with the increase of TiO_2 content the magnetization gradually decreases, while the out-of-plane coercivity (H_C perpendicular) increases and then decreases (as shown in fig. 2). On the other hand there is no significant change in the in-plane coercivity.

The maximum out-of-plane coercivity is obtained about 5kOe at 5% TiO_2 content. To understand the coercivity mechanism of the MnAl:TiO_2 films, the angle dependence of the coercivity of the samples measured at various angles from the out-of-plane to in-plane (90°) as shown in fig. 3. The TiO_2 doped MnAl shows faster decrement of the coercivity than MnAl films. This might be due to some decoupled grains with the doping of TiO_2 content. This result is similar to the case FePt:TiO_2 as reported earlier [9].

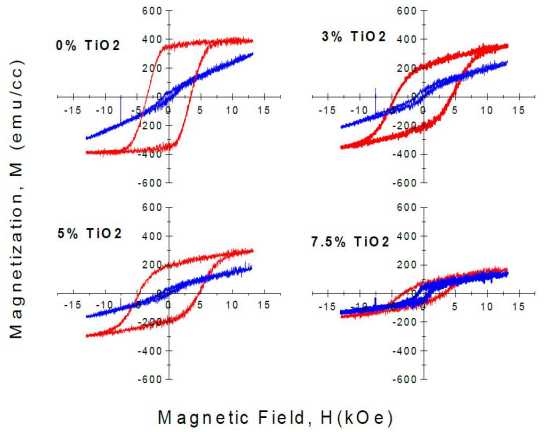


Fig. 1 The out-of-plane (red) and in-plane (blue) M-H loop of MnAl:TiO_2 films with the various contents of TiO_2.

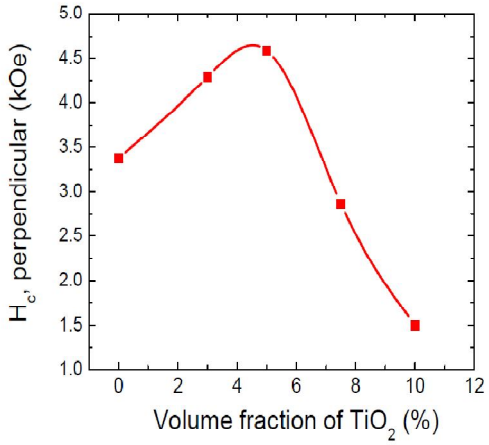


Fig. 2 The variation of perpendicular coercivity, H_C, perpendicular (kOe) with the volume fraction of TiO_2 content.

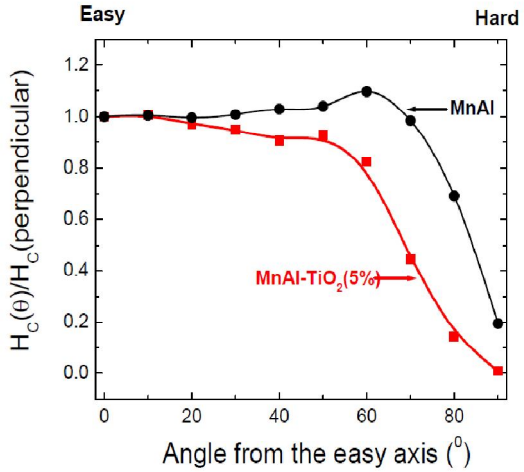


Fig. 3 Angular dependence of H_C (□)/H_C (perpendicular) of MnAl and MnAl:TiO_2 film.

Fig. 4 shows the XRD spectra of MnAl:TiO_2 films with the variation of TiO_2 content. In all cases, the CrRu (200) peaks are observed around 64°. At 0% TiO_2, the MnAl peaks are observed at around 24° and 52°. These peaks are attributed to (001) and (002). This indicates the epitaxial growth and the presence of □-phase of MnAl. With the increase of TiO_2 content, the peak intensity of (001) decreased. At above 7.5% TiO_2 content, the (001) peaks are disappeared. This suggests that the increase of TiO_2 content destroys the □-phase of MnAl films. With the increase of TiO_2 content, the magnetization decreases. Thus, the magnetic properties are consistent with the XRD results.

Fig. 4 The scan of the XRD diffraction pattern of MnAl films doped with the various TiO_2 content.

The surface morphology of MnAl film with various TiO_2 content were studied and the results are depicted in the figure below (fig.5).

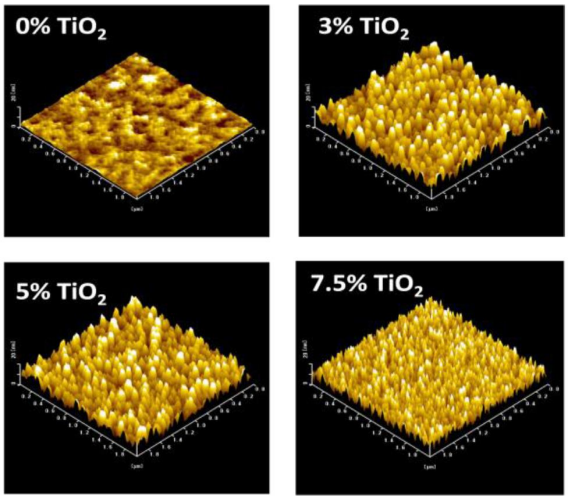


Fig. 5 The AFM image of MnAl:TiO2 films with various concentration.

It is observed that the surface roughness increases with the addition of TiO_2 and then decreases. The maximum surface roughness is about 3 nm at 3% TiO_2 content.

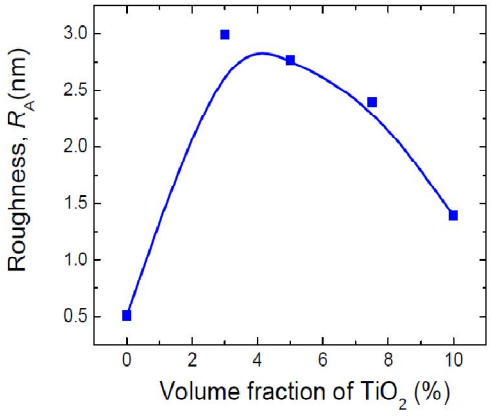


Fig. 6 The variation of surface roughness, R_A(nm) of MnAl:TiO_2 with volume fraction of TiO_2 content.

CONCLUSIONS

The magnetic and structural properties of MnAl:TiO_2 films of various TiO_2 content are studied. With the incorporation of TiO_2, the MnAl peaks are degraded and above 7.5% TiO_2 content the MnAl peak are disappeared. This result indicates the destruction of τ-phase of MnAl films with TiO_2 content. This is consistent with the decrement in saturation magnetization. The doping of TiO_2 might affect the grain size to decrease which causes to increase in out-of-plane coercivity, (H_C perpendicular). The maximum H_C perpendicular is obtained at about 5% TiO_2 content. The saturation magnetization is about 250 emu/cc at this content. The surface roughness of MnAl:TiO_2 films is found to increase with the addition of TiO_2. However, with the increase of more TiO_2, the surface roughness gradually decreases. Therefore, the effect of doping TiO_2 into MnAl films on the structure and magnetic properties are systematically studied. The study is very important for the possibility of MnAl:TiO_2 films for the applications point of view.

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