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Microstructure and magnetic properties of nanocomposite FePt/MgO and FePt/Ag films

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Abstract

An in-plane magnetic anisotropy of FePt film is obtained in the MgO 5 nm/FePt *t* nm/MgO 5 nm films (where $t = 5$, 10 and 20 nm). Both the in-plane coercivity ($H_{c\parallel}$) and the perpendicular magnetic anisotropy of FePt films are increased when introducing an Ag-capped layer instead of MgO-capped layer. An in-plane coercivity is 3154 Oe for the MgO 5 nm/FePt 10 nm/MgO 5 nm film, and it can be increased to 4846 Oe as a 5 nm Ag-capped layer instead of MgO-capped layer. The transmission electron microscopy (TEM)-energy disperse spectrum (EDS) analysis shows that the Ag mainly distributed at the grain boundary of FePt, that leads the increase of the grain boundary energy, which will enhance coercivity and perpendicular magnetic anisotropy of FePt film.

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Keywords: FePt/MgO films; FePt/Ag films; Coercivity; Perpendicular magnetic anisotropy

Practically, for further enhancement in the areal recording density of the magnetic recording media, the grain size of the films has to be reduced further. Face-centered-tetragonal (FCT) $L1_0$ ordered FePt nanograins film has attracted much attention for next generation high-density magnetic recording medium, because it has high magneto-crystalline anisotropy of about 7×10^7 erg/cm^3, which can overcome thermal instability even the $L1_0$ FePt grains down to about 3 nm [1]. However, FePt is not a viable magnetic recording material, owing to its $L1_0$ FePt phase develops at a higher temperature around 600 °C [2,3], which results in the grain growth. It is very important to reduce ordering temperature and to accelerate ordering process of $L1_0$ FePt phase for successful industrial application.

The element Cu can decrease ordering temperature of $L1_0$ FePt, but it will enlarge the grain size [4]. On the other hand, although the grain size of $L1_0$ FePt can be reduced by adding the AlN [5] and Ag [6] into the FePt film, the ordering temperature will be increased due to the decrease in the diffusivities of Fe and Pt atoms in the composite films. Several works on the lowering of ordering temperature and the enhancement of coercivity of FePt films were achieved by adding underlayer or capped layer to the FePt films, e.g., introducing an Ag [7], Cu [8] or Ti [9] underlayer as well as an Ag [10] or Au [11] capped layer to the FePt film.

In this study, the effects of MgO- and Ag-capped layer on the microstructures, coercivities, and magnetic anisotropy of the FePt film are investigated.

The MgO underlayer with 5 nm thickness is deposited onto naturally oxidized Si (1 0 0) substrates. The FePt magnetic layer with thickness in the range of 5–20 nm and a MgO-capped layer or an Ag-capped layer of 5 nm thickness are deposited subsequently onto the MgO underlayer. Both MgO underlayer and MgO-capped layer are sputtered at ambient temperature by RF magnetron sputtering under an Ar pressure of 10 mTorr and a sputtering power of 100 W. The as-deposited MgO/FePt/MgO and MgO/FePt/Ag films are annealed at 600 °C for 30 min in vacuum which is higher than 5×10^{-7} Torr. The composition of the FePt film determined by X-ray energy disperse spectrum (EDS) is $Fe_{50.2}Pt_{49.8}$.

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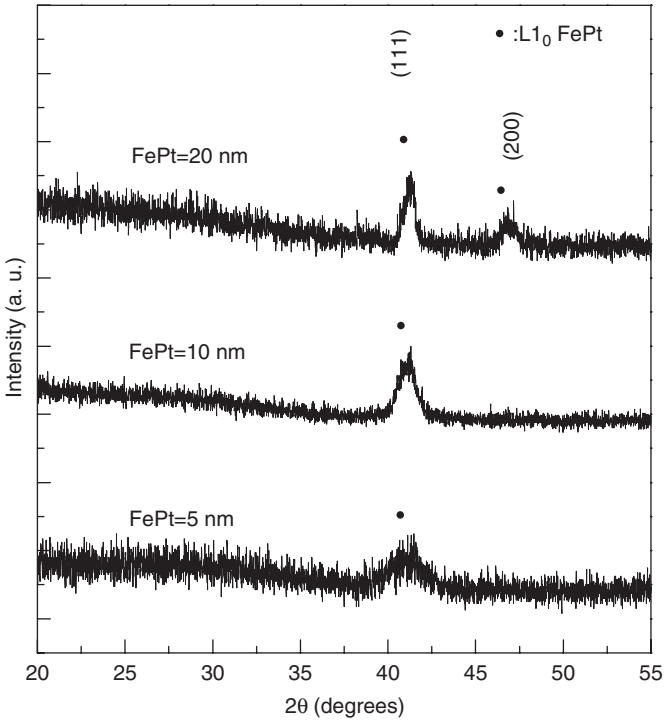

Fig. 1. X-ray diffraction patterns of various MgO 5 nm/FePt t nm/MgO 5 nm multilayer films after annealing at 600 °C for 30 min.

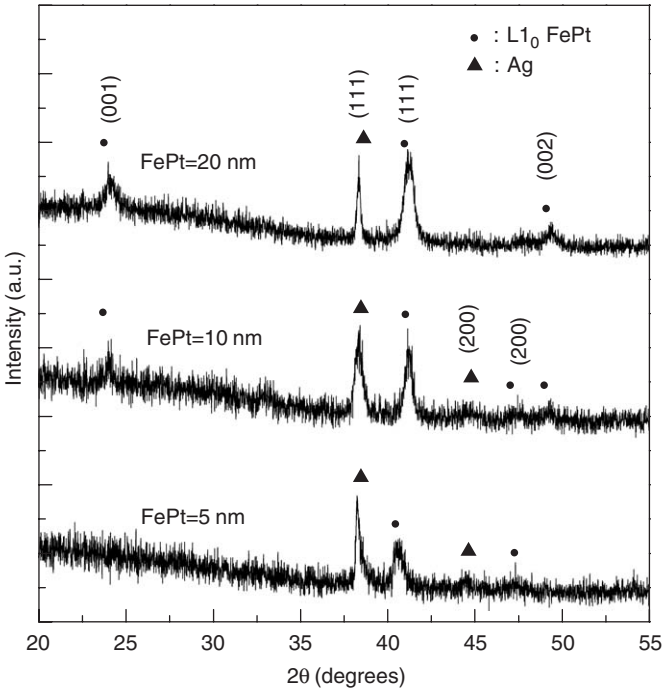

Fig. 2. X-ray diffraction patterns of various MgO 5 nm/FePt tnm/Ag 5 nm multilayer films after annealing at 600 °C for 30 min.

The microstructures of the films are investigated by a Philips Tecnai F30 field emission gun (FEG) transmission electron microscopy (TEM) and X-ray diffractometer (XRD) with Cu-K_α radiation. Compositions of the films are determined by EDS and the depth profiles of elements in the film are analyzed by Auger electron spectroscopy (AES). The magnetic properties of the films are measured using a vibrating sample magnetometer (VSM) at room temperature.

Fig. 1 shows the X-ray diffraction patterns of various MgO 5 nm/FePt t nm/MgO 5 nm multilayer films (where $t = 5$, 10 and 20 nm) after annealing at 600 °C for 30 min. When the thickness of FePt magnetic layer is 5 nm, a weak and broad $(1\,1\,1)_{FePt}$ peak can be observed. This implies that only a few and very small FePt grains exist in this FePt layer. As the magnetic layer thickness is increased to 10 nm, the $(1\,1\,1)_{FePt}$ peak intensity is enhanced but the peak width is decreased, which indicate an enhancement in the $(1\,1\,1)_{FePt}$ preferred orientation and the increase in the grain size of FePt film. As the thickness of FePt layer is further increased to 20 nm, the width of $(1\,1\,1)_{FePt}$ peak is further decreased and $(200)_{FePt}$ peaks appeared, which reveals the grain size of FePt is further increased and the in-plane magnetic anisotropy of the FePt films is enhanced because the easy crystal axis of $L1_0$ FePt is [0 0 1].

Fig. 2 shows the X-ray diffraction patterns of various MgO 5 nm/FePt t nm/Ag 5 nm multilayer films (where $t = 5$, 10 and 20 nm) after annealing at 600 °C for 30 min. Comparing with Fig. 1, the $(1\,1\,1)_{FePt}$ peak intensity is greatly enhanced and the $(0\,0\,1)_{FePt}$ and $(0\,0\,2)_{FePt}$ peaks of the FePt films can be clearly observed as the FePt layer thickness is larger than 5 nm, indicating that the Ag instead of MgO-capped layer will enhance perpendicular magnetic anisotropy of the FePt film.

Fig. 3 shows the M–H loops of (a) MgO 5 nm/FePt 10 nm/MgO 5 nm, and (b)MgO 5 nm/FePt 10 nm/Ag 5 nm films after annealing at 600 °C for 30 min. It is found that both the in-plane coercivity and perpendicular magnetic anisotropy of FePt films are enhanced by introducing an Ag instead of a MgO-capped layer, which is consistent with the observation of XRD. The in-plane coercivity is 3154 Oe for the MgO-capped layer films, but it is increased to 4846 Oe for the Ag-capped layer films. These results may be due to the diffusion of Mg and O atoms into FePt layer through FePt grain boundary and react with Fe or Pt atoms, that leads to decrease the coercivity for the MgO-capped layer films. On the other hand, although the Ag atoms can also diffuse into FePt layer for the Ag-capped layer films, Ag is immiscible with either Fe or Pt atoms. TEM-EDS analysis confirms that the Ag mainly distributed at grain boundary of FePt [12], and results in the increase of the grain boundary energy, and threrfore enhance the coercivity and increase perpendicular magnetic anisotropy of the FePt film.

Both the $H_{c\|}$ value and perpendicular magnetic anisotropy of FePt films are enhanced by introducing an Ag instead of a MgO-capped layer. The $H_{c\|}$ value of the MgO 5 nm/FePt 10 nm/MgO 5 nm films is 3154 Oe and it is increased to 4846 Oe for the MgO 5 nm/FePt 10 nm/Ag 5 nm films. The Ag mainly distributed at grain boundary of FePt, which leads to the increase of grain boundary energy,

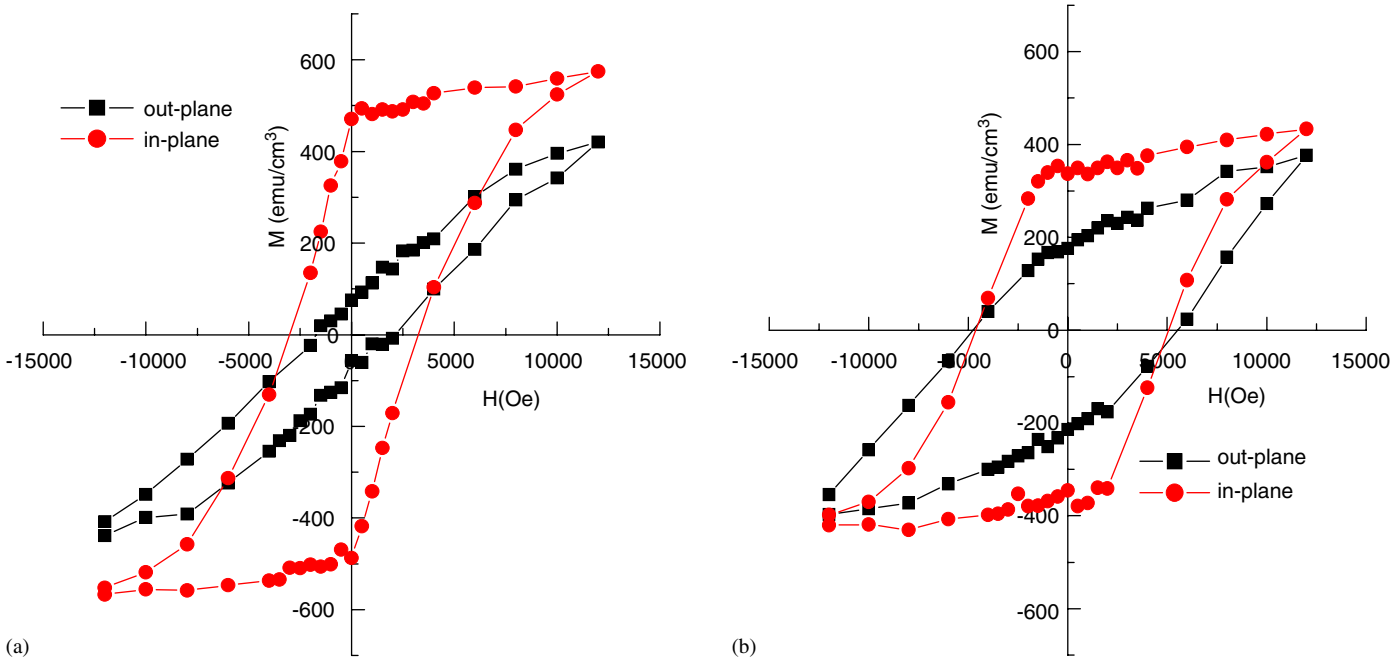

Fig. 3. *M–H* loops of (a) MgO 5 nm/FePt 10 nm/MgO 5 nm, and (b)MgO 5 nm/FePt 10 nm/Ag 5 nm films.

therefore, enhances coercivity and increase the perpendicular magnetic anisotropy of FePt film.

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