Applied Surface Science 258 (2012) 8124–8127

Contents lists available at SciVerse ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Magnetic properties and magnetization reversal process of $L1_0$ FePt/Fe bilayers magnetic thin films

Liwang Liu[a], Wei Sheng[a], Jianmin Bai[a], Jiangwei Cao[a,*], Yuanfu Lou[a], Ying Wang[a], Fulin Wei[a], Jia Lu[b]

[a] *Key Laboratory for Magnetism and Magnetic Materials of the Ministry of Education, Lanzhou University, Lanzhou 730000, PR China*
[b] *Center for Geo-environment Science, Faculty of Engineering and Resource Science, Akita University, Akita 010-8502, Japan*

ARTICLE INFO

Article history:
Received 19 February 2012
Received in revised form 27 April 2012
Accepted 1 May 2012
Available online 9 May 2012

Keywords:
FePt
Coercivity
Exchange interaction
Magnetic domain

ABSTRACT

The $L1_0$ FePt (10 nm)/Fe (δ nm, δ = 0–15) bilayers were fabricated by using magnetron co-sputtering. The $L1_0$ FePt single layer shows good perpendicular orientation and the in-plane hysteresis loop shows almost a linear behavior. When δ is less than 3 nm, the FePt/Fe bilayers show behaviors like one magnetic phase, the coercivities are close to the values determined by Zeeman energy. When δ is larger than 3 nm, the in-plane hysteresis loops show behaviors similar to a soft magnetic film, the coercivities of the bilayers decreases slowly with the increasing Fe thickness because of confining by the exchange length of FePt layer and Fe layer. The measured coercivities values are optimally fitted by a $1/t_{Fe}{}^{1.15}$ relation. The magnetization reversal process and magnetic interaction were also investigated.

1. Introduction

Hard/soft magnetic bilayers have been studied extensively in recent years for their potential application as exchange spring magnet or exchange coupled composite (ECC) media for magnetic recording [1]. The ordered FePt thin film has been known to be a promising candidate as hard magnetic layer in exchange coupled system for its large magnetocrystalline anisotropy ($Ku \approx 7 \times 10^7$ erg/cm^3) [2]. Recently, many theoretical research have been done [3–5] and a great deal of experiments have been performed on FePt-based systems, e.g., exchange-coupled $L1_0$-FePt/CoCrPt bilayers [6], hard magnetic FePtCu alloy films with softer Co/Pt multilayers [7], $L1_0$-FePt/FeRh exchange spring films [8], FePt/Fe_3Pt hard-soft exchange-coupled magnetic nanocomposites [9], FePt/$FePt_3$ nanocomposites films [10], FePt/BN films [11], $L1_0$-FePt/Fe thin films [12–18]. Among them, FePt/Fe system was more remarkable for the small magnetocrystalline anisotropy constant and large magnetic saturation polarization of Fe, which may result in a significant remanence enhancement of the exchange-coupled hard/soft magnetic bilayers [12]. Although the magnetization behavior and magnetization reversible process of the $L1_0$ FePt/Fe bilayers were studied theoretically by many research groups, available experiment results remain insufficient. Moreover, at present no explicit analytical results of the soft layer thickness dependence of the coercivities exist. In this work, the magnetic properties and magnetization reversal process of FePt/Fe bilayers were investigated. The variation of coercivities with the increasing Fe thickness was emphasized.

2. Experiments

The FePt (10 nm)/Fe (δ nm, δ = 0–15) bilayers were fabricated on Si (1 0 0) substrate by using magnetron sputtering. The base pressure of the sputtering system was less than 1.7×10^{-7} Torr and the working pressure was 5 mTorr under high purity argon gas. The FePt layers were deposited by co-sputtering from pure Fe and Pt targets. The nominal composition is $Fe_{60}Pt_{40}$, which was characterized by using EDX. After deposition, the FePt single layers were annealed at 700 °C for 1 h in a vacuum furnace. The microstructure of the films was identified by using X-ray diffractometry (XRD) with Cu Kα radiation. The magnetic hysteresis loops and remanence curves were measured at room temperature by using vibration sample magnetometer (VSM) with a maximum magnetic field of 1.6 T. The magnetic domain structures of the films were detected by using an Asylum Research magnetic force microscopy (MFM) in AC mode.

3. Experimental results

Fig. 1 shows the θ–2θ XRD patterns of FePt (10 nm) and FePt/Fe (δ nm, δ = 3, 6, 10, 15) samples. Formation of the ordered $L1_0$ phase is apparent from the presence of the (0 0 1) superstructure reflection. The insert pattern is the rocking curve of FePt (0 0 1) diffraction peak with a FWHM of around 3.7°. Fe (2 0 0) peak appears when the Fe layer is up to 15 nm, which is too weak to observe below 15 nm.

* Corresponding author. Tel.: +86 931 8912837.
E-mail address: caojw@lzu.edu.cn (J. Cao).

0169-4332/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.apsusc.2012.05.006

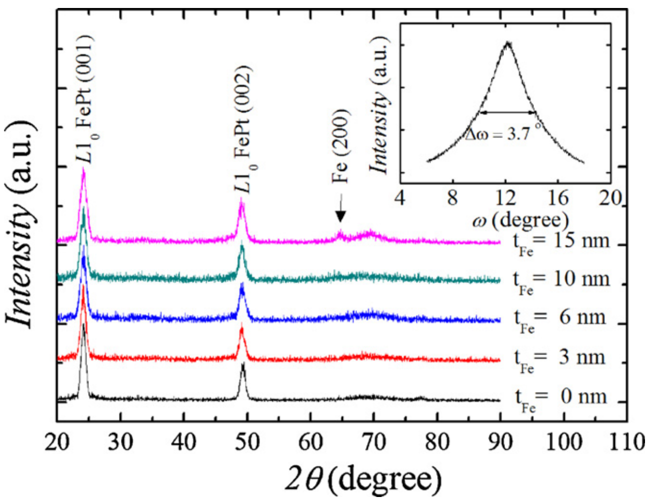

Fig. 1. θ–2θ XRD patterns of the FePt (10 nm) and FePt/Fe (δ nm, δ = 3, 6, 10, 15) samples.

The fact that the diffraction patterns do not change demonstrates that the deposition of the Fe layer does not modify the features of the FePt layer [19].

Fig. 2 shows the typical M–H loops (left) and demagnetization curves and remanence curves (right) of the FePt (10 nm)/Fe (δ nm, δ = 0–15) bilayers. In Fig. 2(a), the $L1_0$ FePt (10 nm) thin films presents a good perpendicular anisotropy with a square loop and a linear loop for out of plane and in-plane direction, respectively. Fig. 2(b)–(e) displays M–H loops of different thickness of Fe (δ = 2, 3, 6, 10 nm), respectively. When δ is less than 3 nm, the FePt/Fe bilayers show behaviors like one magnetic phase due to strong interface coupling. Whereas, when δ is larger than 3 nm the in-plane hysteresis loops deviate from the linear shape and show behaviors similar to a soft magnetic film. This implies that the FePt/Fe bilayers transforms from a rigid magnet to a spring magnet with increasing Fe thickness.

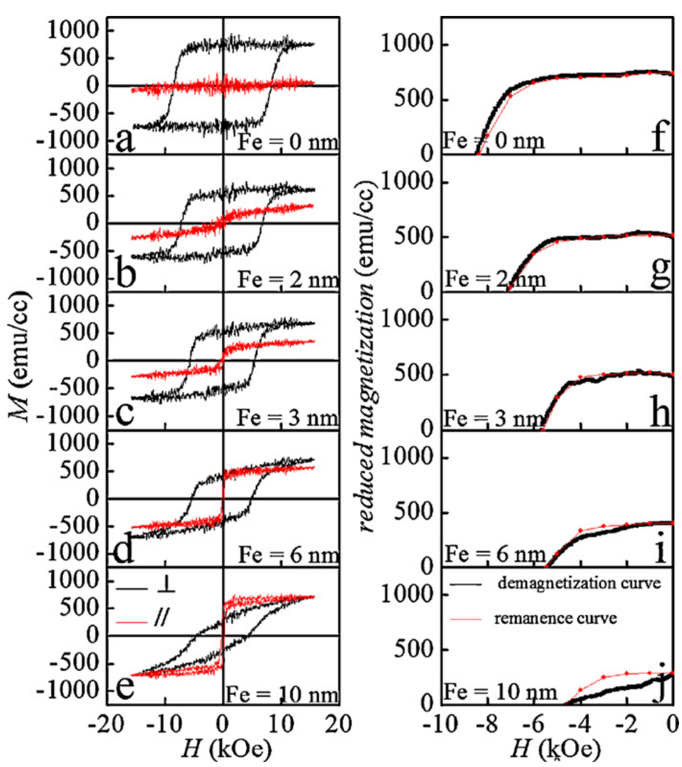

Fig. 2. Magnetic hysteresis loops and demagnetization and remanence curves of the different thickness of Fe (δ = 0, 2, 3, 6, 10 nm) samples.

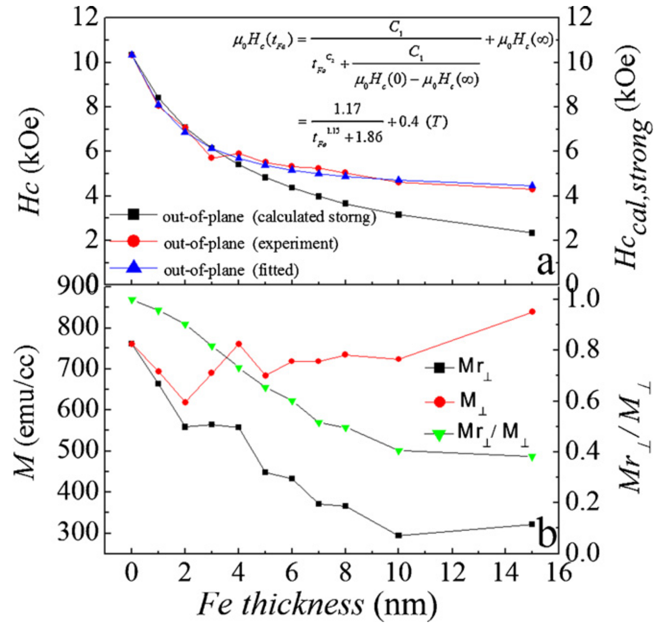

Fig. 3. Hc, magnetization and squareness of out of plane thin films dependence of the Fe thickness.

Fig. 2(f)–(j) presents the demagnetization curves (second quadrant of M–H loops) and remanence curves corresponding to M–H loops. For FePt/Fe (δ nm, δ = 0, 2, 3) thin films, the remanence curves are close to the second quadrant of M–H loops, which implies that the magnetization reversal in them is dominated by irreversible rotation of magnetic moment. As a result, they have similar coercivity and remanence coercivity values. The reversible component of the magnetization increases due to exchange spring behavior between FePt layer and Fe layer when δ is above 3 nm, as plotted in Fig. 2(i) and (j). It can be found that, with thicker Fe layer, the Fe magnetization turns to the in-plane direction, the area between demagnetization curves and remanence curves is larger. The reasons of these phenomena are the following: When the Fe thicknesses are larger than 3 nm, the magnetic reversal processes is close to exchange spring behavior. As a negative field is applied, the magnetization of top-most layer in the Fe layer begins to rotate first and torques each successive layer until the soft/hard interface is reached. The demagnetization process is

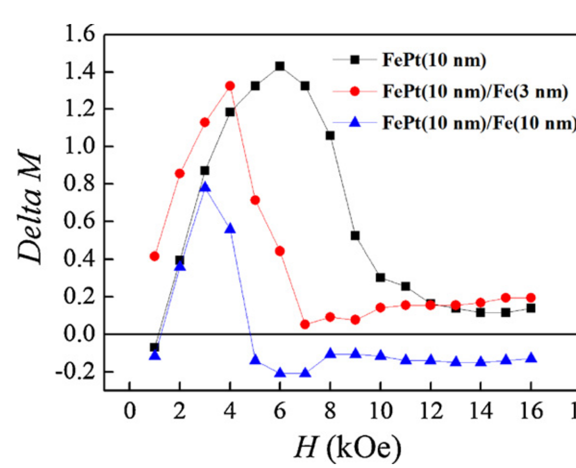

Fig. 4. Delta M curves of the FePt (10 nm) and FePt/Fe (δ nm, δ = 3, 10) thin films.