Available online at www.sciencedirect.com
ScienceDirect
Journal of Magnetism and Magnetic Materials 310 (2007) e921–e923
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Largely enhanced coercivity of FePt film at low temperature by introduction of CrRu underlayer

S.C. Chen[a,*], P.C. Kuo[b], A.C. Sun[b], C.Y. Chou[b], Y.H. Fang[b], C.T. Lee[b]

[a]Department of Materials Engineering, MingChi University of Technology, Taipei 243, Taiwan
[b]Institute of Materials Science and Engineering and Center for Nanostorage Research, National Taiwan University, Taipei 106, Taiwan

Available online 20 November 2006

Abstract

In situ ordered $L1_0$ FePt films with large coercivity have been prepared at low temperature by DC magnetron sputtering the FePt magnetic layer on a CrRu underlayer with preheated natural-oxidized Si (1 0 0) wafer substrates. The results showed that granular $L1_0$ FePt nanoparticles with a large in-plane coercivity of 4000 Oe and an isolated uniform size of 10.7 nm can be achieved by introducing a 50 nm CrRu underlayer under the 25 nm FePt film deposited at a low substrate temperature of 350 °C.

PACS: 75.50.Ss; 75.60.Jk; 75.70.Ak

Keywords: DC magnetron sputtering; FePt film; CrRu underlayer; In-plane coercivity

In order to increase the areal recording density of the magnetic recording thin film, the grain size of the film must be reduced. The minimal stable grain size is $D_p = (60K_BT/K_u)^{1/3}$ for a storage time of about 10 years [1], where K_u is the magnetocrystalline anisotropy, K_B is the Bolzmann's constant and T is the absolute temperature. Due to the K_u of the fully ordered $L1_0$ FePt phase being as high as 7×10^7 erg/cm^3, a FePt grain size even as small as about 3 nm can resist thermal instability, which leads the $L1_0$ FePt film to attract much attention for the next generation high-density magnetic recording media. However, the formation of the $L1_0$ FePt phase requires heat treatment at a high temperature around 600 °C [2], which results in the grain growth. In this study, we use CrRu underlayer to enhance the coercivity of FePt film at a low temperature of 350 °C.

The CrRu underlayer thickness (t_{CrRu}) in the range of 10–100 nm and the FePt magnetic layer of 25 nm are both deposited by DC magnetron sputtering at a substrate temperature of 350 °C. The base pressure in the sputtering chamber is better than 5×10^{-7} Torr. The magnetic properties of the films are measured using a vibrating sample magnetometer (VSM) at room temperature. The microstructures of the films are investigated by a Philips Tecnai F30 field emission gun transmission electron microscopy (FEG-TEM) and X-ray diffractometry (XRD). The compositions of the films are determined by EDS, and they are $Fe_{55}Pt_{45}$ and $Cr_{90}Ru_{10}$ for the FePt and CrRu films, respectively.

According to a previous study [3], the in-plane coercivity of single-layer FePt film with thickness below 30 nm only has several hundred Oe after annealing at a low temperature of 350 °C. However, as shown in Fig. 1(a)–(c), the in-plane coercivity can be increased to 1700 Oe by introducing a 10 nm CrRu underlayer under the 25 nm FePt film which deposited at 350 °C. And it is enhanced significantly to 4000 Oe as t_{CrRu} is increased to 50 nm.When the t_{CrRu} is further increased to 100 nm, the in-plane coercivity is increased slightly to 4280 Oe. On the other hand, we had reported that the perpendicular magnetic anisotropy of FePt films can be obtained as introducing a Pt buffer layer between FePt magnetic layer and Cr underlayer [4]. But, in this work, all of the CrRu/FePt bilayer films without Pt buffer layer show in-plane magnetic anisotropy, which is consistent with the (2 0 0) preferred orientation of FePt

*Corresponding author. Tel.: +886 2 29089899; fax: +886 2 29063269.
E-mail address: chensc@mail.mit.edu.tw (S.C. Chen).

0304-8853/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmmm.2006.10.965

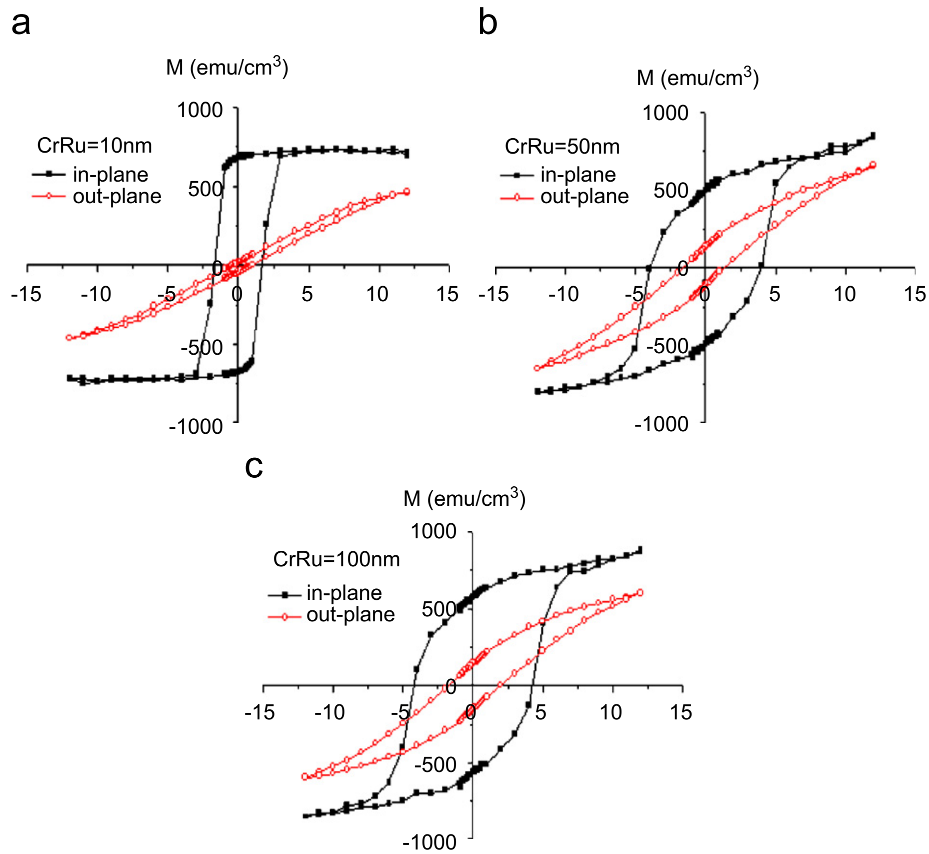

Fig. 1. *M–H* loops of (a) CrRu 10 nm/FePt 25 nm, (b) CrRu 50 nm/FePt 25 nm, and (c) CrRu 100 nm/FePt 25 nm films, which deposited at substrate temperatures of 350 °C.

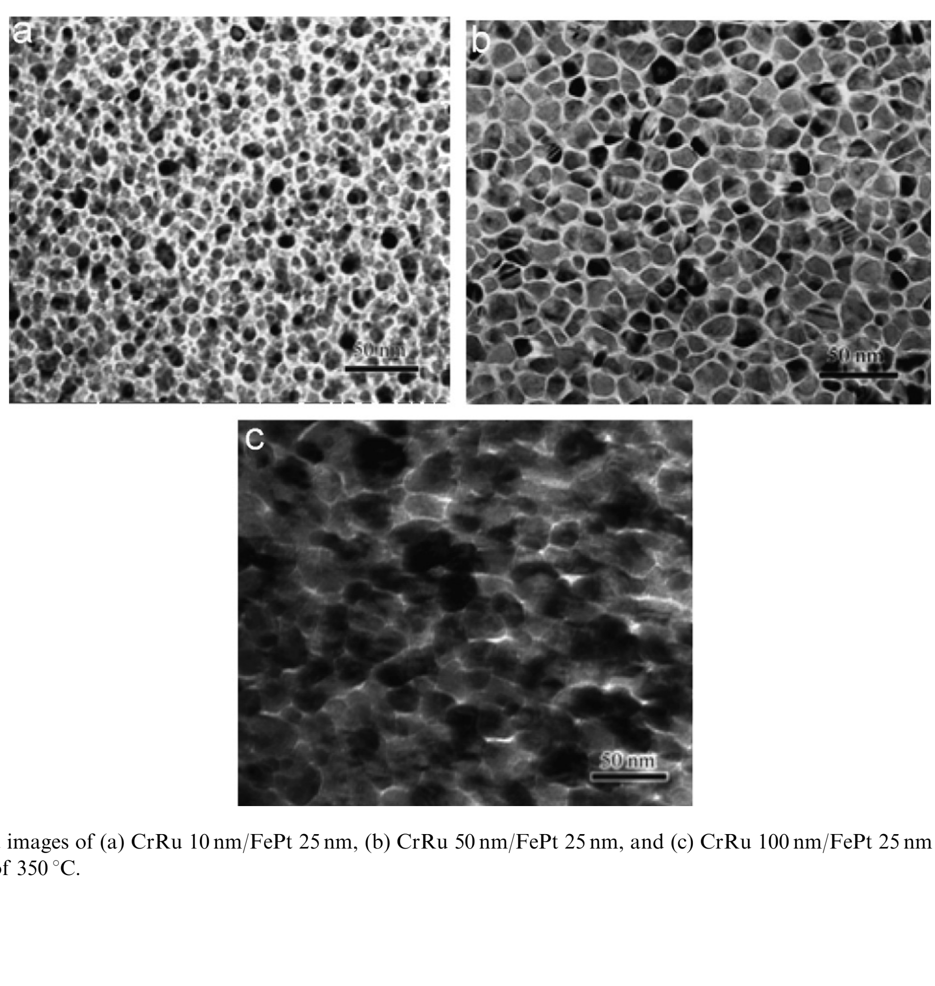

Fig. 2. TEM bright field images of (a) CrRu 10 nm/FePt 25 nm, (b) CrRu 50 nm/FePt 25 nm, and (c) CrRu 100 nm/FePt 25 nm films, which deposited at substrate temperatures of 350 °C.

films determined by XRD. Fig. 2(a)–(c) are the TEM bright field images of the CrRu 10 nm/FePt 25 nm, CrRu 50 nm/FePt 25 nm, and CrRu 100 nm/FePt 25 nm films, respectively. By introducing a 10 nm CrRu underlayer, the average grain size of FePt film is about 6.3 nm and the size distribution is large. When the t_{CrRu} is increased to 50 nm, the average grain size increases to 10.7 nm and the film morphology shows uniform size and the particles are isolated. Further increasing t_{CrRu} to 100 nm, the grain size is further increased to 21.3 nm, but the particle isolation and uniformity disappear.

The amount of in-plane coercivity increase of about 135% as t_{CrRu} increases from 10 to 50 nm may be due to the following reasons: (I) For randomly orientated non-interacting particles, the dependence of coercivity (H_c) on the particle size (D) can be described as [5]

$$H_c = 0.96K_u[1 - (D_p/D)^{0.77}]/M_s, \quad (1)$$

where M_s is the saturation magnetization. The minimal stable grain size (D_p) of FePt alloy is about 3 nm. The increase in particle size from 6.3 to 10.7 nm results in an increase in coercivity of about 44%. (II) For $t_{CrRu} = 10$ nm, the particle sizes of the FePt film are widely distributed and some particle sizes are smaller than 3 nm, which becomes superparamagnetic particles. However, the isolated FePt particles with uniform size are observed as $t_{CrRu} = 50$ nm, which leads to increase of coercivity [6]. (III) Wong et al. [7] have reported that the degree of interfacial misfit is larger as the grain size is larger in Cr/Co film, and this will introduce stacking fault and misfit dislocation into the Co layer in order to reduce the degree of interfacial misfit. Likely, in our CrRu/FePt system, by increasing t_{CrRu} from 10 to 50 nm, the average grain size increases from 6.3 to 10.7 nm, which results in the increase in degree of interfacial misfit in the CrRu/FePt films and increasing misfit defect in the FePt layer. The transformation of FCC soft FePt to FCT hard $L1_0$ FePt phase becomes easier. Therefore, the coercivity of FePt film will be increased because the degree of order of FePt layer is increased as the t_{CrRu} is increased from 10 to 50 nm.

With further increase of t_{CrRu} from 50 to 100 nm, although the grain size is increased significantly from 10.7 to 21.3 nm, the in-plane coercivity is increased slightly from 4000 to 4280 Oe. The film morphology changes from discontinuous to continuous, forming interconnected particles, which leads the easy domain wall motion in the magnetization process [6]. This results in the decrease of coercivity. Therefore, as the t_{CrRu} increases from 50 to 100 nm, the increase of in-plane coercivity is out of proportion to the increase of grain size.

In conclusion, isolated $L1_0$ FePt nanoparticles with large in-plane coercivity of 4000 Oe and uniform particle size of 10.7 nm can be obtained from CrRu 50 nm/FePt 25 nm bilayer films deposited at a low temperature of 350 °C.

This work was supported by the National Science Council and Ministry of Economic Affairs of Taiwan through Grant No. NSC 94-2216-E-131-003 and 94-EC-17-A-08-S1-0006, respectively.

References

[1] D. Weller, A. Moser, L. Folks, M.E. Best, W. Lee, M.F. Toney, M. Schwickert, J.-U. Thiele, M.F. Doerner, IEEE Trans. Magn. 36 (2000) 10.
[2] T. Suzuki, K. Ouchi, IEEE Trans. Magn. 37 (2001) 1283.
[3] A.C. Sun, P.C. Kuo, S.C. Chen, C.Y. Chou, H.L. Huang, J.H. Hsu, J. Appl. Phys. 95 (2004) 7264.
[4] A.C. Sun, P.C. Kuo, J.H. Hsu, H.L. Huang, J.M. Sun, J. Appl. Phys. 98 (2005) 076109.
[5] D.H. Ping, M. Ohnuma, K. Hono, M. Watanabe, T. Iwasa, T. Masumoto, J. Appl. Phys. 90 (2001) 4708.
[6] T. Shima, K. Takanashi, Y.K. Takahashi, K. Hono, Appl. Phys. Lett. 81 (2002) 1050.
[7] Bunsen Y. Wong, Ji Feng Ying, Ken Johnson, IEEE Trans. Magn. 36 (2000) 2360.