鐵鉑薄膜沉積在金底層上高矯頑磁力之探討

申繼陽、袁輔德

摘 要

試片的製備為：在室溫下先沉積一層厚度為 60 奈米的金底層，然後在該底層上再沉積一層厚度從 5 奈米至 100 奈米的鐵鉑層；接著進行一段二十分鐘的熱處理，溫度從攝氏 400 至 800 度不等。尚未進行熱處理的雙層膜（鐵鉑層為 20 奈米）的結晶結構是由等向的面心立方的金和面心立方的鐵鉑非序化相所構成。當 400 度的熱處理完畢之後，廣泛的序化轉變完成了，且平行膜面的矯頑磁力達到 7 kOe 左右，當熱處理溫度提高到 800 度時，矯頑磁力大幅上升至 28 kOe。從鐵鉑晶格常數的恒定可知，儘管經歷了劇烈的序化-非序化的相轉變，以及極高溫的熱處理，金原子仍未擴散進入鐵鉑二元相中。最大的矯頑磁力值出現在鐵鉑厚度為 5 奈米的試片中，其可達到 33 kOe。所有的雙層膜試片均呈現磁性單相行為；伴隨矯頑磁力的提高，試片的殘餘磁化量由 583 emu/cm^3 下降至不到 400 emu/cm^3。磁力顯微鏡的結果指出鐵磁性的鐵鉑晶粒分布在非磁性的金基地中，平均分隔距離為 0.4 微米。從以上的結果可知，良好的晶粒隔絕以及較小的晶粒尺寸可明顯的提昇具有相似序化度的鐵鉑薄膜的磁性質。

關鍵詞：鐵鉑、高矯頑磁力、晶粒隔絕、磁區結構、金底層。

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HIGH COERCIVE FePt THIN FILMS DEPOSITED ON Au UNDERLAYER

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Abstract

Samples were prepared by deposited an Au underlayer with a constant thickness of 60 nm at room temperature, and then deposited the FePt layer. The thickness (x nm) of FePt layer ranged from 5 nm to 100 nm. A 20 minutes post annealing with temperature ranged from 400˚C to 800˚C process was applied. The as-deposited biayer thin film was composed of the fcc Au and disorder FePt (fcc) phase with random orientation. As the post annealing was applied at 400°C, extensive ordering transformation occurred and the in-plane coercivity (H_c) was about 7 kOe. While the annealing temperature further increased to 800°C, H_c largely increased to 28 kOe. The unchanged lattice parameter of FePt order phase confirmed that the Au atoms did not diffusion into the FePt grain even went through an intensive order-disorder phase transformation at very high temperatures. A maximum value of H_c of about 33 kOe was found x=5 nm sample. Samples exhibit magnetically single phase behavior, and the remanence magnetization decreases from 584 to less than 400 emu/cm^3 with the increasing coercivity. Result of MFM indicates the magnetic phase of ordered FePt dispersing in the non-magnetic matrix of gold. The average isolation distance of those interaction domains was measured to be about 0.4 μm. Comparing these data, we learn that well grain isolation and fine grain size highly enhance the coercivity of the FePt thin films with similar ordering parameter.

Keywords: FePt, high cuercivity, grain isolation, domain structure, Au underlayer.

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I. INTRODUCTION

Ordered FePt have been commonly acceptted as a promissing material for perpendicular magnetic media with ultra high recording density of exceeding 1 Tbit/inch^2. This is because its very high anisotropy (~7×10^7 erg/cm^3) and high Curie temperature (~450˚C). Several improvements for recording application have been made; for example, the reduction of transition temperature from disorder phase to chemically ordered structure and the control of magnetic easy axis. However, there still has challenge left: large read-write noise. This problem mainly arose from the exchange interactions between the neighboring grains. Many efforts have been successfully made to decrease the interactions by forming the nanocomposited granular structures [1,2], that is, embed ordered FePt grains in a non-magnetic matrix. This magnetic particle isolation structure promotes noncooperate switching [3] which effectively reduces noise. Our recent work reported that through a two-stage Au top-layer diffution process, ordered FePt continuous thin films can be partically separated [4], and this causes a drametic increase in coercivity. Independent magnetization reversal process was also reported [5]. However, the incompletely isolated grains still results in interaction domains which rising noise. In this study, we attempt to further improve grain isolation in FePt film by a different approach of underlayer annealing. Unlike the Au top-layer, the gold layer was inserted between the FePt layer and subatrate followed by a post annealing in the experiment. Very high coercivities of about 33 kOe were found. Crystal and magnetic domain structures were also investigated.

II. EXPERIMENTAL

The thin-film samples were deposited using an rf magnetron sputtering system. The background pressure was about 1.0×10^{-7} torr, and the argon pressure was fixed at 10 mtorr. The Au underlayer with a constant thickness of 60 nm was firstly deposited on the quartz substrate at room temperature, and then deposited the FePt layer. The thickness (x nm) of FePt layer ranged from 5 nm to 100 nm. In order to promote the ordering transformation and the interlayer diffusion, after the thin film deposition process, a 20 minutes post annealing process was applied at an argon pressure of 10 mtorr. The annealing temperature ranged from 400˚C to 800˚C.

Chemical composition of the FePt layer analyzed by inductively coupled plasma (ICP) method was $Fe_{51}Pt_{49}$. The crystal structures were identified with x-ray diffractometer (XRD) by θ-2θ scan. Magnetic properties were measured at 298 K using a SQUID magnetometer with a maximum applied field of 5 T. MFM were used to study the domain structures of the samples in as-made state.

III. RESULTS AND DISSCUSSION

The as-deposited FePt (20 nm)/Au-underlayer (60 nm) biayer thin film was composed of the fcc Au and disorder FePt (fcc) phase with random orientation. As the post annealing was applied and the temperature was increased to 400°C, extensive ordering transformation occurred and the in-plane coercivity (H_c) was about 7 kOe. While the annealing temperature further increased to 800°C, H_c largely increased to 28 kOe. From the analysis of lattice parameter of FePt order phase, it was confirmed that the Au atoms did not diffusion into the FePt grain even went through an intensive order-disorder phase transformation at very high temperatures. Similar results have been found in the previous works [4,5]. Thickness dependence of FePt layer on coercivity for the films annealed at 800°C was shown in Fig. 1. It appeared that the coercivity was decreased with the increasing thickness of FePt layer. A maximum value of H_c of about 33 kOe was found x=5 nm sample, which is higher than the top-layer diffusion films. Several hysteresis loops of the FePt/Au films in Fig. 1 were shown in Fig. 2. Samples exhibit magnetically single phase behavior, and the remanence magnetization decreases from 584 to less than 400 emu/cm^3 with the increasing coercivity. Figure 3 showed the virgin-state magnetic domain structure of x=5 thin film after an annealing at 800°C. Isolated magnetic domains can be clearly observed, which indicated the magnetic phase of ordered FePt dispersing in the non-magnetic matrix of gold. The average size of the isolated domain is about 250 nm. This large size revealed that every single isolated domain consists of a number of FePt grains with similar direction of magnetization. The average isolation distance of those interaction domains was measured to be about 0.4 μm. While the thickness of FePt layer was increased, size of interaction domain increases accompanying the reduction of distance between domains. As x ≥ 40, isolated domains began to interconnect, and continuous domain structure was gradually formed while x increased to 100. Comparing these data, we learn that well grain isolation and fine grain size highly enhance the coercivity of the FePt thin films with similar ordering parameter.

In this study, we found that gold is an ideal material of non-magnetic matrix to decouple the FePt thin film. Nano-composited structure of FePt-Au with high chemical ordering was successfully obtained, and a significant coercivity enhancement induced by microstructure modification was achieved. The formation of this decoupled FePt structure can be useful to magnetic recording applications.

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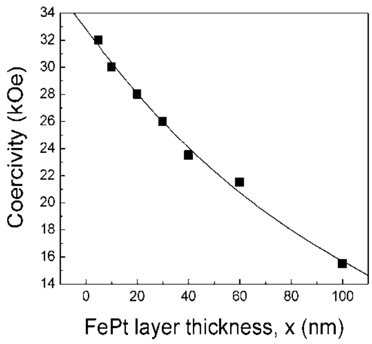

Fig. 1 Thickness dependence of FePt layer on coercivity for the FePt (x nm)/Au-underlayer (60 nm) thin films annealed at 800°C.

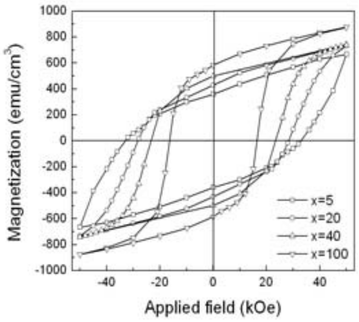

Fig. 2 Hysteresis loops of the FePt (x nm)/Au-underlayer (60 nm) , (x=5,20,40,100) samples annealed at 800°C.

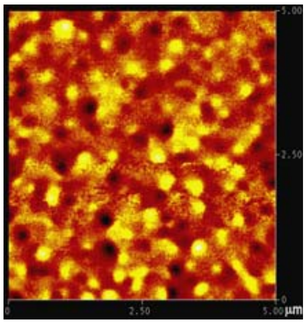

Fig. 3 MFM image of bilayer FePt(5nm)/Au-underlayer (60nm) thin film annealed at 800°C.