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The study of magnetic properties and microstructures of nano-size FePt islands on amorphous carbon film

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ABSTRACT

This work focuses on the formation mechanisms of nano-island FePt film on commercial copper grids covered with an amorphous carbon film. FePt films of different thickness (1–7.5 nm) were deposited on amorphous carbon film and then post-annealed at 700 °C for 30 min. The configuration of the film was changed during the annealing process due to the surface energy difference between the amorphous carbon films and FePt alloy. We have prepared nanometer-size island-shaped FePt films on the amorphous carbon films and investigated their magnetic properties and microstructures. A discontinuous nano-size island magnetic film can reduce the exchange coupling of the media and increase the recording density.

1. Introduction

As the density of magnetic recording media increases to ultra-high density, the grain size of the thin film recording media must be very fine. As a result, thermal fluctuation will overcome the magnetic anisotropy energy and disarrange the magnetic moments of the recording bits. This phenomenon is known as superparamagnetism. Therefore, patterned media have been suggested as potential candidates to overcome this physical limitation [1,2]. E-beam lithography and focused ion beam milling have been investigated as methods of fabricating patterned magnetic thin films [3–5].

Patterned media with single-domain magnetic dots also could be obtained by fabricating discontinuous magnetic films. A discontinuous nano-size island magnetic film can reduce the exchange coupling of the media and increase the recording density. Due to large magnetocrystalline anisotropy, which helps to provide thermal stability and high signal-to-noise ratios of the media, the ordered FePt alloy with $L1_0$ structure (face-centered tetragonal, fct) has attracted much attention in recent years for the next generation of magnetic recording media [6–8]. FePt films have been frequently prepared by sputter-deposition. Generally, when deposited at room temperature, the crystal structure of FePt films is disordered phase (face-centered cubic, fcc). In order to transform the films to $L1_0$-FePt, they have been annealed at high temperature [9]. Based on a previous study [10], the samples were annealed at 700 °C for 30 min.

In this study, we describe a method to fabricate self-assembled and well-separated FePt nano-size islands with perpendicular magnetic anisotropy on amorphous carbon film for ultra-high density recording media.

2. Experiments

FePt films with different thickness (1–7.5 nm) were prepared by dc magnetron sputtering (base pressure, 4×10^{-5} Pa) of Fe and Pt targets alternately to fabricate an $(Fe/Pt)_n$ multilayer on amorphous carbon film and then post-annealed at 700 °C for 30 min. The thickness of each Fe/Pt bi-layer in the $(Fe/Pt)_n$ multilayer was 0.12 nm. The chemical composition of FePt films was $Fe_{58}Pt_{42}$ after sputtering deposition. The thickness of the film was measured with an atomic force microscope (AFM). The composition of the film was estimated with an energy dispersive spectrometer (EDS). Magnetic properties of the films were measured with a superconducting quantum interference device (SQUID). The film structure was identified with a field emission gun high resolution transmission electron microscope (FEG-TEM).

3. Results and discussion

Fig. 1 shows the XRD patterns of FePt(1–7.5 nm)/amorphous carbon films which annealed at 700 °C for 30 min. It can be found that the diffraction peaks of these ultrathin FePt films (thinner than 7.5 nm) are too weak to be detected by XRD [11]. Fig. 2 shows the plane-view FEG-TEM images and selected area elec-

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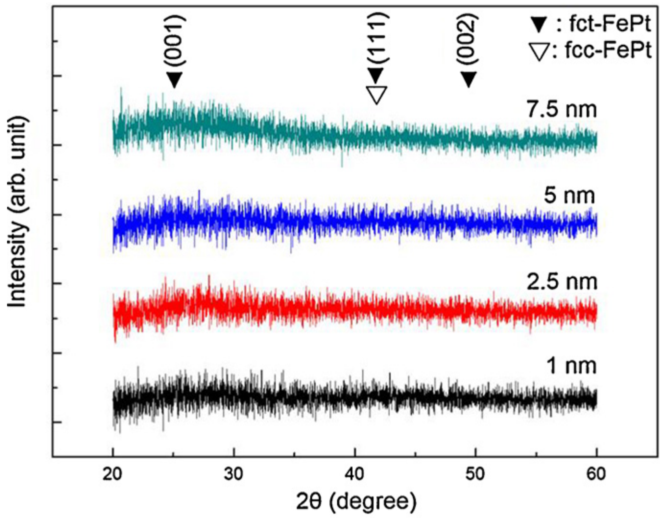

Fig. 1. XRD patterns of FePt(1–7.5 nm)/amorphous carbon films which were annealed at 700 °C for 30 min.

tron diffraction patterns of FePt films with different thickness after annealing at 700 °C for 30 min. When the film thickness was 1 nm, the FePt film formed island-like FePt grains with a grain size below 8 nm, as shown in Fig. 2(a). The structure of the carbon substrate was amorphous. The surface energy of the amorphous carbon (about 2×10^{-6} to 6×10^{-6} J/cm^2) was much smaller than that of ordered FePt crystal (about 2.7×10^{-4} J/cm^2) [12,13]. During annealing, the surface energy difference between the amorphous carbon substrate and FePt alloy caused the FePt films to form island shapes to reduce the surface energy of the sample. Because of increases in the thickness and mass of FePt films, cluster growth and coalescence occurred easily. The interconnected and elongated FePt islands in Fig. 2(b)–(d) demonstrate these phenomena. The selected area electron diffraction patterns reveal that some disordered FePt (fcc-FePt) still remained in the films after annealing. Lim et al. [14] reported that the degree of long range ordering increases linearly with the FePt thickness. According to Laplace-Young model [15], the driving force for forming FePt islands is proportional to the surface energy difference between the amorphous carbon substrate and FePt alloy, and is inversely proportional to the mean radius of the grain. Due to the grain size is limited by the film thickness [16], the thinner FePt films would form smaller islands and the islands will be aggregated when the film is thicker. This phenomenon could be observed in Fig. 2. The grain size of 5 nm and 7.5 nm-FePt films (above 40 nm) is obviously larger than that of 1 nm and 2.5 nm FePt films (below 20 nm). Therefore, in order to obtain island-shaped FePt films, the thickness of FePt films must be reduced to below 2.5 nm. However, this will cause the degree of chemical ordering of the FePt to decrease slightly. One possible approach to resolve this problem for future inves-

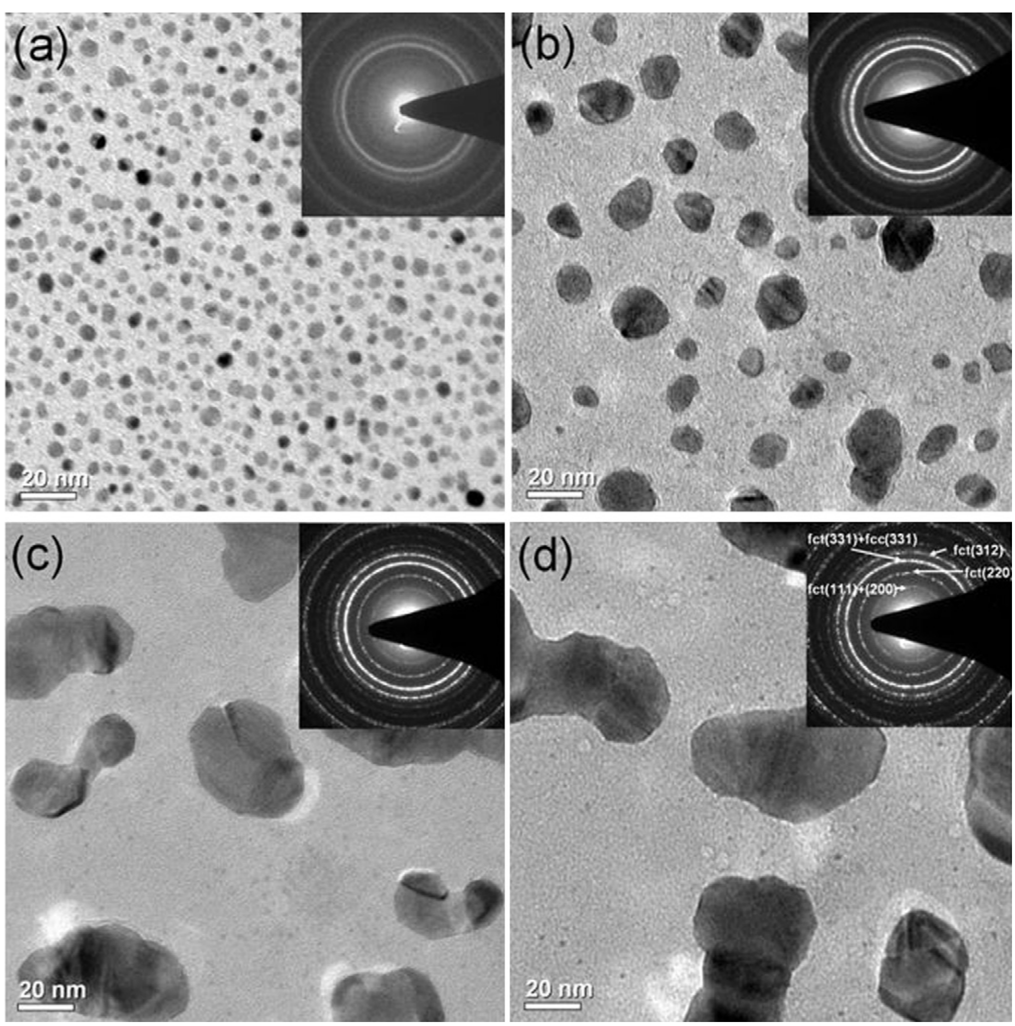

Fig. 2. Plane-view FEG-TEM images and selected area electron diffraction patterns (insert) of FePt films with different thickness after annealing at 700 °C for 30 min. Film thickness is (a) 1, (b) 2.5, (c) 5, and (d) 7.5 nm.