$L1_0$ ORDERED HIGH COERCIVITY FePt-C NANOGRANULAR FILMS WITH HIGH ASPECT RATIO FOR HEAT ASSISTED MAGNETIC RECORDING MEDIA

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INTRODUCTION

Heat assisted magnetic recording (HAMR) proposed as one of the alternative and new technologies to increase the areal density of beyond 2 Tbit/in^2 in hard disk drive (HDD) approaches its commercialization [1]. According to the standardization of Advanced Storage Technology Consortium (ASTC), this HAMR technology requires the recording medium consists of (i) densely dispersed ferromagnetic particles of high magnetocrystalline anisotropy (K_u) with uniform grain size between 4 and 6 nm and columnar type grains with aspect ratio, h/D (h is the height and D is average diameter of the grain) of at least 1.5 to obtain good signal to noise ratio, (ii) narrow size distribution between 10 and 15 % and reduced number of misoriented grains for obtaining controllable switching field distribution and (iii) high out-of-plane coercivity (H_C) of more than 3 T.

Among various materials available with high K_u, FePt based alloys are considered to be one of the promising materials. The realization of FePt-C based nanogranular films on single crystal MgO(001) substrates was first reported by Ko et al [2] and Perumal et al [3]. Subsequently, different research groups have attempted to fabricate FePt-C based nanogranular films on low cost substrates using different underlayers [4,5]. However, the development of FePt-C nanogranular films with high H_C and high aspect ratio remains challenge due to strong driving force for phase separation between FePt and C, which led to the formation of second layer of FePt-C with random orientation. To overcome the first problem, Zhang et al. added Ag into the FePt-C granular films to enhance the coercivity above 3 T [6] and demonstrated 550 Gbit/in^2 HAMR recording on the FePt-C granular films using a HAMR static tester [7]. On the other hand, the growth of FePt columnar grains was reported recently from industrial laboratories in FePt-X systems [8,9]. However, neither the information on the fabrication process of the columnar structure nor the type of X has been revealed. Varaprasad et al. reported an alternative way to achieve the columnar growth of FePt grain by using a compositionally graded sputtering method [10] with the stack structure of MgO(001)/ FePt-xC (2 nm)/ FePt-yC (2 nm)/ FePt-zC(2 nm)/ FePt-xC (2 nm)/ FePt-yC (2 nm) with x, y and z as 25, 30 and 35 vol.% of C, respectively. However, the achievable minimum grain size and highest aspect ratio was limited to 7.8 nm and 1.3, respectively. As to the reduction of the grain size and increase of aspect ratio, one needs to understand the detailed growth process of the columnar media structure from the nucleation and growth stage to the coarsening stage on heated substrates. Hence, we, in this study, report systematic investigations of layer-by-layer growth mode of FePt-C nanogranular films deposited as graded structure with different C volume fraction using magnetron sputtering technique to understand the growth mechanism of columnar FePt grains without the formation of second layer, reduced grain size of about 6.4 nm with narrow size distribution, high aspect ratio of about 2 and the resulting magnetic properties.

EXPERIMENTAL

FePt-C films were deposited by co-sputtering FePt and C targets onto single crystalline (001) oriented MgO substrate under 0.48 Pa Ar partial pressure. Although for industrial applications the FePt-C ferromagnetic layer must be grown on an appropriate seed layer through various buffer layers on glass disk substrates, in this study, we however used (001) MgO substrate as a model system. We have used stack structure for the deposition of the film with graded C vol. %. During film deposition, C target was continuously sputtered and the target power was controlled manually to vary C vol. % in different layers. For instance, the first film is made of 2 nm thick FePt-C(30.4 vol.%) only; while the second film consist of

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2 nm thick of each FePt-C (30.4 vol.%) and FePt-C (28.7 vol.%) layers and so on. The thickness of the each FePt-C layer with a particular C vol. % is fixed to be about 2 nm, e.g., two layer sequence gives a total thickness of 4 nm and 4 layer sequence provides 8 nm thick FePt-C film. Crystal structure and the degree of $L1_0$ order were analyzed using X-ray diffraction (XRD) with Cu-K_α radiation. Microstructures of the films were examined by in-plane and cross-sectional transmission electron microscopy (TEM) using FEI Tecnai 20. The room temperature magnetic properties were measured by superconducting quantum interference device vibrating sample magnetometer (SQUID-VSM, Quantum Design Inc.) with an applied magnetic field of up to ±7 T.

RESULTS

Fig. 1 shows the in-plane and cross-sectional TEM images of FePt-31vol.%C with the nominal thickness of 12 nm, which was deposited by the compositionally graded process. The in-plane TEM image shows a uniform microstructure with the average grain size of 6.4 nm and the cross sectional TEM image shows the aspect ratio of about 2. Note that the film thickness of 12 nm is double than the critical thickness of the single layer formation of 6 nm in the FePt-C system. The perpendicular H_C is 42 kOe with good squareness as required for recording media. In the in-plane magnetization curve, straight line and negligibly small hysteresis are evident. This indicates that the FePt grains are strongly [001] oriented in the perpendicular direction. The decreasing order of C concentration up to certain film thickness (6 nm in the present study) and the subsequent increase of C concentration provides excellent nanogranular films with good columnar growth of FePt grains without any second layer grains. With this study, we can selectively choose the total film thickness between 8 and 12 nm and then search for optimization methods to refine the grain size below 6 nm and the resulting magnetic properties by tuning the C vol. % in the films.

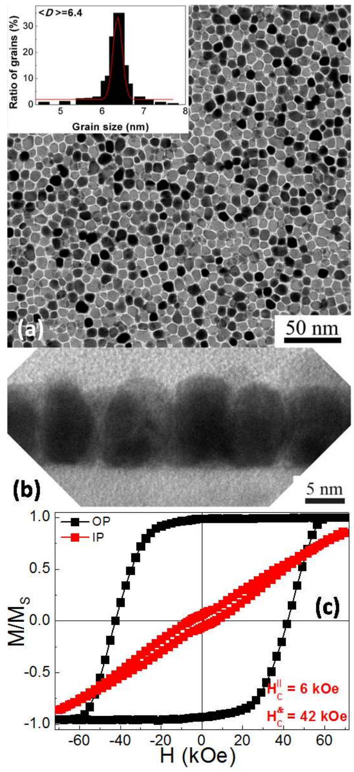

Fig. 1 In-plane and cross sectional TEM image of an optimized FePt-C film deposited by the compositionally graded process.

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