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MgO-C interlayer for grain size control in FePt-C media for heat assisted magnetic recording

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Currently, the most common recording media used for heat assisted magnetic recording is granular $L1_0$ based FePt-C directly deposited on a highly textured polycrystalline MgO underlayer. In this study, a thin granular MgO-C interlayer is inserted between the MgO underlayer and the granular $L1_0$-FePt-C magnetic layer to control the grain size of the magnetic media. By varying the deposition conditions of the MgO-C interlayer, we can vary the size of the $L1_0$-ordered FePt grains from about 10.5 nm to 7.6nm, while keeping the carbon composition in the magnetic layer unchanged. With the optimized interlayer, the $L1_0$-FePt-C media of grain size to 7.6 nm shows good squareness and perpendicular coercivity of 47 kOe as well as an order parameter of S = 0.85. [http://dx.doi.org/10.1063/1.4973500]

INTRODUCTION

The $L1_0$-ordered FePt magnetic material possesses many important properties suited for heat assisted magnetic recording.[1,2] Carbon and various oxides have been used as segregants to create a granular microstructure in the magnetic layer and to form both magnetic and thermal isolations between adjacent FePt grains. Highly textured (001) continuous polycrystalline MgO thin film layers have been the choice of the underlayer for the granular FePt-X layer, where X has been either carbon or an oxide.[3–5] One important reason is the lattice epitaxy relationship between the MgO and FePt. The slightly larger MgO lattice constant compared with that of the FePt yields a stretching tensile strain to the FePt grain,[6] promoting ordering in the perpendicular direction in particular when FePt is deposited at sufficiently high temperature, ~ 600 °C.[7] The FePt grains usually do not have one-to-one grain matching with that of the MgO layer. The segregants which formed at the grain boundaries in the granular FePt layer do not match that of MgO grain boundaries in the underlayer and thus the FePt grains can easily grow over the MgO grain boundaries, creating a significant probability for either multi-variant or poorly ordered FePt-$L1_0$ grains.[8,9] Hence, the grain size of the FePt-X layer is usually controlled by the volume percentage of the segregant(s) X: a higher percentage of segregants(s) usually lead to smaller FePt grain sizes, or the deposition condition of the FePt-X layer itself. Changing the MgO grain size of the underlayer usually has little effect on the grain size of the FePt-X layer.

If we want to create one-to-one grain matching between MgO underlayer grain and the FePt grain directly above, one strategy would be to have a matching of their grain boundaries. By inserting a thin MgO-C granular interlayer layer between the MgO underlayer and the FePt-X granular layer,

we have succeeded in controlling the FePt grain size through this thin interlayer while keeping the FePt-X composition unchanged.

EXPERIMENTAL

A film stack of Si/SiO_2|MgO (7nm) |MgO-$C_{Xvol.\%}$ (2nm) | FePt (0.2nm) | FePt-$C_{30vol.\%}$ (8nm) (X= 0, 20, 30, 40) is deposited using an ultra-high vacuum AJA sputtering system with 2×10^{-9} Torr base pressure. Si with 100 nm thick thermally grown SiO_2 substrates are used to prepare these film stacks. MgO, FePt alloy and carbon targets with 2 inch size and 99.9% purity are used deposit films. All substrates were cleaned with acetone, IPA, DI water and finally dry etching with oxygen plasma. The MgO underlayer is deposited at room temperature with 50W RF, 10 mTorr and target to substrate distance is around 70mm. A 2 nm of MgO-C interlayer was deposited at room temperature using co-sputtering technique at 20, 30 mTorr with 120W RF for MgO whereas for carbon we varied the DC power to attain various volume percentages. We used an ultra-thin 0.2 nm FePt layer to prevent carbon coating between MgO-C and FePt-C granular layers. We used exactly the same sputtering conditions to deposit FePt-$C_{30vol.\%}$ granular films. All FePt-$C_{30vol.\%}$ films were deposited at 600°C to promote $L1_0$ ordering. The film structure and microstructure were examined by the standard x-ray diffraction (XRD) and transmission electron microscopy (TEM) techniques. The moment (M_s) *vs* field (H) curves of the film samples were measured with a Quantum Design physical property measurement system-vibrating sample magnetometer (PPMS-VSM).

RESULTS AND DISCUSSION

From the literature, it is well-known that carbon and FePt will form a well isolated granular microstructure due to strong phase separation tendency.[3] We use the same idea to prepare a phase separated interlayer on which we can grow the FePt-C media. We choose the MgO and carbon system. We varied the carbon volume % and Ar pressure for MgO-C interlayer to refine the MgO grain size. Figure 1(a) and (b) show in-plane TEM micrographs of MgO-C interlayer grown at 30 mTorr with 20, 30 volume% of carbon respectively. These samples showed a well separated granular microstructure. The MgO grain size estimated from the micrographs were 12, and 7 nm for 20, and 30 volume% carbon in MgO-C interlayer respectively. From this study we believe that we can vary MgO grain size in the interlayer by changing deposition conditions. We have changed both the pressure and carbon volume % to find the best MgO-C interlayer for FePt-$C_{30vol\%}$. From our experiments MgO-$C_{40vol.\%}$ deposited 20 mTorr gave optimized microstructure and good perpendicular coercivity. We used an ultrathin FePt layer used to prevent carbon coating and improve texture. Without the ultrathin FePt layer, the FePt-C layer is more interconnected and less ordered (results were not included).

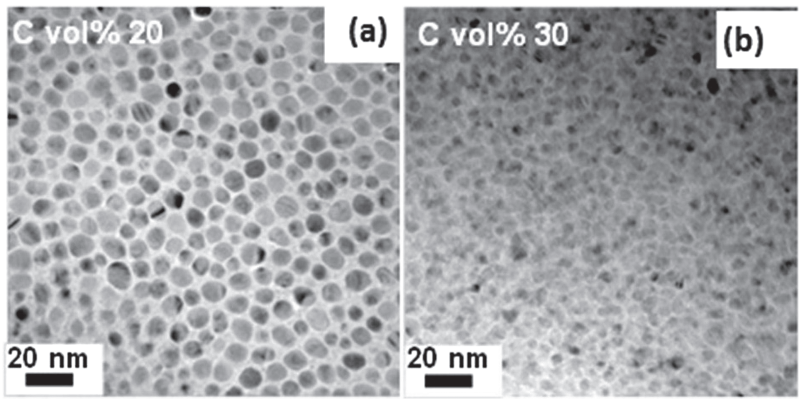

FIG. 1. (a), and (b) In-plane TEM micrographs of Si/SiO_2 |MgO (7 nm) |MgO-$C_{Xvol\%}$ (2 nm) film stack with X= 20, and 30 respectively deposited at 30 mTorr.

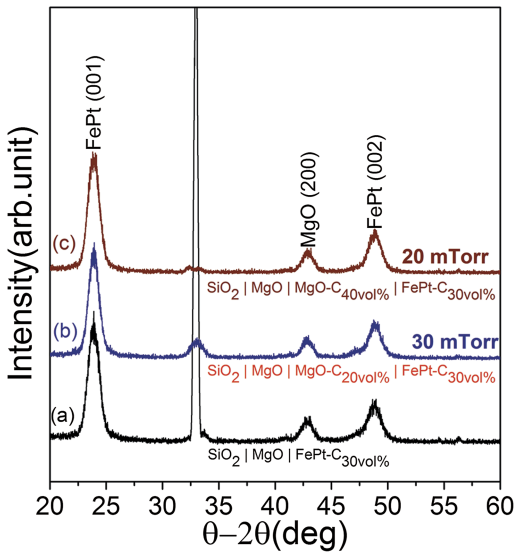

FIG. 2. (a), (b), (c), and (d) XRD micrographs of Si/SiO_2 |MgO (7 nm) |MgO-$C_{Xvol\%}$ (2 nm)| FePt (0.2 nm) | FePt-$C_{30vol\%}$ (8 nm) film stack with X= 0, 20, and 40 respectively.

Fig. 2 shows the XRD patterns of Si/SiO_2|MgO (7nm) |MgO-$C_{Xvol.\%}$ (2nm) | FePt (0.2nm) | FePt-$C_{30vol.\%}$ (8nm) with X vol.% C x=0, 20, 40. Strong $(001)_{FePt}$ and $(002)_{FePt}$ peaks indicate all thin films are well textured. The large integrated intensity ratio of $(001)_{FePt}/(002)_{FePt}$ indicates high $L1_0$ ordering in all thin films. The order parameter is S = 0.90 for the one with only polycrystalline MgO. The MgO-C interlayer with 20, 40 volume% carbon containing films have S = 0.84, 85 respectively. The order parameter is calculated using the method of En Yang, etc.,[10] by considering the geometric features of the X-ray diffractometer, the crystallographic texture of FePt films, and film thickness. In the case of FePt-$C_{30vol.\%}$ grown on polycrystalline MgO and MgO-$C_{20vol\%}$, there are small "bumps" at $(111)_{FePt}$ and $(200)_{FePt}$ peak due to the fact that some of FePt grains grown on polycrystalline MgO grain boundaries are less ordered and misaligned. However, $(111)_{FePt}$ disappears when the MgO-$C_{40vol\%}$ interlayer is used and the intensity of $(200)_{FePt}$ reduces when the carbon content in

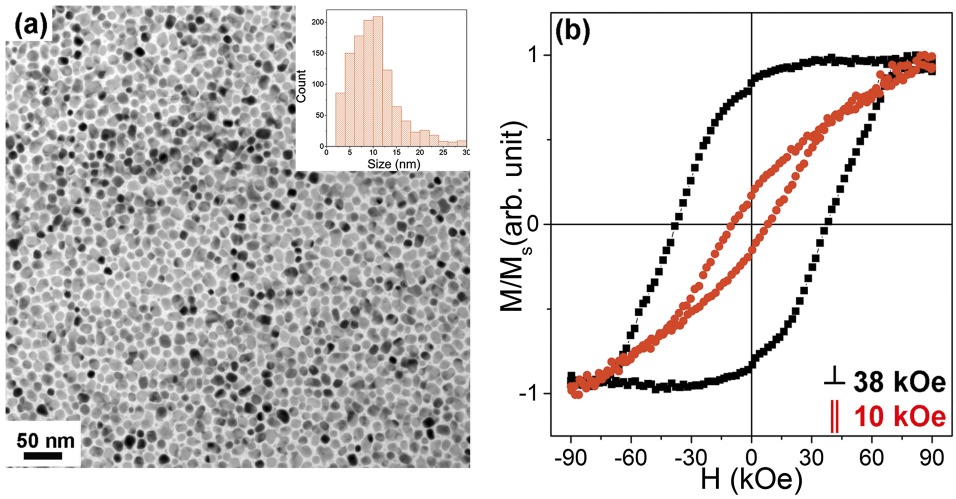

FIG. 3. (a) In-plane TEM micrographs and (b) is M-H loop of film stack with Si/SiO_2|MgO (7 nm) | MgO-$C_{20vol\%}$ (2 nm) | FePt (0.2 nm) | FePt-$C_{30vol\%}$ deposited at 30 mTorr.

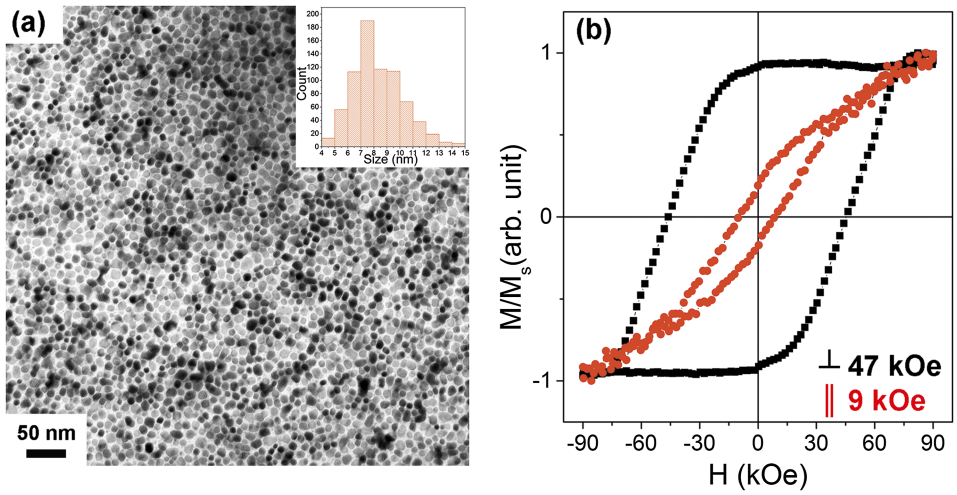

FIG. 4. (a) In-plane TEM micrographs and (b) is M-H loop of Si/SiO_2|MgO (7 nm) | MgO-$C_{40vol\%}$ (2 nm) | FePt (0.2 nm) | FePt-$C_{30vol\%}$ deposited at 20 mTorr.

MgO-C interlayer increases. This implies that FePt grains are refined by varying the carbon content in MgO-C interlayer.

The in-plane TEM micrograph shown in Fig. 3(a) is Si/SiO_2|MgO (7nm) | MgO-$C_{20vol.\%}$ (2nm) | FePt (0.2nm) | FePt-$C_{30vol.\%}$ (8nm) is the sample with 20 % carbon volume in MgO-$C_{20vol.\%}$ interlayer, a well isolated FePt grains were observed. Inset in Fig. 3(a) shows the grain size distribution estimated for the sample, which is 10.2 ± 2.5nm. Fig. 4(a), shows the optimized microstructure of Si/SiO_2|MgO (7nm) | MgO-$C_{40vol.\%}$ (2nm) | FePt (0.2nm) | FePt-$C_{30vol.\%}$ (8nm) using 40 volume% C in MgO-$C_{40vol.\%}$ interlayer deposited at 20 mTorr. The microstructure displays FePt grains with grain size of 7.6±1.9nm and well isolated grains. By tuning the MgO grain size we are able reduce the grain size as well as size distribution. From our experimental results, we can see a clear grain size reduction from 10.5nm to 7.6nm by using MgO-C interlayer with refined MgO grains, carbon content in the FePt is kept constant for all cases. By varying carbon content in MgO-C interlayer we are able to refine the FePt grainsize to 7.6nm. In the case of 40 volume % of carbon containing

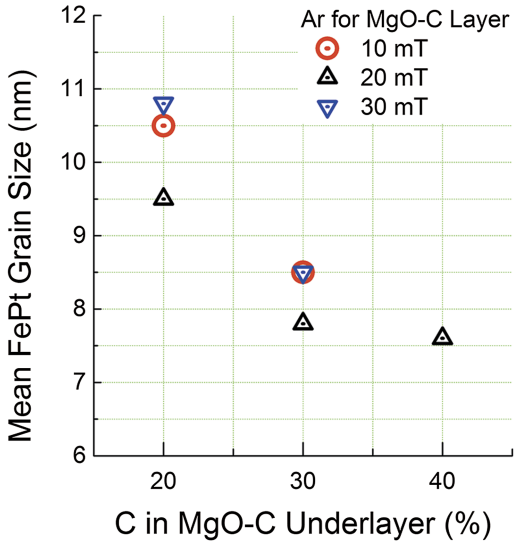

FIG. 5. Average FePt grain size in the recording layer measured as function of carbon composition in MgO-C layer at different deposition conditions.

interlayer gave smaller grain size and narrow distribution. All the films showed single layer structure from the out of plane observation (not included in this paper).

Fig. 3(b) shows in-plane and out plane room temperature moment *vs*. field (M-H) curves for the sample stack Si/SiO_2|MgO (7nm) | MgO-$C_{20vol.\%}$ (2nm) | FePt (0.2nm) | FePt-$C_{30vol.\%}$ (8nm). From the in-plane measurement we can say that this sample have strong perpendicular anisotropy with H_k of 85 kOe and $^{\perp}$ H_c of 38 kOe. This supports the XRD analysis these films have a high $L1_0$ ordering of (S=0.84). The soft kink observed at zero field can be accounted for the small grains below 3 nm size present in the film. The open loop in the in-plane measurements suggest that these samples have misaligned grains, and agree with our XRD measurements. We see "bumps" at 41° (111) and 47.7° (200) for this sample. Fig. 4(b) shows M-H loops Si/SiO_2|MgO (7nm) |MgO-$C_{40vol.\%}$ (2nm) | FePt (0.2nm) | FePt-$C_{30vol.\%}$ (8nm). Out-of-plane M-H loops of these samples have good squareness and $^{\perp}$ H_c of 47 kOe, which suggest that these films have narrow size distribution as well as good $L1_0$ ordering (S=0.85). The in-plane loop of this sample has H_c of 9 kOe, which suggests that the texture was improved for the M-$C_{40vol\%}$ templated layer.

Fig. 5 summarizes the average FePt grain size in the FePt-C layer for different carbon concentration of the MgO-C interlayer deposited at different Ar pressures while the deposition condition and the composition of the FePt-X layer remain unchanged. The significant range of the FePt grain size change by just varying the MgO-C interlayer condition along with the obtained excellent $L1_0$ ordering and good magnetic properties strongly indicates the one-on-one grain growth between the MgO-C interlayer and the FePt grain in the FePt-C layer. Further investigation is needed to confirm this hypothesis.

SUMMARY

We have developed a granular MgO-C interlayer inserted in between the (001) textured MgO underlayer and the granular FePt-C recording layer. The effect of a granular MgO-C interlayer on the microstructure, especially grain size and its distribution, of the granular recording layer has been investigated. It is found that the FePt grain size can be controlled by the deposition conditions and the carbon concentration of the MgO-C interlayer alone. The FePt-C layer shows good magnetic properties with $L1_0$ order parameter as high as S=0.85. It is reasonable to suggest that the granular MgO-C interlayer enables a one-to-one grain growth match between the MgO grains within and the FePt grains in the granular FePt-C layer directly above.

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