Mo AND W DOPPING EFFECTS ON CoCrPt RECORDING THIN FILM MEDIA

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Abstract --- In order to optimize the magnetic recording properties for CoCrPt recording thin film media, different Mo and W doping CoCrPt based magnetic thin films were fabricated by using DC magnetron sputtering method. It was observed that Mo and W doping could increase the coercivity ($H_C$), at the same time maintain lower Pt content. Sole W doping showed no apparent trend of enhancing the coercivity by rising the Mo contents. For samples with less W or Mo doping, the saturation magnetization ($M_s$) value increased significantly when we tried to further doping. This trend was preserved for different working pressure. But for samples with higher W or Mo contents, $M_s$ is unlikely to change much. It suggested that doping atoms may easily penetrate into Co rich grain core area and help Cr atom reset at the grain boundary. Evidences from X-ray diffraction study showed that lattice constants of Co were varied by more Mo doping. On the other hand, coercive squareness ($S^*$) studies found that moderate W content doping, may have less exchange coupling.

Keyword: W, Mo, doping, coercivity, $S^*$, XRD
Introduction:

Co based alloy longitudinal thin film media have evolved from binary Co based alloys [1-5] to ternary [6,10] and quaternary [11-14] Co based alloys throughout the years. Magnetic properties are constantly improved for ultrahigh density recording purpose. Addition of Cr was originally to improve corrosion resistance [5], but it was found that it can increase the coercivity and reduce the medium noise through reduction of intergranular exchange [15]. B addition to CoCrPt was found to expand the Co lattice and increase the coercivity [16]. Ta and Pt have not been found to segregate, but it was shown that Ta and Pt could enhance the magnetocrystalline anisotropy of HCP Co by alloying and expanding the lattice [17,18]. However, it was also reported that the addition of Pt has the undesired effect of increasing the average grain size [19].

To further improve the coercivity for Co based alloy, CoCrPt with Mo and W doping magnetic thin films have been proposed whose coercivity could reach as high as about 3200 Oe. With those doping elements, Pt contents in Co alloys were reduced, which has great potential for commercial application for its comparable lower cost. However, the reason why magnetic coercivity could be improved with small amount of Mo and W doping has not well understood.

In this study, we simultaneously used W and Mo as doping elements to form a matrix to optimize the magnetic coercivity in these five element thin films. Combined with related magnetic properties and detailed crystallographic study by x-ray diffractometry, we tried to understand the role of W and Mo as a doping element for improving the coercivity. Pressure dependence for various magnetic properties were also characterized.

Experiment:

W and Mo doping CoCrPt alloy thin Films were all fabricated by using a four-target DC magnetron sputtering system. Rectangular metal alloy target were used for main Co based alloys, it had the following composition (Co–80at.%, Cr–12at.%, Pt–8at.%). Pure W and Mo round chips were put in the drilled hole on the metal alloy target. The amount of doping for W and Mo elements was controlled by adding and removing identical round chips on metal alloys target. The number of chip ranges from 2 to 4 for Mo and from 5 to 7 for W. The estimated addition doping content for one Mo and one W chip was estimated 0.5 at.%. The number of chips was assumed to be proportional to the doping element content.

Co based alloy thin layer with thickness of 26 nm and Cr underlayer with thickness of 100nm was deposited on glass substrate. Negative RF substrate bias voltage (200 V) was used in the experiments. The substrate was heated to 300°C during the sputtering process. The base vacuum pressure was lower than 2×10⁻⁶ Torr. The working pressure was varied from 3 mTorr to 9 mTorr.

Crystallographic structure was checked by Philips X-pert MRD diffractometer and peak position were estimated by least-square method, where we assumed gaussian distribution of peak amplitude. D-spacing of the lattice
plane was deduced from Bragg's law equation. Relative grain size was calculated from broadened peak width the magnetic properties were detected and characterized by a DMS 1660 vibrating sample magnetometer (VSM).

Result and Discussion:

CoCrPt magnetic thin films with different Mo and W content were fabricated and the obtained coercivity was as high as 3345 Oe which is 600 Oe higher than those without any doping under the same sputtering conditions.

Fig. 1 Magnetic coercivity dependence on Mo contents for different Mo contents: a) 5 W chips; b) 6 W chips; c) 7 W chips at different working pressure from 3 mtorr to 9 mtorr

Fig. 2 Magnetic coercivity dependence on W contents for different W contents: a) 2 Mo chips; b) 3 Mo chips; c) 4 Mo chips at different working pressure from 3 mtorr to 9 mtorr
Magnetic coercivity dependence on Mo doping content and W doping content was shown in Figure 1 and Figure 2. It is observed that $H_c$ dropped unanimously with increasing Mo contents. Especially for low W content, coercivity lost about 50% at 3 mTorr working pressure. But W content variation did not show any significant decrease for low Mo contents, except for higher W contents. On the other hand, high working pressure for magnetic layer seemed has negative effect on improving $H_c$. This can be understood based on the structure zone model (SZM) developed by Thoronton [20], which predicted that higher pressure induced smaller...
grain size. When grain size were smaller, number of superparamagnetic domains would be increased to reduce the coercivity.

Saturation magnetization dependence on W and Mo doping was shown in Figure 3. and Figure 4. At lower W or Mo contents, saturation magnetization (M_s) increased significantly (5–7 times increase) with increase in their doping content. This trend was well preserved at a wide range of sputtering working pressure from 3 mtorr to 9 mtorr. But for samples with higher W or Mo contents, high M_s value was not observed. It indicated that Mo and W could affect Co rich grain core area by penetration or they could help to dodge the Cr atoms to the grain boundaries.

Typical x-ray diffraction spectrum (4 Mo and 5 W chips prepared at 9 mtorr working pressure) was shown in Figure 5. Various bcc Cr and hcp Co peaks were observed. Corresponding calculation for those spectrums showed a relative grain size dependence on doping in Figure 6. W had different influence on grain growth for two types of Mo contents. Higher Mo doping led to larger grains and grain size was enlarged for further W doping. The result was opposite functioned for lower Mo contents.

Both a axis and c axis lattice constant for HCP Co was estimated from raw x-ray peaks position. It was found that a axis lattice constant did not change much for different W and Mo doping. However, c axis lattice constant altered significantly. In case of lower Mo doping, c axis lattice was monotonously compressed. It could be due to the element with
larger atomic radius getting out from Co-rich grain core area. Using this effect, saturation magnetization increase as a function of W and Mo doping could be explained. Alternatively, in the case of high Mo doping, W could not monotonously modify the lattice constant, which may indicate it had reached the limitation of W intermetallic solubility with this Co alloy. To clarify the above mechanism, $S^*$ was also measured for different doping condition. It was found that $S^*$ decreased for moderate W content, which reflected better decoupling of magnetic interactions. In this doping region, coercivity properties was optimized for most working pressure, which indicate that W would repress the movement of large element atoms that is harmful to further improve the coercivity.

Summary:

W and Mo doping played a very important role in Co alloy magnetic thin films. We charaterized the magnetic properties at different doping conditions and achieved optimized coercivity as high as 3345 Oe. Analysis of crystallographic structure properties obtained from x-ray diffraction and comparison of different relationship for saturation magnetization, W and Mo was found to have ability to draw out large atoms from Co-rich grain core area before it reached the limitation. This process helped to improve the coercivty at lower doping contents. Grain size dependence on doping content and coercive squareness was also charaterized and discussed.

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Reference: