Ultra-Low Noise Properties of Co-Pt and SiO₂ Granular Magnetic Recording Media

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Abstract—The disk characteristics of granular media comprising Co-Pt and SiO₂ have been examined to demonstrate their high-density recording capabilities. The grain size increased when RF-bias was applied during sputtering. A coercivity was 2 kOe at a magnetic moment (Mrt) of 0.4 memu/cm² and a Co-Pt content of 50vol.% when a Cr seed layer used. The mean grain size was less than 10 nm and the grains were thoroughly isolated in the SiO₂ matrix. The normalized media noise was less than 10⁻⁷ µVrms/µVpp up to 200 kfcI. Transition patterns of more than 200 kfcI were clear at a track-width of 1 μm. The surface roughness was similar to that of a bare glass substrate. No degradation in magnetic properties was observed after 1000 hrs. in an 80°C-75% R.H. environment.

I. INTRODUCTION

The storage density of hard disk drives (HDDs) has been increasing by about 60% per year in recent years [1]. Magneto-resistive (MR) heads promote improvements in storage density, since they are relatively more sensitive to signal fields from the media. The key media issue is the reduction of recording noise in taking full advantage of MR heads. Recording noise results from inter-granular coupling between magnetic grains [2], and several attempts have been made to reduce this coupling in Co-Cr based metal media. These include the adoption of Cr seed layer and the selective-diffusion of Cr-based non-magnetic materials to the grain boundary [3]. On the other hand, the adoption of a granular structure is regarded as another potentially effective approach to achieving low-noise media. Granular media consist of fine magnetic particles dispersed in a non-magnetic matrix, such as SiO₂ or C [4]. Inter-granular coupling is expected to be extremely low, since the magnetic particles are physically separated by the matrix. Good mechanical durability can also be expected since a hard material can be used as the matrix. The authors have attempted to utilize Co-Pt as the magnetic particles in a granular media, since Co-Pt is large in both magneto-crystalline anisotropy and saturation magnetization [5]. In this paper, the ultra low-noise properties of granular media comprising Co-Pt and SiO₂ are described. The surface roughness and environmental durability are also presented to demonstrate the material’s basic capabilities as regards proximity recording.

II. EXPERIMENTAL

The granular media were prepared by magnetron co-sputtering using a Co-20at.%Pt target and an SiO₂ target simultaneously. Figure 1 is a schematic drawing of the sputtering apparatus used in the study. Substrates revolved on the rotating holder. The volume content of Co-Pt particles in the granular film was controlled by the sputtering power to the individual targets. RF-bias was applied during sputtering so as to control the size of the Co-Pt particles. Table 1 shows typical sputtering conditions used in the study.

Fig. 1 Schematic drawing of sputtering apparatus used in this study.

<table>
<thead>
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<th>Table 1 Sputtering conditions for granular media</th>
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<tr>
<td>Ar gas pressure / flow rate</td>
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<tr>
<td>Substrate revolution speed / rotation speed</td>
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<tr>
<td>Input power to Co-Pt target</td>
</tr>
<tr>
<td>Input power to SiO₂ target</td>
</tr>
<tr>
<td>Deposition rate</td>
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<td>Substrate bias power density</td>
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Measurements of electrical resistance were carried out to make a basic interpretation of the isolation of the magnetic particles. Magnetic properties were measured using a vibrating sample magnetometer (VSM) and a torque magnetometer. The film micro-structure was observed by cross-sectional transmission electron microscope (TEM) and the nano-scale composition was analyzed by energy dispersion X-ray analyzer (EDX). Signal and noise characteristics were measured with a spin-stand type of apparatus. The magnetic profile of the recording domains was observed by magnetic force microscope (MFM). Finally, the surface roughness of the media was measured with a surface-analyzer.

III. RESULTS AND DISCUSSION

The surface resistance of a granular film deposited on a 1cm-square glass substrate exceeded $10^6 \Omega$ when the volume content of Co-Pt was less than 60 vol.%. The authors interpret this as meaning that the metal grains are isolated by the $\text{SiO}_2$ matrix in this composition range. For Co-Pt contents above 50 vol.%, a large in-plane coercivity ($\geq 2\text{ kOe}$) was obtained when RF substrate-bias was applied during sputtering.

Figure 2 shows TEM overviews of the granular films. The samples were thinned by milling before TEM observation in order to avoid the overwrapping grains along the thickness direction. The size of the Co-Pt grains was Super-paramagnetically small when no substrate-bias was applied, whereas the grains grew as ferro-magnets when bias was applied. The impingement of energetic Ar ions during film formation seemed to promote the surface-migration of sputtering atoms and to enhance the grain-growth.

Figure 3 shows coercivity as a function of granular film thickness. Open symbols: data without Cr seed layer; closed symbols: data with Cr seed layer.

The initial growth of Co-Pt grains was enhanced by the use of the Cr seed layer.

Figure 4 shows a cross-sectional view of the granular media (a) and the micro-composition of the film (b). Conical-shaped grains grew in contact with the Cr seed layer and spherical grains grew surrounded by the $\text{SiO}_2$ matrix. Both grain types comprised close to Co-20at.%Pt, which coincides with the target composition. The impurity level in the grains was below the analytical limit of EDX. The grain-boundary was mostly stoichiometric $\text{SiO}_2$. Levels of Co and Pt in the matrix were only several atomic percent. The spotty electron-diffraction pattern indicates that the grains were hcp-crystallites with a random-orientation of the c-axis. Torque-loss measurements showed that the anisotropy field was 8 kOe. The index of the thermal-stability ($\nu\text{Ku/kT}$) at room-temperature was estimated to be about 100. Elevated-temperature VSM measurement showed that the ferro-magnetic properties were maintained up to 200°C.
Figure 5 shows the normalized media noise (Nml/S0) as a function of linear density. The granular media exhibit a value less than $10^{-3}$µm$^{1/2}$µVm/µVpp up to 200 kfc. This is distinctly lower than the noise of conventional metal media, as shown in Fig. 5. The bit error rate was $2 \times 10^{-8}$ at 220 kfc, which was one order of magnitude less than that of metal media. MFM observations showed that transition patterns of more than 200 kfc were clear even with a recording track-width of 1µm. Figure 6 shows the surface roughness of the granular media along with a bare glass substrate for comparison. The maximum roughness was less than 4 nm in a short-range scan. A flying height of 20 nm was also obtained in a long-range head-scan. Thus the granular media poses no particular problems as regards proximity recording. Furthermore, an accelerated life test indicated that no degradation in magnetic properties occurred after 1000 hrs. in an 80°C-75%R.H. environment. The disk characteristics of granular magnetic recording media comprising Co-Pt and SiO$_2$ have been examined to demonstrate their high-density recording capabilities. Grains grew under an RF-bias during sputtering due to enhanced surface migration by energetic Ar ions. A coercivity was 2 kOe at an Mrt of 0.4 memu/cm$^2$ and a Co-Pt content of 50vol.% when a Cr seed layer was used. Cross-sectional TEM analysis showed that the grains were thoroughly isolated in the SiO$_2$ matrix. The grains were hcp-crystallites with random orientation, and the anisotropy field was 8 kOe. The normalized media noise was less than $10^{-2}$µm$^{1/2}$µVm/µVpp up to 200 kfc. Transition patterns of more than 200 kfc were clear at a track-width of 1µm. The maximum surface roughness was less than 4 nm. No degradation in magnetic properties was observed after 1000 hrs. in an 80°C-75%R.H. environment. The Co-Pt and SiO$_2$ granular media are considered promising candidates for high-density recording HDDs.

REFERENCES


IV. CONCLUSION