Effects of Preparing Conditions on the Recording Properties of Double-layered Perpendicular Rigid Disk

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Abstract---The isolation of magnetic intergranular coupling is a great importance in the latest high density media. In order to attain this, a small quantity of nitrogen was added to CoCr thin film during sputtering deposition, which brought both increment of coercive force (He) and reduction of the coercive force (He) dispersion. It is due to a decrease of grain size and magnetic isolation of each grain. Consequently it is confirmed that the reproduced output voltage and Dso is improved, but on the other hand media noise is enhanced with increasing nitrogen addition. The origin of this media noise enhancement will be also discussed.

I. Introduction

In longitudinal thin-film media, the signal-to-noise ratio (SNR) suffer from the media noise, which increases with recording density [1]. This noise originates from the zig-zag wall transition due to intergranular exchange coupling, and films with well defined non-magnetic grain boundaries exhibit better SNR [2][3]. On the other hand, in perpendicular media, the experimental results of low transition noise has been confirmed in CoCr thin-film media [2][4].

The control method of fine structure parameters has been investigated in order to improve recording property at high recording density, such as grain size, magnetic isolation of each grain and crystallographic orientation of the CoCr layer of perpendicular rigid disk. An ideal CoCr layer consists of perpendicularly oriented fine-grains which are isolated magnetically each other. In addition, it has been suggested that narrow Hk dispersion of CoCr layer is desirable to improve the high density recording performance [5].

A number of literatures have been published about a few kind of impurity gases which affect the crystallinity and the magnetic property of sputtered thin film [6][7][8]. The effects of excessive nitrogen addition on CoCr thin film have been described in some literatures; it degrades the crystallographic orientation and the perpendicular anisotropy [6][7]. It has been reported by Ouchi et. al. that the proper quantity of nitrogen addition rather enhances the perpendicular anisotropy [6].

In this work, the effects of nitrogen addition on high density recording property was investigated with regard to a decrease of grain size and a magnetic isolation of each grain with nitrogen addition during the CoCr deposition.

II. Experimental and Discussion

(a) Crystallinity and Surface morphology

Disks were prepared by RF sputtering on 3.5" glass substrate; Cr under layer of 30nm, NiFeNb back layer of 1μm, CoCr recording layer of 80nm, SiO2 protective layer of 4nm, in order. The CoCr layer was deposited at substrate temperature 200℃. Back ground pressure of 3X10⁻⁷Torr was established before introducing Ar gas. Nitrogen gas ranged 0.05~0.3% of the Ar gas pressure was added. The NiFeNb underlayer showed a preferential fcc(111)
Table.1 Crystallographic and magnetic parameters

<table>
<thead>
<tr>
<th>N₂/Ar (vol.%)</th>
<th>CoCr hcp(00.2)</th>
<th>Lattice parameter(Å)</th>
<th>Peak intensity (a.u.)</th>
<th>Δθ50</th>
<th>Ms (emu/cc)</th>
<th>HcL(Kerr) (Oe)</th>
<th>ΔHc/HcL(Kerr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>2.029</td>
<td>79.9</td>
<td>3.0</td>
<td>514</td>
<td>1380</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>0.05%</td>
<td>2.035</td>
<td>87.1</td>
<td>3.1</td>
<td>499</td>
<td>1764</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>0.1%</td>
<td>2.038</td>
<td>74.7</td>
<td>3.3</td>
<td>478</td>
<td>1704</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>0.3%</td>
<td>2.043</td>
<td>69.5</td>
<td>3.6</td>
<td>474</td>
<td>1056</td>
<td>0.17</td>
<td></td>
</tr>
</tbody>
</table>

orientation with typical rocking curve widths of Δθ50 ~4.5° and a soft magnetic property with Hc~0.15Oe.

Table-1 shows the measured crystallographic and magnetic parameters of CoCr layer. The lattice parameter of hcp(00.2) increases gradually with increasing nitrogen concentration, therefore the additive nitrogen is included in the CoCr lattice. The X-ray diffraction peak intensity and Δθ50 about hcp(00.2) slightly changed up to 0.3%N₂ concentration (N₂ pressure~5X10⁻⁶Torr) of the introducing Ar gas pressure. These data show that the crystallinity of CoCr isn’t almost degraded up to 0.3%N₂ concentration.

The surface morphology were observed with contact atomic force microscopy(contact-AFM) to investigate the effect of nitrogen addition on the fine structure of CoCr thin film. Fig.1 shows the distribution of the CoCr grain diameter measured from the contact-AFM image.

Without nitrogen addition some grains grow so large about 100nm. However, with increasing nitrogen addition the mean diameter became smaller and the distribution of grain diameter became narrower. The nitrogen seems to inhibit grain growth and contribute the uniformity of the grain diameter.

(b) Magnetic property

Kerr hysteresis loops were measured to evaluate Hc and Hc dispersion on the disks. The Hc dispersion is represented by the ΔHc/Hc which was measured using the minor loop method proposed by Tagawa and Nakamura [9]. Saturation magnetization(Ms) was measured with VSM. As shown in Table-1 the Ms values gradually decrease with increasing nitrogen concentration, which is only slightly changes.

Fig.2 HcL and ΔHc/HcL by Kerr effect as a function of nitrogen concentration

However, Hc and ΔHc/Hc values drastically changes as a function of nitrogen concentration as shown in Fig.2. About 0.05% nitrogen addition leads to the increase of Hc value and the minimizing Hc dispersion which is suitable for perpendicular magnetic recording.

The narrow Hc dispersion can be explained from the fact that the uniformity of grain diameter is improved. The increase of Hc value with nitrogen addition suggests that the additive nitrogen contributes to the magnetic isolation of each grain. These results mean that it’s possible to improve magnetic property for high density recording media with an appropriate nitrogen addition.

(c) Recording property and media noise

A single pole head with a FeSi/SiO₂ multi-layered thin film (Tm:0.25µm, Tw:29µm, N:50turns) was used to evaluate recording characteristics, here the linear velocity was 2m/s. Fig.3 shows normalized output voltage at each recording density (20,80,120kFRPI) as a function of additive nitrogen concentration. At the 0.05% nitrogen concentration the output voltage has maximum value, and decreases with excess nitrogen addition. Plots of D₅₀ show the same tendency as the output (Fig.4).
These results almost correspond to the trend of the change of the Hc and the ΔHc/Hc values as increasing nitrogen concentration. But the minimum of ΔHc/Hc strictly doesn't correspond to the maximum of Dso, which may be caused by another parameter, for example an effect of CoCr initial layer not to contribute to Kerr effect.

On the other hand, with nitrogen addition the isolated reproduced waveform come to have a clear under-shoot as shown in Fig.5. Perpendicular recording media generates the demagnetizing field due to shape anisotropy under the uniformly magnetized state in one direction. As this demagnetizing field is eliminated near a sharp magnetic transition, a relatively strong perpendicular magnetization remains there (Fig.5(a)). Fig.5 (b) and (c) show models of transition magnetization configurations expected from the reproduced waveform. Because an existence of intergranular exchange coupling forces magnetization of each grain to keep parallel, the magnetization vector can't incline greatly against neighboring magnetization vector. As a result the magnetic transition comes to be smooth. Although under the magnetically isolated grains, a transition is formed sharply, and the perpendicular magnetization is demagnetized quickly as far from the transition. This quick decay of magnetization causes the under-shoot of reproduced waveform. Therefore it's concluded that the wave forms shows a clear under-shoot because of the magnetic isolation of each grain with nitrogen addition.

Besides our perpendicular media shows a broad noise peak around about 2MHz under the dc-erased state (Fig.6(a)). The dc-erased noise increases with nitrogen concentration. In this figure the noise decrease drastically at about 5MHz, which is caused by the wavelength response of the head, referred to as main pole thickness loss. And the expansion of noise spectrum is confirmed corresponding to increasing disk liner velocity, therefore the origin of this noise is peculiar to the media. The shape of noise spectra suggests that the noise arise from something of long range ordered magnetic inhomogeneity. Since the dc-erased state is magnetostatically unstable for perpendicular magnetization mode, this magnetic inhomogeneity would originate from some ripple structure.

Because perpendicular magnetization mode is stable at high density, it will be expected that this fluctuation of magnetization will be reduced by recording high density bit pattern. Fig.6(b) shows the noise spectra at 200kFRPI. The high noise level under dc-erased condition has reduced at 200kFRPI. This tendency is remarkable for a higher nitrogen concentration. As mentioned above, nitrogen addition reduce the intergranular exchange coupling. As a result the magnetization of each grain is mainly dominated by magnetostatic force, and the ripple structure may be enhanced as shown in Fig.7.

For the 0.05% nitrogen addition, media SNR is improved about 2dB at 120kFRPI, although it decreases about 2dB at low density because of the increase of the media noise.
III. Conclusion

From the contact-AFM observation on the CoCr thin film, nitrogen addition during the deposition contributes to a prevention of grain growth and uniformity of grain diameter. Hc value has a maximum, and Hc dispersion is narrower with the appropriate nitrogen addition (0.05%). Probably small addition of nitrogen up to 0.1% contributes mainly to magnetic isolation of each grain, and excess addition of nitrogen above 0.1% reduces perpendicular anisotropy. To verify the above conclusion, a precise magnetic measurement must be required with single layer CoCr thin film.

As a result output voltage and Dso was improved with nitrogen addition. And the media SNR was improved about 2dB at 120kFRPI.

The mechanism of this media noise origin hasn't yet come to be clear. The media noise should decrease at narrow track and high liner density in principle of perpendicular recording. For the purpose it may be effective to thin the CoCr layer thickness in order to sharpen the perpendicular head field.

From the contact-AFM observation, it was found that our CoCr grain diameter was still relatively large about 50nm. The decrease of the grain diameter will be effective to the noise reduction. Some literatures have been published about noise reduction with making growth fine grained CoCr heteroepitaxially on the fine grained NiFe under layer[10][11].

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References