Investigation of hard drive disk surface oxidation on magnetic recording properties

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Hard drive disk magnetic recording properties are strongly related to disk surface oxidation, and becomes more sensitive as the areal recording density continues to increase progressively in hard disk drives. Disk cleaning processes with and without H_2O_2 chemical cleaning solutions were used on textured NiP/Al substrates to study the effects of surface oxidation on the performance of the hard disk. Atomic force microscopy, magnetic force microscopy, X-ray diffraction, X-ray photoelectron spectroscopy, vibrating sample magnetometer and Guzik are employed to elucidate the surface morphology, oxide composition, magnetic orientation ratio and related magnetic recording properties.

Based on the results, cleaning without H_2O_2 chemical solutions offers a lower surface oxidation, more uniform surface morphology, higher orientation ratio and better magnetic recording properties as compared to cleaning with H_2O_2 chemical solutions. A lower direct current erase noise is the major contributing factor for the resulting signal noise ratio improvement when H_2O_2 was not added in cleaning process.

Keywords: Hard drive disk, Surface oxidation, Orientation ratio, Magnetic properties

Introduction

The magnetic recording properties, such as read/write signal to noise and media noise, are strongly related to disk surface oxidation, and as the areal recording density keeps increasing progressively on hard disk drives, most disk makers are focusing on sputter alloy compositions and perpendicular media to achieve the required magnetic recording performance.[1–7] It has not been explored yet whether reducing surface oxidation through the disk cleaning process can make a contribution in magnetic improvement. Magnetic recording properties are strongly related to orientation ratio which is controlled by the following three primary factors:

(i) the circumferential texturing process[8,9]
(ii) the crystallography of the layered structures[10,11]
(iii) the surface oxidation[12] of textured NiP/aluminium substrate after the cleaning process.

In order to increase the density longitudinal recording, an increase in the media orientation ratio (OR) has been proposed. Experimental data show that medium with high OR has higher signal to noise ratio (SNR).[13] Reducing the surface oxidation becomes very important when the disk surface roughness is lowered to an ultra smooth morphology (AFM R_a<0·5 nm). The purpose of this study is to reduce disk surface oxidation by using a H_2O_2 free cleaning process to improve the magnetic recording properties.

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Experimental

Mechanical texture NiP/Al substrates were created with texturing tape and slurry combinations (diamond and coolant) using an electronic distance control texture machine. Then, textured NiP/Al substrates using two kinds of cleaning processes, to remove slurry and contamination in addition to detergent, were investigated in this paper. The solution composition ratio of two cleaning processes for disks A and B are $H_3PO_4/H_2O_2/H_2O=1:1:3$ and $H_3PO_4/H_2O=1:4$ respectively. The major difference between the two cleaning processes is disk A with 20% concentration H_2O_2 chemical solution and disk B without H_2O_2 chemical solution. After cleaning, all disks were sequentially deposited with a 3 nm CrMo under layer, 2·8 nm CoCr stabilising layer, 1·5 nm Ru layer, 15 nm CoCrPtB based magnetic layer and 2·5 nm hydrogenated carbon overcoat using an Intevac 250b disk direct current (dc) sputtering system, and then were dip coated with a 1·4 nm lubrication layer on the disks. Atomic force microscopy (AFM) was utilised to characterise the textured surface morphology. Magnetic force microscopy (MFM) was used to observe the signal and dc erase images of disks. Vibrating sample magnetometer was used for the measurement of hysteresis loop and magnetic OR. Direct current erase spectrum and related magnetic recording properties were measured using a Guzik write/read tester. X-ray photoelectron spectroscopy was used to measure the surface composition of disks. An XRD spectrum was employed to elucidate the crystallography structures of disks A and B. The effects of surface oxidisation and surface morphology on crystallography

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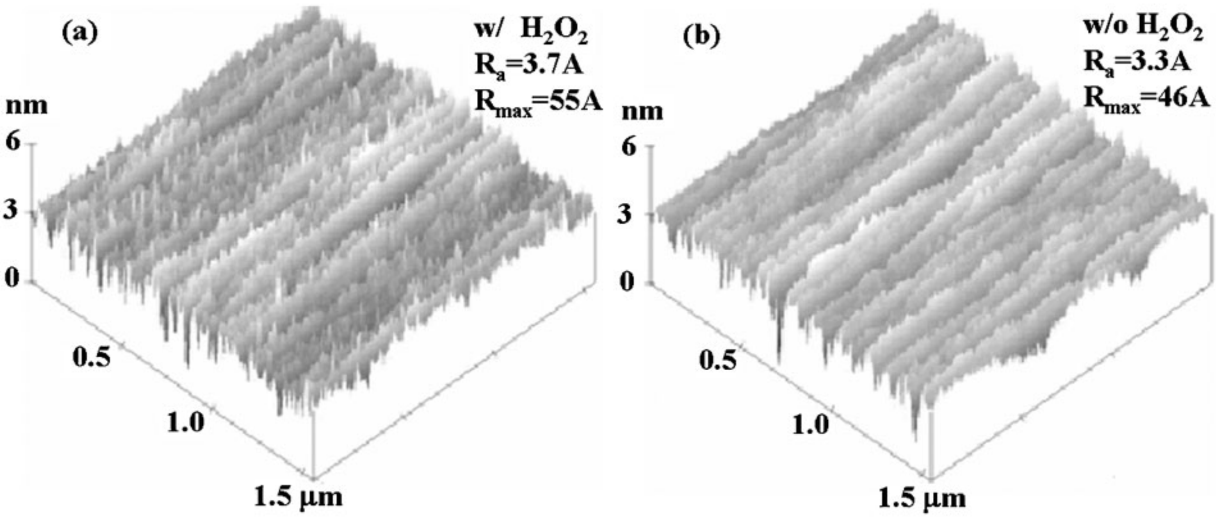


1 Atomic force microscopy surface morphology of *a* disk A and *b* disk B

structure have been studied as well as OR and magnetic recording properties using the two kinds of cleaning processes.

Results and discussion

Surface morphology and oxidation

Figure 1*a* and *b* shows the surface morphology of disk A (with H_2O_2) and disk B (free H_2O_2) by AFM. In Fig. 1*a*, there are many asperities found on the disk A surface, resulting from using a clean process with H_2O_2. The major difference in cleaning between disks A and B is disk A with 20% concentration H_2O_2 chemical solution. Because of the higher H_2O_2 concentration in disk A cleaning process, the etching by H_2O_2 causes an oxidised NiP surface, which in turn makes the surface asperities easier.

Disk B exhibits a smaller surface roughness of 3·3 Å R_a and 46 Å R_{max} than that of disk A. It shows that the R_{max} is increased dramatically from 46 to 55 Å for disk A, revealing that disk A is much more inclined to the surface oxidation phenomena after H_2O_2 cleaning. On the other hand, when cleaning using free H_2O_2 chemical solution, it is therefore expected to offer lower surface oxidation when compared to disks with cleaning processes containing H_2O_2. As shown in Table 1, the O (oxygen) atomic percentage of disk A is 42·9 which is higher than that of B (41·4), thus indicating that the NiP surface layer of disk A is more oxidised than that of disk B.

It is well known that mechanical texturing on NiP plated Al substrates induces a magnetic anisotropy on a medium, which is called anisotropic medium or oriented medium. The OR is a parameter that characterises the directional preference of the magnetic properties of a recording medium. It can be defined as the ratio of the remnant magnetisation M_r or the coercivity H_c, or the coercive squareness S^* along the circumferential direction to the along the radial direction.

Table 1 Surface compositions of disks A and B, at.-%

Disk	C	N	O	P	Ni	Ni/P
A	12·8	0·2	42·9	10·6	33·5	3·2
B	14·0	0·3	41·4	10·4	33·9	3·2

The origin of the magnetic anisotropy induced by mechanical texturing process has been studied experimentally.[14] The possible mechanisms such as shape anisotropy due to shadowing effect during film growth, preferred orientation of Cr (100) and Co (1120), C axis alignment and stress effect, etc. are discussed by Johnson *et al.*[15]

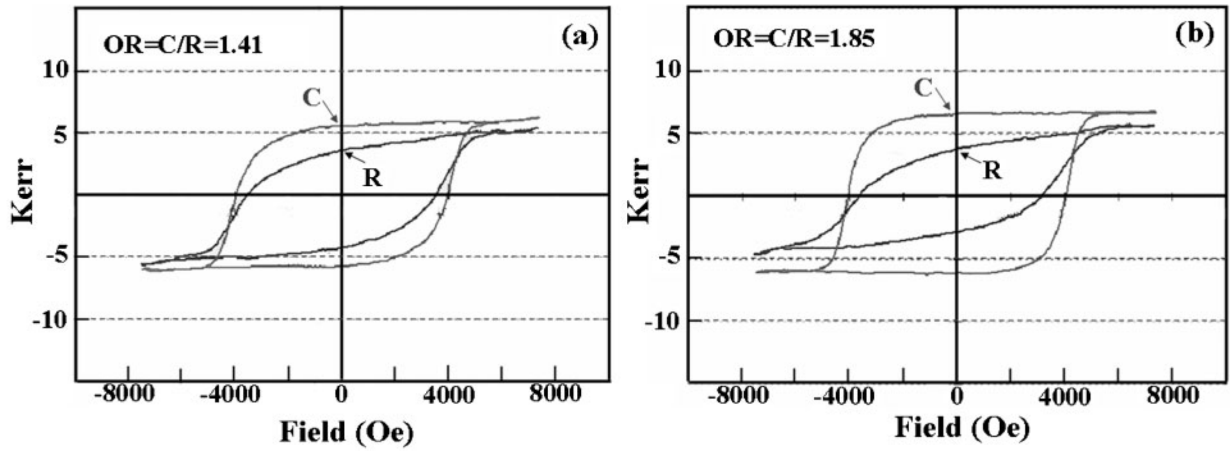
Mechanical texturing process is a process to generate circumferential texture patterns (grooves) on the NiP surface with tape and diamond slurry. Its potentiality of better surface morphology performance is considered to meet the magnetic alloy deposition requirement of longitudinal recording. It has been demonstrated that the texturing process induces preferential in plane alignment along the texture line grooves[16] and distribution of the magnetic coupling at the texture lines.[17]

Circumferential and redial direction of hysteresis loop of disks A and B is shown in Fig. 2. The OR, being used to characterise the anisotropy of the media, is the ratio of the remnant magnetisation along the circumferential direction to that along the radial direction. The reason for using this OR is because it is difficult to extract coercivity and S^* correctly from the hysteresis loop of an antiferromagnetic coupling medium. The OR is 1·41 for disk A and 1·85 for disk B. Disk B's OR is 30% higher than that ofdisk A. This is attributed to the surface morphology of disk A (with H_2O_2) surface having many asperities resulted from the surface oxidation phenomena after H_2O_2 cleaning. Usually, clear and uniform texture patterns result in higher OR.[18] This result indicates that surface asperity induced by H_2O_2 utilisation in the cleaning process can cause a lower OR value.

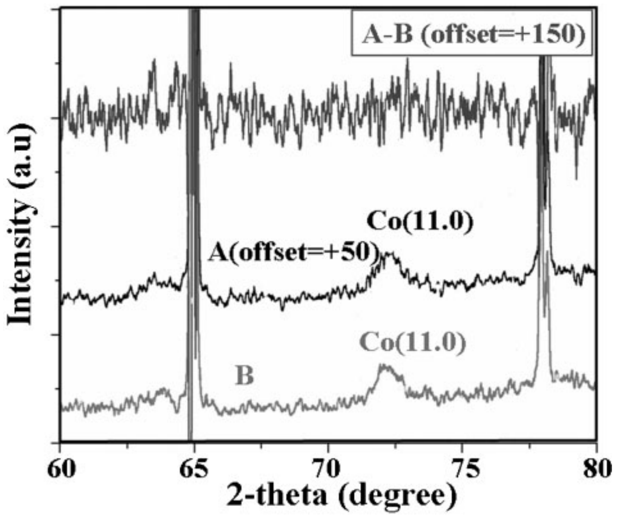
Magnetic recording performance

Magnetic recording properties are strongly related to OR which in turn is controlled by the surface morphology and oxidation of textured NiP/aluminium substrate after the cleaning process. Figure 3 shows the XRD diffraction spectrum of disks A and B. It does not find a significant difference between disks A and B, in terms of crystallography structures of Cr (200) parallel to Co (11·0).

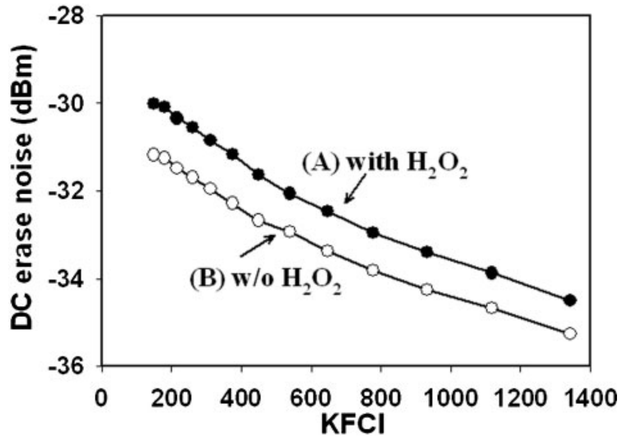
However, comparing the magnetic parameter peformance of disks A and B, as listed in Table 2, when given



2 Circumferential and redial direction of hysteresis loop of *a* disk A and *b* disk B



3 X-ray diffraction spectrum of disks A and B



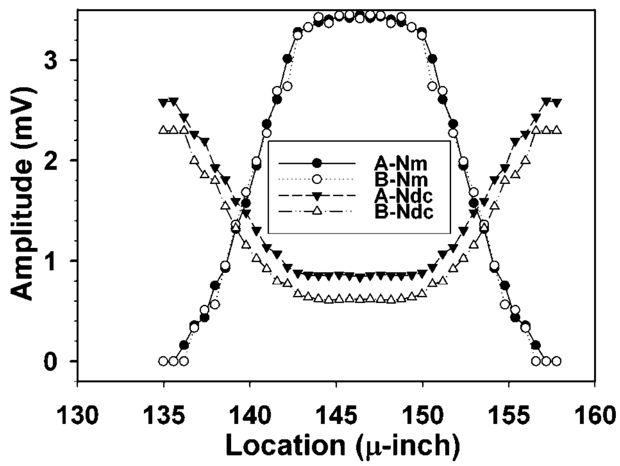
4 Direct current erase noise versus different KFCI of disks A and B

the same H_c (4400 Oe) and M_r (0·39 memu cm^{-2}). Note that spectral SNR is the signal to integrated noise ratio, PW is the width of an isolated pulse at 50% of amplitude and LF is the signal measured in low frequency of 70 mHz respectively. The Spectral SNR has good correlation with OR that indicates the high OR results in low dc noise, as shown in Fig. 4. Therefore, the sample with higher OR has higher signal to noise ratio. Disk B shows a higher signal at low, middle and high frequencies respectively, and a narrower PW_{50} compared with disk A. More importantly, a 1·0 dB spectral SNR improvement was found with disk B using the free H_2O_2 solution.

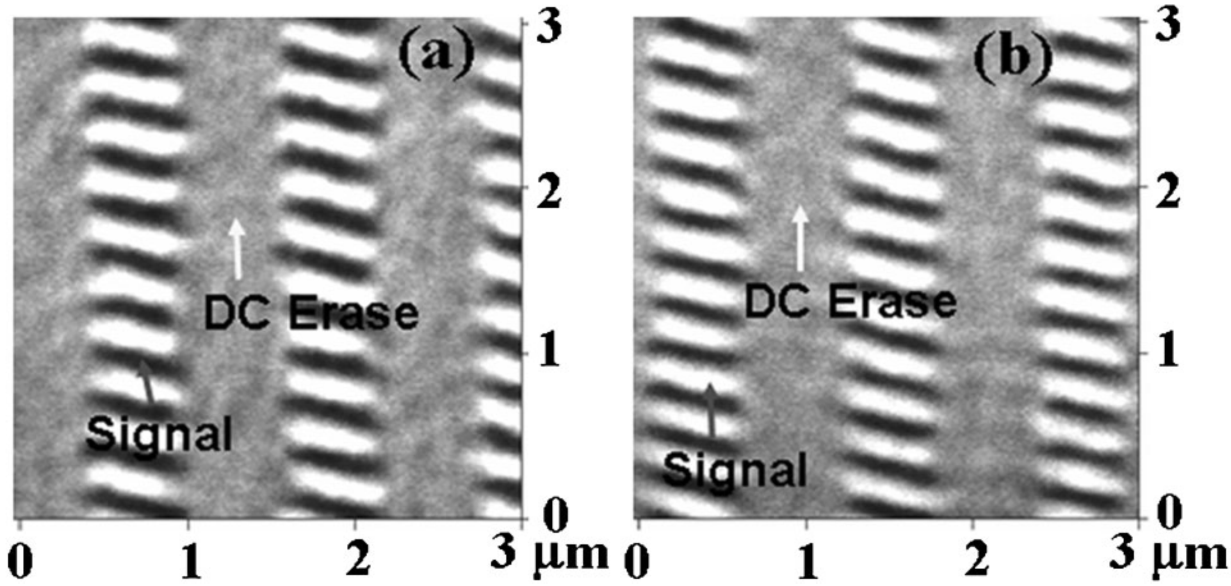
Further studying the dc erase noise at various KFCI shows that there is ~1·0 dB difference between disks A and B, as shown in Fig. 4. Guzik RWA combined with Guzik spinstand technique is used to measure the off track media noise N_m and dc erase noise N_{dc} at various radial locations. Figure 5 shows that there is no significant difference of media noise N_m between disks A and B, but disk B has a lower dc erase noise. Figure 6 shows the MFM images of disks A and B. In disk A, the dc erase noise tracks show more obvious contrast when comparing with disk B, revealing that the dc erase noise of disk A is higher than that ofdisk B. The dc erase noise has good correlation with OR. That indicates that the higher OR results in a lower dc erase noise which in turn leads to a high spectral SNR. Therefore, disk B with a higher OR has a higher Spectral SNR. This result

Table 2 Parametric data of disks A and B

Disk	HF, mV	MF, mV	LF, mV	PW, nm	Spectral SNR, dB
A	0·406	0·878	1·220	164·3	17·48
B	0·425	0·914	1·270	161·0	18·42



5 Off track media noise N_m and dc erase noise N_{dc} of disks A and B at different radial locations



6 Images (MFM) of *a* disk A and *b* disk B

suggests that a better magnetic performance can be achieved using a free H_2O_2 cleaning process.

Conclusions

The surface roughness decreased from R_a=3·7 Å (R_{max}=55 Å) to R_a=3·3 Å (R_{max}=46 Å) using free H_2O_2 chemical solution in the cleaning process. Reducing the disk surface oxidation using the free H_2O_2 cleaning process, can improve the OR and dc erase noise. The major factor that causes the improved Spectral SNR in this cleaning process is the dc erase noise reduction.

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