Reliability of Perpendicular Magnetic Recording Media

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1. Introduction

Perpendicular magnetic layer technology that provides low-noise and high recording density is a fundamental technology for perpendicular magnetic recording media, but in order to ensure good reliability in an actual hard disk drive (HDD) device, the substrate, cleaning technology, soft underlayer, protective layer, etc. must be optimized for use with perpendicular magnetic recording media. This paper describes the design of the substrate and soft underlayer, and the cleaning technology and protective layer technology, including the HDI (head-disk interface) technology, for use with perpendicular magnetic recording media.

2. Substrate and Soft Underlayer Design for Use with Perpendicular Magnetic Recording Media

The substrate and soft underlayer designed for use with perpendicular magnetic recording media are technical components that support the recording density of perpendicular magnetic recording media. The soft underlayer constitutes a magnetic circuit together with a recording head, and functions to enhance the recording resolution by causing an abrupt change in the strength of the head's magnetic field applied to the magnetic recording layer and in the magnetic field gradient when a magnetized bit is being written. However, since the soft magnetic material has low magnetocrystalline anisotropy, it is susceptible to the effects of shape anisotropy, and depending on the shape of the substrate surface, a complicated structure with many different separated magnetic domains, each having their own magnetic orientation, is likely to result. A large magnetostatic leakage field occurs at the boundaries (domain walls) between magnetic domains, causing a large noise known as "spike noise" when a signal is being reproduced.

In conventional longitudinal magnetic recording media, the media is textured in the circumferential direction in order to make it anisotropic in that direction. However, when this type of textured substrate is used in perpendicular magnetic recording media, the aligning of the soft underlayer in the circumferential direction creates a problem. This is because the soft underlayer is affected greatly in the direction of the shape anisotropy, and the easy axis of magnetization could become aligned in parallel with the grooves of the texturing. The soft underlayer aligned in the circumferential direction forms a 180° domain wall at a location in the circumferential direction. A large magnetostatic leakage field is generated from the domain wall, and this creates spike noise during signal playback. Figure 1 shows mapped envelopes of the playback signal. When looking at the output waveform, the waveform appears to be stepped, and thus is not suitable for perpendicular magnetic recording media.

For perpendicular magnetic recording media requiring a recording density of 150 Gbits/in^2 or above, a greater degree of surface flatness than ever before is needed. Also, in terms of tribology, when roughness is reduced so that the surface becomes flat, frictional force increases and takeoff performance deteriorates. "Takeoff performance" describes the performance of a magnetic head, after have crashed, flying over the media surface again.

In order to satisfy these requirements, a surface that is flat and random, with high uniformity is required. In consideration of these requirements, Fuji Electric has developed technology for controlling ultraflat random roughness.

Using this technology, various characteristics were

Fig.1 Envelope map of reproduced signal

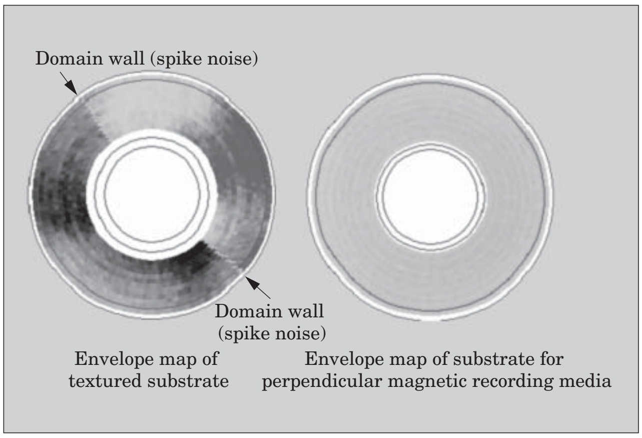


Fig.2 Surface roughness vs. flying characteristics

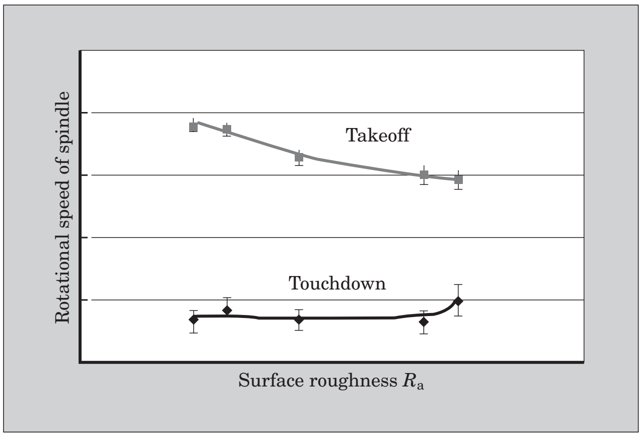


Fig.3 LUL durability in a reduced pressure environment

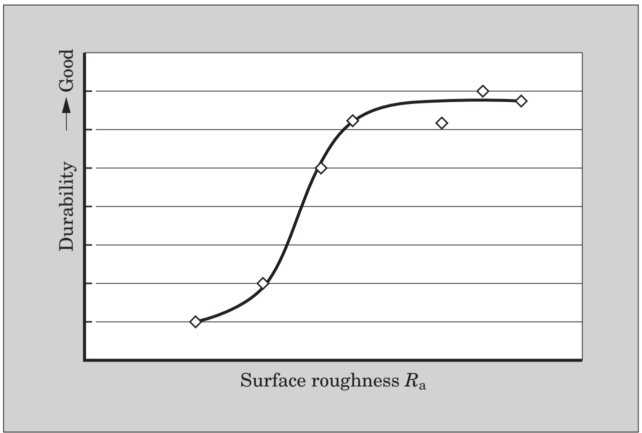


Fig.4 Surface roughness vs. parametrics

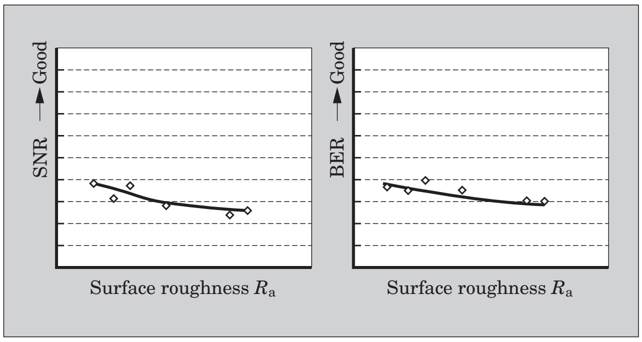
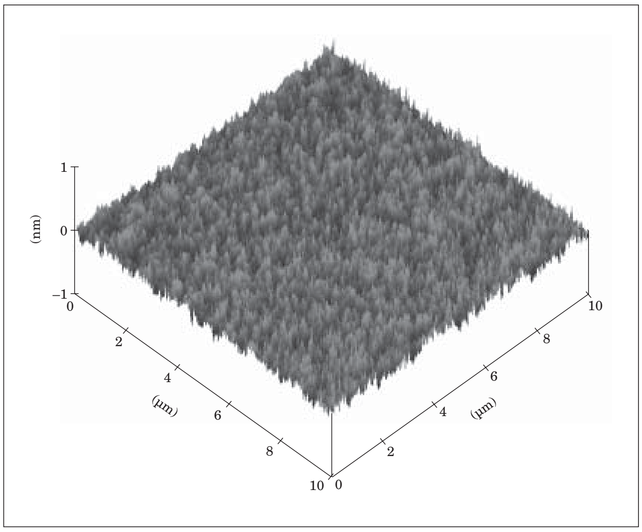


Fig.5 Surface profile of substrate for perpendicular magnetic recording media



measured while controlling the surface roughness of the media.

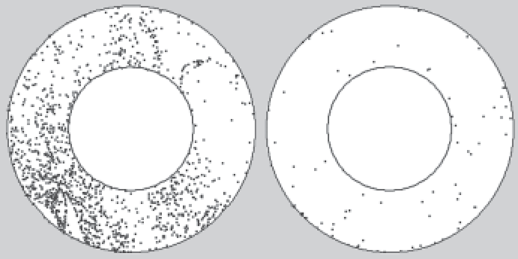
The floating performance was evaluated with two types of criteria: the rotational speed at which a magnetic head flying above magnetic media touches down and makes contact with that media due to a reduction in rotational speed of the spindle, and the rotational speed at which a magnetic head in physical contact with the media takes off and begins to fly above the media due to an increase in rotational speed of the spindle. As can be seen in the results shown in Fig. 2, as the surface roughness increases, take-off becomes easier and the floating performance improves. The touchdown speed exhibits no dependency on roughness, but appears to worsen if the surface becomes excessively rough.

The durability was evaluated by conducting an LUL (load/unload) test, which is typically performed with 2.5-inch HDDs. The LUL test evaluates durability by repeatedly moving the magnetic head from its ramp load position in a standby state towards and away from the surface the magnetic media. With this evaluation, no significant difference is observed at usual atmospheric pressure, but in an environment of reduced pressure, a trend as shown in Fig. 3 is observed. By increasing the roughness of the surface, an improvement in LUL characteristics is observed in a reduced pressure environment.

As described above, we have verified that the provision of random roughness on the substrate surface results in improvement to both the flying performance and durability characteristics. However, by increasing the surface roughness, the crystalline c-axis (easy axis of magnetization) that forms the perpendicular magnetic layer becomes susceptible to anisotropic dispersion due to the effect of the roughness, and the magnetic characteristics deteriorate. As a result, the parametrics also deteriorated when measured with the magnetic head. Specifically, there is slight deterioration in the SNR (signal-to-noise-ratio) and the BER (bit error rate) of the parametrics. This is shown in Fig. 4.

Ultimately, by controlling the roughness to an optimal value, we designed a substrate for low-defect perpendicular magnetic recording media having stable flying performance, and good durability and parametrics. Figure 5 shows a surface profile of this substrate. By creating a roughness that is both gently sloping and random, the dispersion of the c-axis is reduced, thereby enabling the production of perpendicular magnetic recording media having excellent durability and flying

Fig.6 Particles after precision cleaning



performance.

3. Cleaning Techniques for Perpendicular Magnetic Recording Media

The substrate for perpendicular magnetic recording media has a multi-layered construction, and the adherence of contaminants to the substrate will cause major defects.

When cleaning the substrate of perpendicular magnetic recording media, the cleaning is required to be more powerful than that used for a substrate of longitudinal magnetic recording media. The use of powerful cleaning in the case of a substrate of longitudinal magnetic recording media has the effect of etching scratches in the texture, and this is a problem because the OR (orientation ratio) decreases. However, with a substrate for perpendicular magnetic recording media, the soft underlayer must not be aligned, and therefore a powerful cleaning technique such as etching may be used. Figure 6 shows substrate particle data before and after cleaning to remove contaminants while etching the glass substrate surface. It can be seen that the cleaning of perpendicular magnetic recording media reduces particles dramatically.

4. Protective Film Technology

Perpendicular magnetic recording media was predicted to have poor corrosion characteristics because its soft underlayer is thick. Therefore, the protective film was provided with a two-layer construction consisting of a high-density layer and a stabilization layer, and film deposition conditions were optimized for the high-density layer to improve the corrosion characteristics.

Specifically, since the CVD (chemical vapor deposition) film is rich in SP^3, film properties of high hydrophobic and lubricating performance were chosen. Figure 7 shows actual results measured by Raman spectroscopy. The film deposition conditions and gas components were controlled to changeover from the conventional SP^2 rich film to an SP^3 rich film. As a result, cobalt corrosion is suppressed, and a highly durable protective film can be formed.

Fig.7 Control of carbon film properties

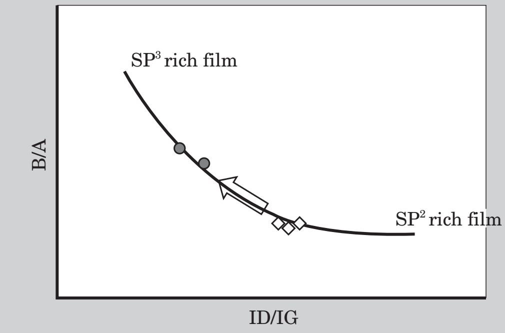


Fig.8 Results of corrosion evaluation of media left at high-temperature and high-humidity

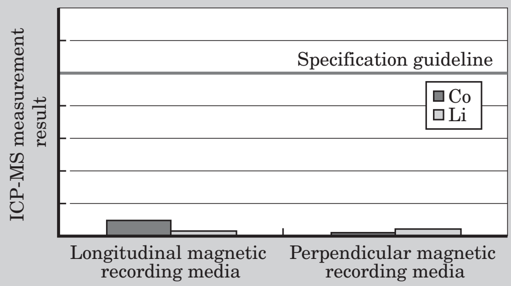


Figure 8 shows the results of a corrosion evaluation performed by ICP-MS (inductively coupled plasma-mass spectrometry) after 96 hours in a high-temperature and high-humidity environment of 80°C and 80 %RH. Both Co and Li could be suppressed to values of 1/10th or less than those of the in-house specifications.

5. Evaluation of HDI Characteristics

We performed evaluated the HDI of the final perpendicular magnetic recording media. The evaluation consisted of the following items.

(1) LUL tests in various environments
- ○ Hot and wet (70°C and 80 %RH)
- ○ Normal temperature and normal humidity
- ○ Cool and dry

(2) High-speed seek tests
(3) Head slap test
(4) LUL tests in reduced pressure environment
(5) Take-off, touchdown tests

The results of (1) LUL tests in various environments, and especially under the severe conditions of 70°C and 80 %RH, are shown for 200 hours and 400,000 cycles in Fig. 9. Even in a high-temperature and high-humidity environment, observation of the media surface with an OSA (optical surface analyzer) verified the absence of carbon wear and lubricant “moguls”, and that there is no decrease in mass. Also,

Fig.9 Load/unload test results

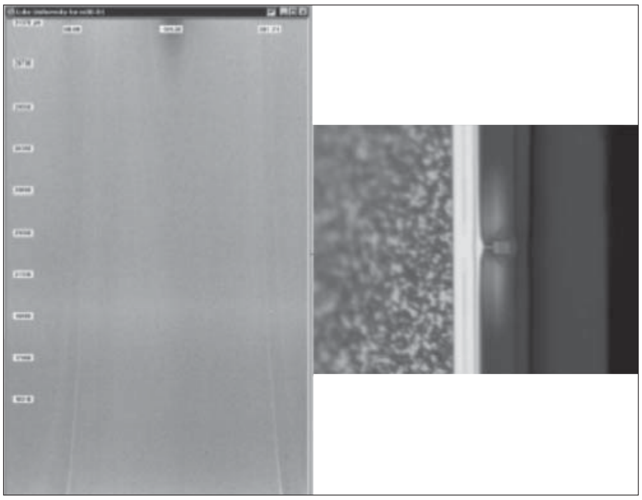
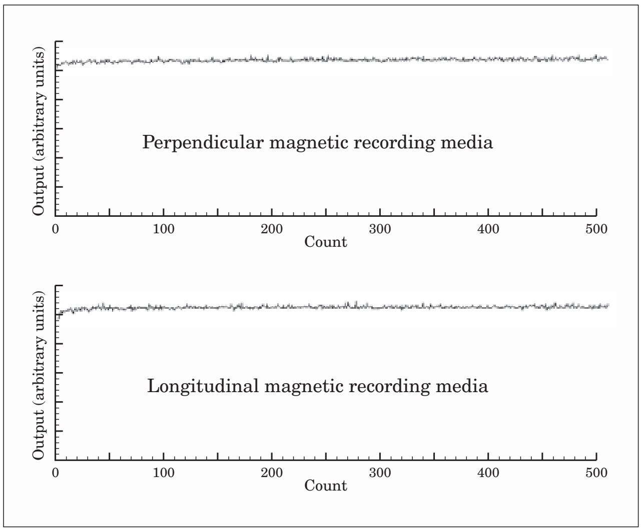


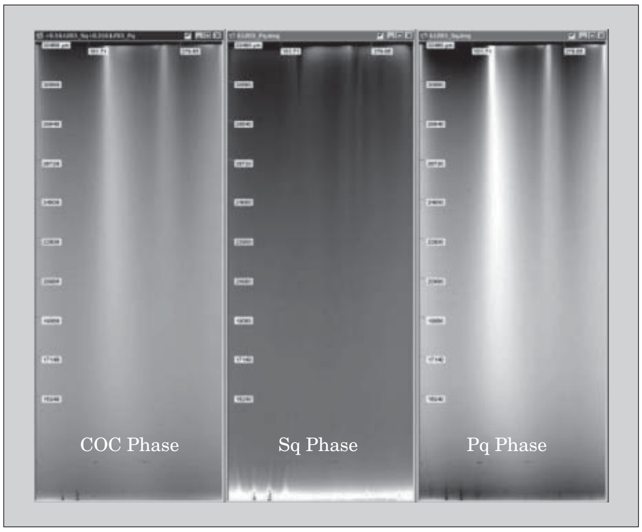
Fig.10 High-speed seek test results



observation of the magnetic head verified the absence of contamination adhering to the slider or pole-tip assemblies.

The results of (2) high-speed seek tests are shown in Fig. 10. The magnetic head performed high-speed seek operations at a speed of 10 Hz, and the AE (acoustic emission) signal was measured for 500,000 cycles. In terms of the AE signal, a trouble-free waveform, compared to that of the longitudinal magnetic recording media, was observed, and the absence of damage to the magnetic recording media on the magnetic head side was also verified.

Fig.11 Head slap test results



The (3) head slap test is a technique for accelerated evaluation of the durability during magnetic head loading and unloading, and is performed by suddenly dropping the magnetic head from the ramp load position while the magnetic media is rotating at a high-speed. Even in this evaluation, as shown in Fig. 11, no wear is generated on the carbon on the media side, and the results were problem-free without verifying a reduction in lubricant.

Items (4) and (5) are dependent upon surface roughness, and as has been reported previously, the surface roughness was controlled and the media was optimized.

As described above, the reliability of perpendicular magnetic recording media has been improved to equal or exceed that of longitudinal magnetic recording media.

6. Conclusion

The application of perpendicular magnetic recording media to HDDs has begun with glass magnetic recording media, and is expected to expand to aluminum magnetic recording media. Ultimately, it is expected that all pre-existing longitudinal magnetic recording media will be replaced with perpendicular magnetic recording media. To achieve this goal, higher recording density and guaranteed reliability of the perpendicular magnetic recording media are crucial, and Fuji Electric intends to continue to innovate and improve technology for this purpose.