A Correlation Analysis between Micro-Waviness of Magnetic Disk Surface and Electromagnetic Conversion Characteristics at the Head/Disk Interface

S. Hara, and T. Oosone
Nagaoka University of Technology
Nagaoka, Niigata, 940-2188 Japan

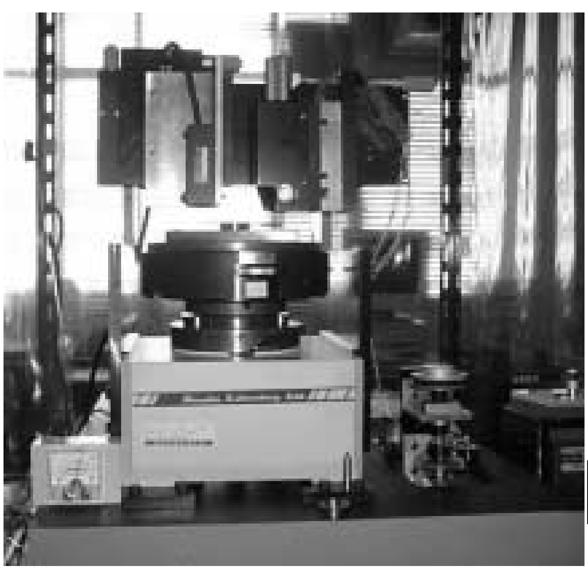
Introduction

In order to increase the information storage density of HDD, it is strongly required to reduce the flying height of the magnetic head. For its realization, the head slider has been advanced to smaller size, i.e. nano-slider or pico-slider. And then, magnetic disks are needed to be as flat as possible even in the short wavelength band. The head slider cannot fly over the disk following the irregularity of the surface if the wavelength of the irregularity is too short [1,2]. Such surface irregularity whose wavelength is shorter or comparable to the head slider length is called “Micro-Waviness”.

Interferometry can be a useful tool to assess such surface waviness of magnetic disks and many optical interferometers are put on the market. "OptiFLAT"® by Phase Shift Technology Inc. is a representative white light interferometer, with which macroscopic surface profiles over the whole area of the disk may be measured and evaluated. Authors build an instrument to measure the circumferential surface profile of the disk and proved the measurement accuracy and suitability of obtained results of the white light interferometer. In addition authors investigated the correlation between the surface geometry (roughness, waviness and form) and fluctuation of the head/medium spacing

Circumferential profile measuring instrument

First of all in this study, a stylus instrument with extremely light load was developed to measure envelope curves along the circumferential tracks of disk surface (see Figure1 and Table 1). The instrument employs diamond stylus and high accuracy static air bearing rotated in very row revolution speed. It was estimated that the repeatability of the instrument is less than 0.5nm.



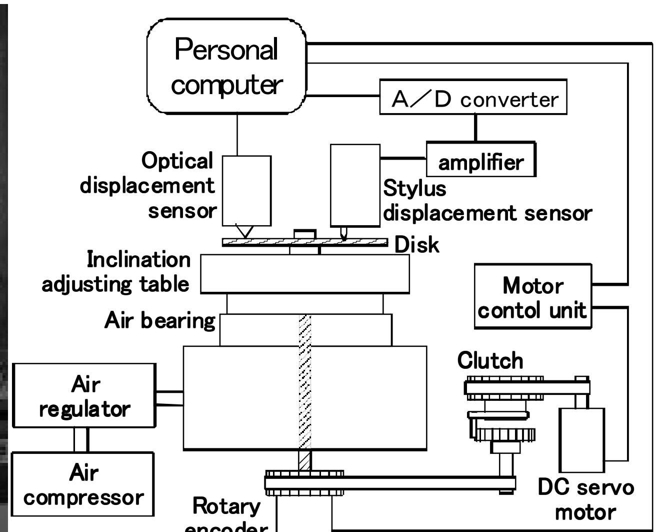


Fig. 1 Circumferential profile measuring instrument using stylus

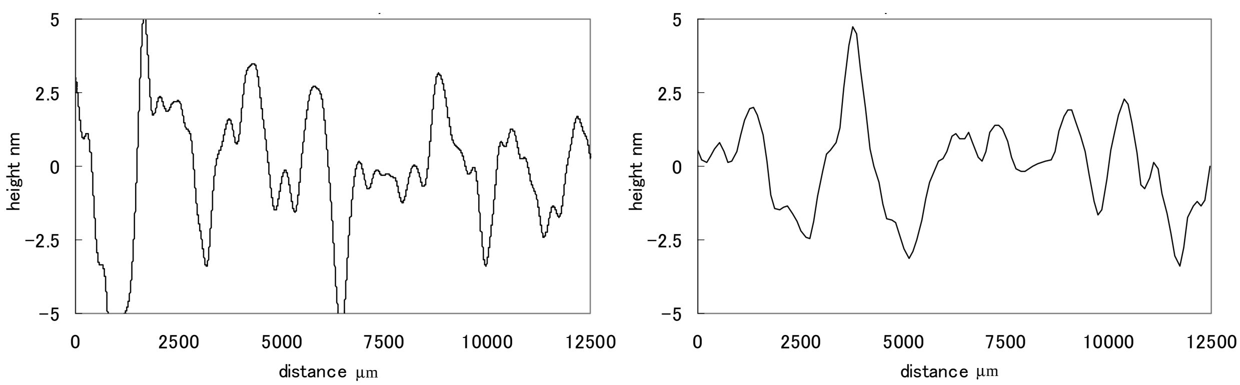
Table 2 shows the prepared aluminum and glass sample disks. Considering the head slider size and its follow-up motion to disk surface, measuring length of 15mm was selected. Applying a 500μm low pass filter, a quite good agreement of the waviness parameter was obtained between the processed profiles with the developed instrument and the OptiFlat as shown on figure 2 and 3. One advantage of the developed instrument is that it has wider surface wavelength band than another because of shorter sampling spacing.

Table 1 Measuring conditions of the stylus instrument

Stylus tip radius	10 μm
Stylus load	0.2 mN
Vertical resolution	0.1 nm
Measuring speed	100 μm/s
Measuring length	15 mm
Sampling interval	2 μm

Table 2 Sample disks

	3.5 inch Aluminum disk	2.5 inch Glass disk
Surface finish	Mechanical texture	Polished
Ra (λ_C= 80 mm)	≈ 1 nm	≈ 0.2 nm
Wa (λ_C= 80 mm, λ_W= 5 mm)	0.4 …1.5 nm	0.4 …1.0 nm
Track for measurement	r = 30 mm	r = 20 mm
Number of samples	14	8



(a) Stylus (b) OptiFLAT

Fig. 2 Circumferential profiles obtained using stylus instrument and OptiFLAT

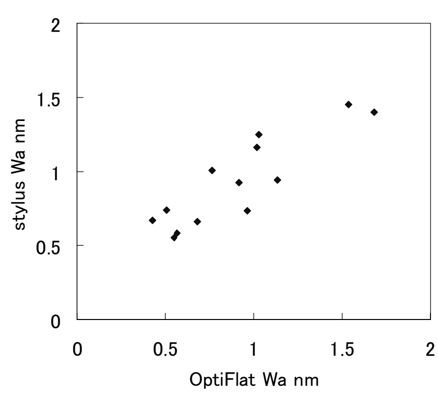


Fig. 3 Correlation between OptiFLAT *Wa* and Stylus *Wa*

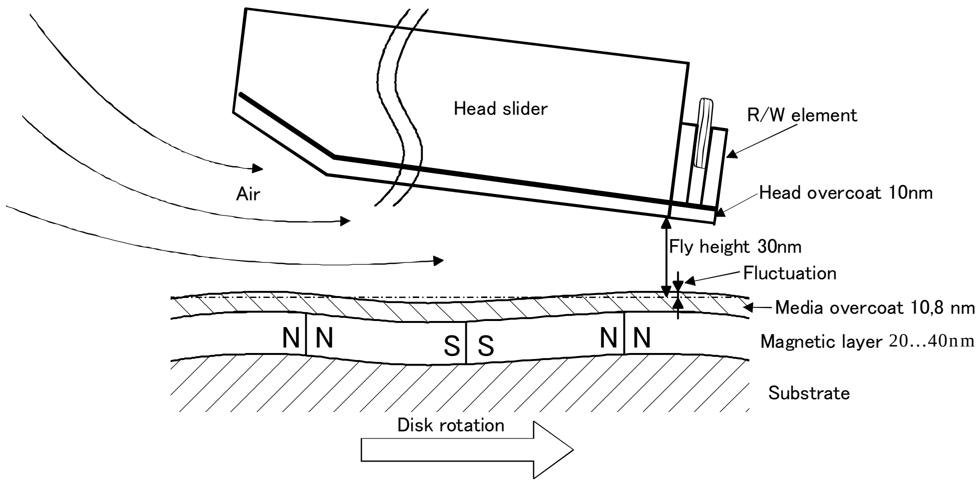


Fig. 4 Fluctuation of spacing between magnetic layer and head

Correlation of the Readout Signal to the surface micro-waviness

The amplitude modulation of the head readout signal is affected by the spacing between the head and the magnetic layer. The schematic of the head slider flotation is shown in figure 4. The relationship between the readout signal V and the spacing d is described as follows [3].

$$V = \frac{9\Delta\rho J W M_r \delta (g+t)}{8\sqrt{2}\, t\, g\, M_{mr}} \tan^{-1} \frac{g}{2(d+a)} \tag{1}$$

Where, g denotes shield gap spacing of the magnetic head, a denotes transition parameter of the magnetic layer, d denotes the head/medium spacing. Other parameters can be regarded to be constant when considering the fluctuation of the spacing. Putting actual values of the g and a, the relation ship can be rewritten as follows

$$\Delta d / d_0 \approx -2(\Delta v / v_0) \tag{2}$$

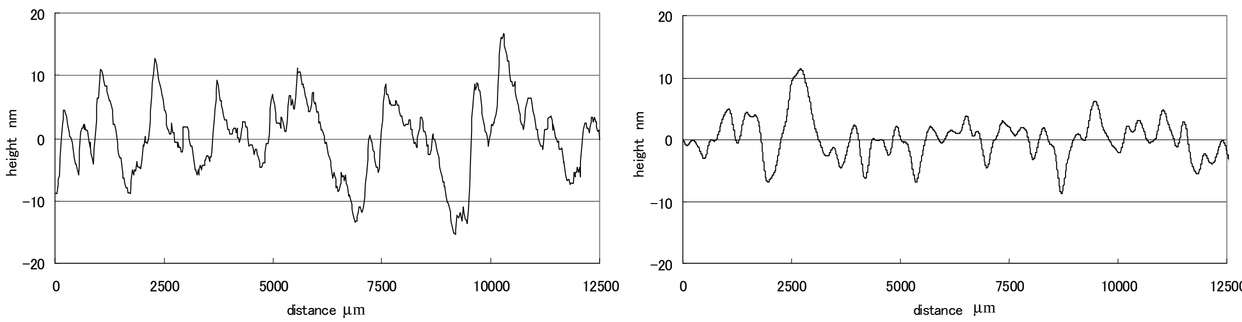
Where, Δd denotes fluctuation of the spacing, d_0: the mean spacing (50 nm), Δv: fluctuation of the readout signal, v_0: the mean readout signal (1.6 ... 2 V). Then, the fluctuation of the readout signal can be converted into the fluctuation of the spacing.

The readout signals of all the sample disks were measured using a disk tester. Conditions of the test were shown in table 3. Example of the result is shown in figure 5. Two curves, (a) and (b), have similar amplitude and waveform, even though the two curves were obtained in completely different principle.

The relationship between the amplitude of the profile and fluctuation of the spacing was investigated using the parameter *Wa*. Figure 6 shows the *Wa* values of 14 aluminum disks

Table 3 Conditions for measuring Read-Out-signal

	Al disk	Glass disk
Write freq.	10 MHz	
Speed	5400 rpm	
Head-slider	MR, Nano-slider	
Radius	30 mm	20 mm
Sampling	5 MHz (3.4 mm)	5 MHz (2.3 mm)



(a) Head readout signal (b) Stylus

Fig. 5 Circumferential profiles calculated from the head readout signal and obtained using stylus

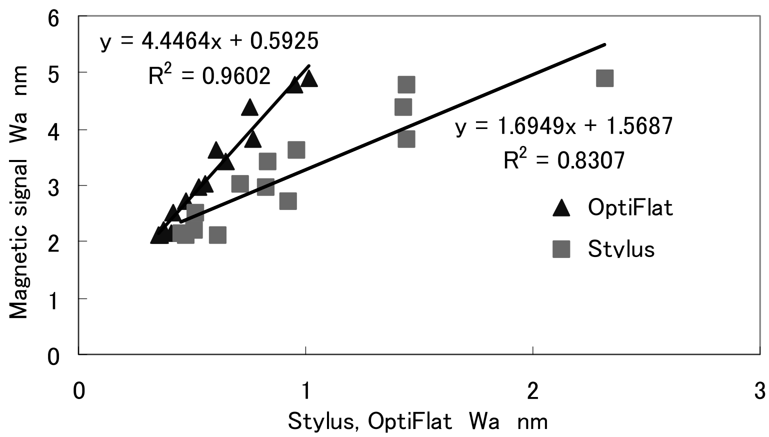


Fig. 6 Correlation between magnetic Wa and Magnetic-Waviness and Aluminum 3mm HPF

when applying the 3mm high pass filter. The correlation was best when the cutoff of the high pass filter was 3mm, which is about the same as the length of the head slider. It can be concluded that the disk micro-waviness has a great influence on the physical head-disk separation or the information storage density of HDD.

Conclusions

1) A quite good agreement of the waviness parameter was obtained between the processed profiles with the developed instrument and the OptiFlat.
2) The correlation between the amplitude modulation of the readout signal and the amplitude of the micro waviness was best when applying the 3mm high pass filter. It is about the same as the length of the employed head slider.

References

[1] Wei Yao, David Kuoa and Jing Gui : Effects of disc Micro-Waviness in an ultra-high density magnetic recording system, Proc. of Interface Tribology Towards 100 Gbit/in^2, (1999)31
[2] P. Yim, P. Wang, Z. Li, T. Dansen, S. Choa & H. J. Lee : The Role of Disk Surface Waviness on Baseline Instability of MR Head, IEEE Transactions on Magnetics, 35, 2(1999)758.
[3] H. Neal Betram : Theory of Magnetic Recording, Cambridge Univ. Pr, (1994).