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LOW FLYING HEIGHT AND HIGH CSS DURABILITY TECHNIQUES

Katsumi Onodera
Kohji Matsuzaki
Michinori Nishimura

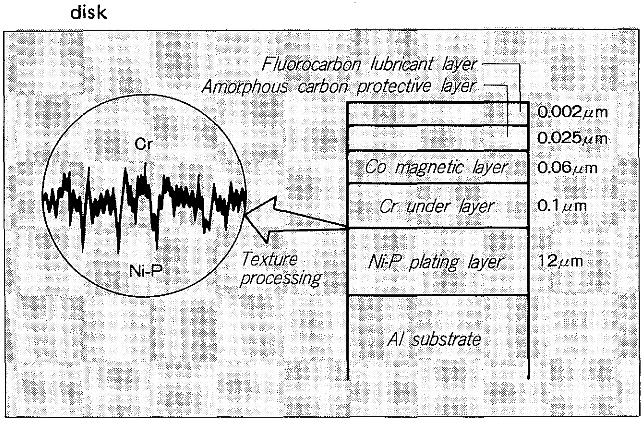
1. INTRODUCTION

Hard disk drive systems read and write information through magnetic heads, which are constructed to utilize an air bearing principle to float with sub-micron clearance above a magnetic disk surface. The head is in contact with the magnetic disk surface while the power is off. When power is turned on, the magnetic disk starts to rotate, the head slides on the surface and then begins to float. When power is turned off, the head comes into contact with the magnetic disk surface again and eventually the magnetic disk stops to rotate. This type of system is called a CSS (Contact Start and Stop) system. In this systems, head contact with and head sliding on the magnetic disk surface occurs every time power is turned on or off. Since magnetic disk with hard thin film heads require CSS durability of several tens of thousands times of power on/off, tribology for the magnetic disk head interface has become a growing concern.

Additionally, in order to increase recording density the flying height of the head is being reduced. To maintain a specific flying height, the disk surface should be controlled to have no asperitics 60% higher than the flying height.

For these reasons, magnetic disk with lower flying height and higher CSS durability is required. This article presents developments by Fuji Electric for this purpose.

Fig. 1 Sketch of the surface layer structure for a sputtered magnetic disk



2. CHARACTERISTICS REQUIRED FOR THE SPUTTERED MAGNETIC DISK

Figure 1 shows a sketch of the layer structure for a sputtered magnetic disk.

In order to achieve high CSS durability, the following characteristics for the sputtered magnetic disk are required.

(1) Low friction coefficient
(2) Superior wear resistivity
(3) Suitability for stable flying of the head.

Since amorphous carbon has a low friction coefficient in the air, it is used as the protective layer for the sputtered magnetic disk in many cases. Although the amorphous carbon layer is not the best material in respect to its wear characteristic, creating sufficient roughness on the surface of the Ni-P layer through a mechanical process called texture technique, which forms the desired roughness on the surface, yields a favorable surface both in friction and wear characteristics. In addition, a liquid lubricant layer of fluorocarbon is applied as the top layer to reduce wear.

To obtain a low flying height, the following are required.

(1) The surface of the sputtered magnetic disk must be flat without any irregular projections.
(2) The substrate should have minimum waviness and must have a superior degree of flatness.
(3) The layers and the surface of the magnetic disk must be free from contamination, which causes the formation of projections.

Though glass substrates are being examined to provide better flatness than aluminum substrates, up to now no significant difference has been found in flying height characteristics.

It is commonly recognized that an extremely flat sputtered magnetic disk surface will provide lower flying heights, but suffer from higher friction coefficients and higher stiction forces. A technological innovation is necessary to overcome the above mentioned contradiction. Relating to this topic, our recent studies on

(1) Surface processing technique,
(2) Sputtering technique of protection layers

are presented in the next chapter.

Fig. 2 Dependence of the friction coefficient and the minimum flying height on t_p (10%–1%)

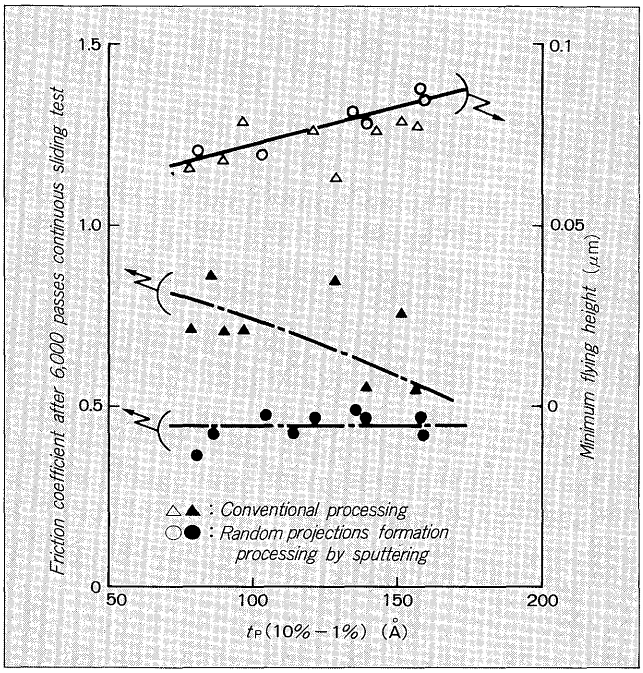
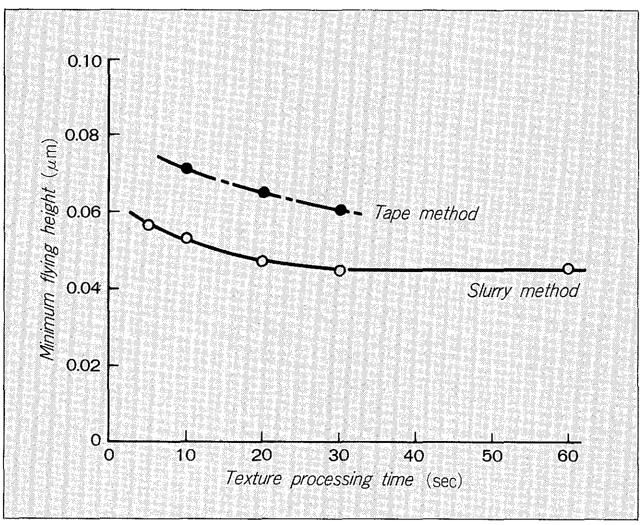


Fig. 3 Comparison of the minimum flying heights between the tape and the slurry texture method

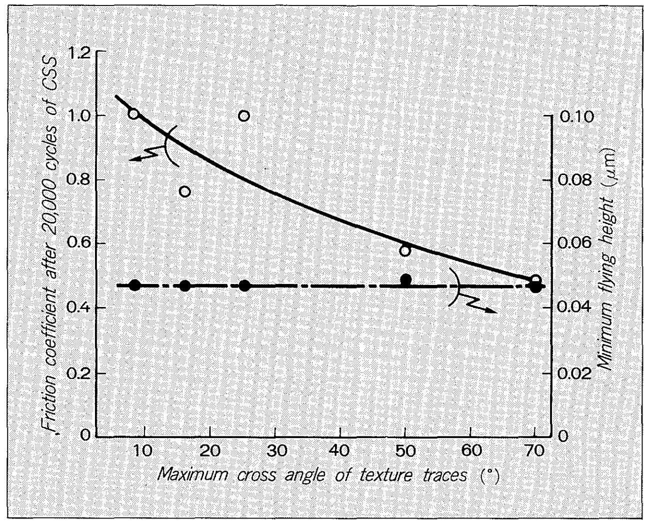


3. DEVELOPMENT OF ESSENTIAL TECHNIQUES

3.1 Surface processing technique

An index t_p (10%–1%) has proved to have greater correlation to friction characteristics and flying height characteristics of the sputtered magnetic disk than the center-line mean roughness R_a. The index t_p (10%–1%) is defined as the difference of the cutting depths at 10% and 1% of the bearing length on the curve of a profile bearing length ratio of the magnetic disk surface. *Figure 2* shows the relationship of the minimum flying height and the

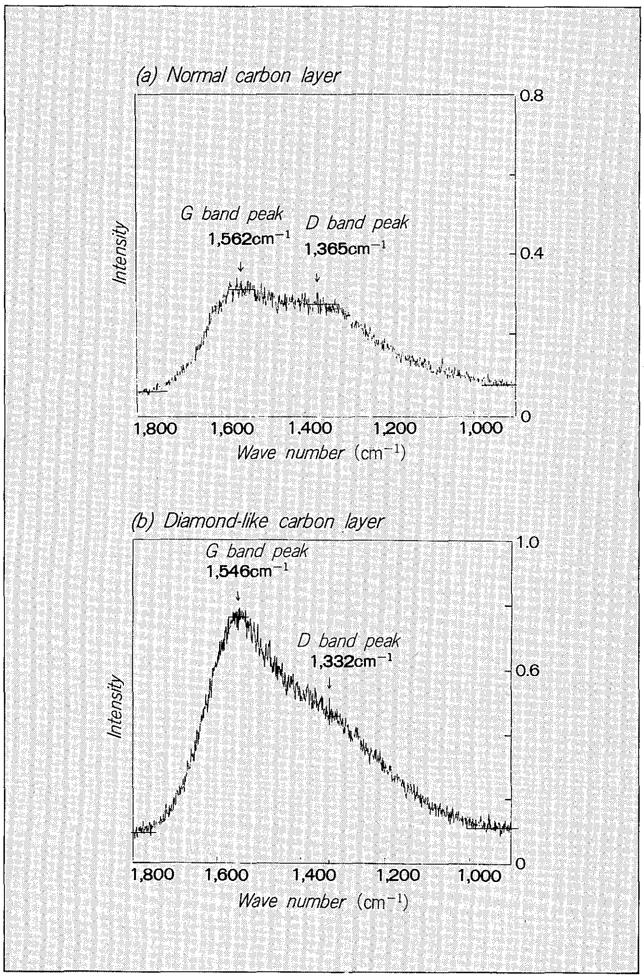
Fig. 4 Dependence of the friction coefficient and the minimum flying height on the maximum cross angle of texture traces



friction coefficient after 6,000 passes of a continuous contact sliding test with the index t_p (10%–1%). A large t_p (10%–1%) indicates many convex points on the roughness curve and a large deviation among their heights. To achieve a low flying height, t_p (10%–1%) should be sufficiently small. On the other hand, a smaller t_p (10%–1%) causes a larger friction coefficient. To solve this problem, we have developed a new technique which deposits random, high density convex points on the layer in the sputtering process. The effect of the new technique is also shown in *Fig 2.* In this technique, the numbers of contact points per unit area between the head and the surface increase independent of the texture processing and this fact seems to suppress any increase in the friction coefficient.

However, any technique based on tape texture processing, even with the above techniques of forming convex points intentionally will have difficulty in achieving a minimum flying height of less than 0.06 μm. To improve the texture process, a slurry texture method was studied, in which freely suspended abrasive material in a slurry is used in place of abrasives fixed to a binder on tape. In this method, the abrasive grains are freely suspended in the slurry and an excessive abrasive force is released by rotation of the grain. This process is considered to effectively prevent projections from forming on the surface due to melting and adhesion of turned up elements. *Figure 3* shows the dependence of the minimum flying heights on the tape or slurry texture processing time. It is clearly evident from the figure that the slurry method yields lower flying heights. The t_p (10%–1%) decreases with longer processing time. *Figure 4* shows the dependence of the friction coefficient after 20,000 times of the CSS and the minimum flying height on the maximum cross angle of the texture trace. The minimum flying height is independent of the angle, but the friction coefficient tends to reduce as the cross angle increases. It is presumed that the real contact area between the head and the surface reduces as the cross angle increases. On the contrary, since the greater cross

Fig. 5 Raman spectrums of a normal carbon layer and a DLC layer



angle reduces the circumferential magnetic orientation ratio of C-axis, reduction in magnetic coercivity and squareness is observed. The cross angle should be chosen with all the factors, the friction characteristics, the magnetic characteristics and the read/write characteristics, considered.

3.2 Protective layer formation technique

Raman spectrum analysis and other analysis reveal that the amorphous carbon layer formed through the sputtering process has a graphite-like structure. The graphite-like amorphous-carbon layer yield high CSS durability when using a head with a MnZn-ferrite slider of equal or lower hardness than that of the amorphous-carbon layer. But in many cases its durability is not superior to the currently prevailing thin film head with hardness 3 to 4 times greater than that of the MnZn-ferrite slider. To cope with this problem a diamond-like carbon layer (DLC layer), formed during sputtering in argon and containing several or several tens % of hydrogen or hydrocarbon molecules such as methane and ethylene, is attracting attention as a solution. *Figure 5* shows the Raman spectrum of the DLC layer. The G band peak is observed to shift towards a lower wave number region. This shift proves a

Fig. 6 G band peak position of Raman spectrum as a function of the total content of hydrocarbon gases

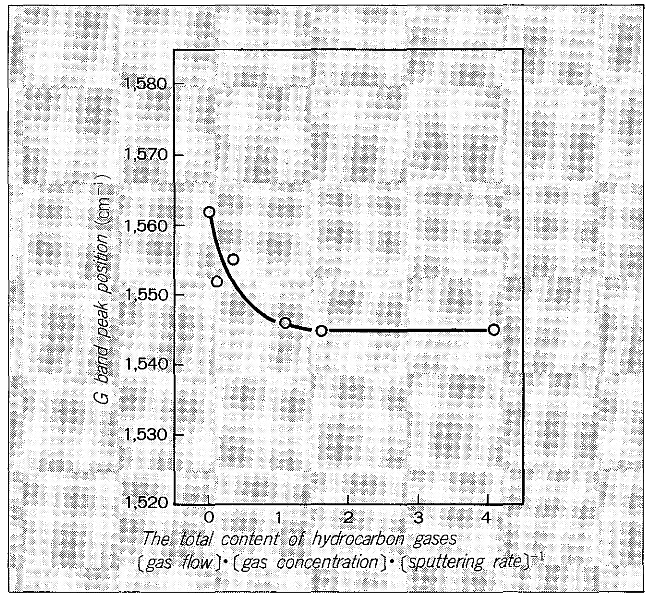
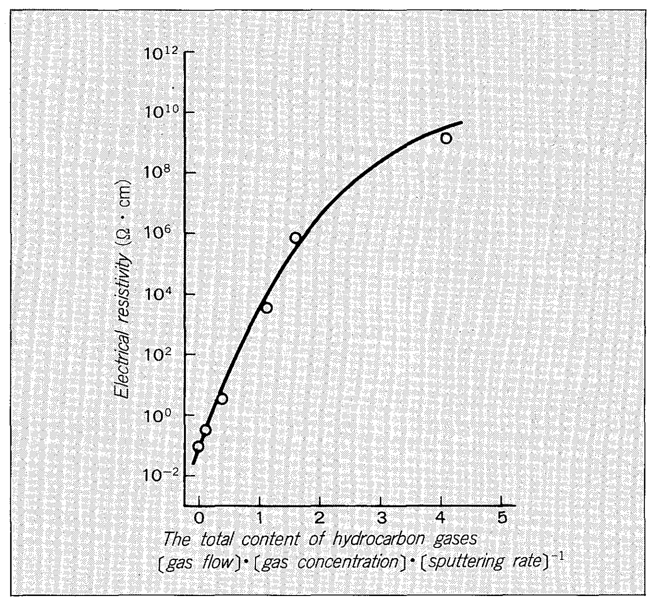


Fig. 7 Electrical resistivity as a function of the total content of hydrocarbon gases



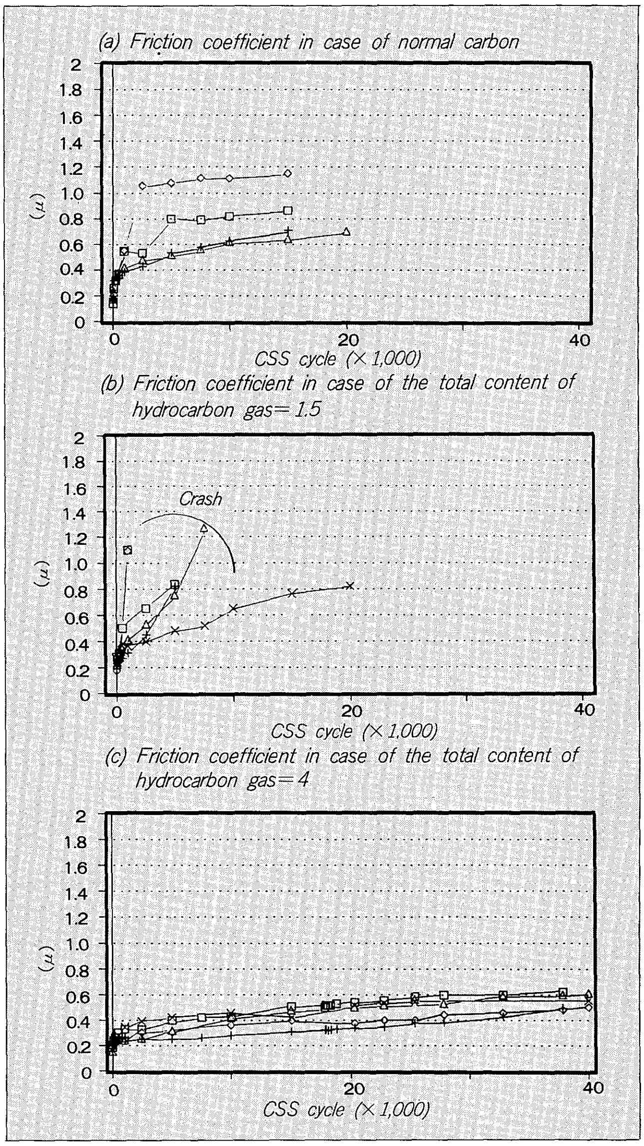
strong SP^3 characteristic (diamond-like characteristic). *Figure 6* shows the relationship between the position of the Raman spectrum G-band peak and the total content of hydrocarbon gases in argon. The total content of hydrocarbon gases in argon on the X-axis in *Fig. 6* is normalized with the following formula:

The total content of hydrocarbon gas

= [gas flow] · [gas concentration] · [sputtering rate]$^{-1}$.

As shown in *Fig. 6*, the diamond-like characteristic dominates with increasing the total amounts of mixed hydrocarbon gases. *Figure 7* shows the dependence of the electrical resistivity of the layer on the total amount of

Fig. 8 CSS test results of the sputtered magnetic disk processed in different total contents of hydrocarbon gases



mixed hydrocarbon gases. The electrical resistivity of the layer increases as the total amount of mixed hydrocarbon gases increases. *Figure 8* shows CSS test results on 3 kinds of sputtered magnetic disk manufactured in the different atmospheres in which the total amount of mixed hydrocarbon gases are 0, 1.5 and 4 respectively. The sputtered magnetic disk used in this tests were fabricated through an optimized texture process. The sputtered magnetic disk processed in the atmosphere with the total amount of mixed hydrocarbon gases of 4 achieves the most favorable result. In the case where the total amount of mixed hydrocarbon gases was 1.5, the probability of crashes was high. The crashes may have been caused by abrasive wear due to increased hardness or changes in the physical properties of the layer due to hydrogen taken in it. Further studies are continuing on this subject.

4. AFTERWORD

Since the CSS system will be used widely in the hard disk drive system for some time to come, the tribology technology for the head magnetic disk interface is still important. Lower flying height and diversified head materials, shapes and sizes will be future trends. To keep pace with these trends, we continue to develope tribology technology including the adaptability of the magnetic disk to the diversified heads. A further aggressive approach, which involves basic experimentation and theoretical studies is being implemented to establish basis for the innovations predicted in the near future, and eventually be reflected to disk products.