# Seek durability for CoCrTa perpendicular flexible disks

# SEEK DURABILITY FOR CoCrTa PERPENDICULAR FLEXIBLE DISKS

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Abstract Seek durability for CoCrTa perpendicular flexible disks was studied using a conventional 3.5" double-sided flexible disk drive. The seek durability strongly depends on the CoCrTa film preparation conditions. The durability is increased by adding a Si underlayer for a CoCrTa film. Disk media yield pressures were evaluated with a scratch test using a sapphire needle. A high media yield pressure leads to a high seek durability. Ta addition to CoCr film increases the media yield pressure. $200\times10^4$ seek operations were attained for the disk construction :protective layer/CoCrTa film/Si underlayer/base film.

## INTRODUCTION

Perpendicular magnetic recording provides extremely high recording densities [1]. A key factor in putting the CoCr thin film flexible disks into practical use is mechanical durability. As a method to evaluate the mechanical durability, pass wear tests on the same recording track have been widely carried out [2,3]. However, it is difficult to evaluate the mechanical durability for head seek operations wherein the head moves from track to track. This paper describes disk mechanical properties to evaluate head seek durability for a CoCrTa perpendicular flexible disk for a double-sided flexible disk drive (FDD).

## EXPERIMENT

**Disk preparation** CoCrTa films [4] were deposited on polyimide films only or on polyimide films on which underlayers were formed by r.f. sputtering under two sputtering power(Pw) conditions. Cr and Ta concentrations in CoCrTa films are 17 at% and 3 at%, respectively. CoCr(20at%Cr) film was also deposited on a polyimide film. Si (600A thick) and $Al_2O_3$/CoCr (500A / 50A thick) films were used as the underlayers. The CoCr underlayer was used as an adhesive layer between the $Al_2O_3$ film and the polyimide film. The magnetic film was coated with a protective layer and lubricant. Table 1 shows the constructions and preparation conditions for the disks. Thicknesses for polyimide film, magnetic film (CoCrTa and CoCr film)and protective layer were 30 μm, 0.3 μm and 0.03 μm, respectively. Head seek resistance for the disks were evaluated using a double-sided FDD (600 rpm), which was controlled by a personal computer. The head seek durability was defined by a seek pass number, at which shallow scratches were observed on the disk surface. The head seek operations were carried out between track 20 to track 50.

**Media scratch test and media yield pressure**

Media scratch resistances were measured by a scratch test apparatus using a sapphire needle (point radius =0.05mm) [2,3]. Figure 1 shows a cross section view of a disk scratched with the needle. Scratch force (SF) and scratch depth (SD) are determined by the disk horizontal yield pressure and the disk perpendicular yield pressure[5]. Horizontal yield pressure $P_H$ and perpendicular yield pressure $P_P$ for a disk are given by

$$P_H = SF/S_H \qquad \cdots (1)$$

$$S_H = R^2(\pi/2 - 0.5\sin 2\theta - \theta)$$

$$P_P = LF/S_P \qquad \cdots (2)$$

$$S_P = \pi * R^2(1 - \sin\theta)$$

$$\theta = \sin^{-1}(1 - SD/R)$$

where $S_H$ and $S_P$ are the cross sections of scratched media and the needle surface area respectively. LF and R are the needle load force and the needle point radius,respectively. Scratch force SF can be resolved into base film scratch force term $SF_b$ and media scratch force term $SF_m$ for the magnetic film, protective layer and underlayer. Therefore, the scratch force is given by

$$SF = SF_m + SF_b \qquad \cdots (3)$$

$$SF_m = P_{Hm} * S_{Hm} \qquad \cdots (4)$$

$$S_{Hm} = \pi * R^2 * (0.5 * \sin 2\theta' + \theta' - 0.5 * \sin 2\theta - \theta)$$

$$\theta = \sin^{-1}(1 - SD/R)$$

$$\theta' = \sin^{-1}\{1 - [SD - \delta]/R\}$$

where $P_{Hm}$ and $S_{Hm}$ are horizontal media yield pressure and film cross section, respectively. Perpendicular media yield pressure $P_{Pm}$ is given by

$$P_{Pm} = [LF - P_{Pb} * \pi * R^2 * (1 - \sin\theta)] / S_{Pm} \qquad \cdots (5)$$

$$S_{Pm} = \pi * R^2 * (\sin\theta' - \sin\theta)$$

where $S_{Pm}$ is needle surface area when the needle is in contact with the scratched film including the magnetic film, protective film and underlayer. $P_{Pb}$ is the perpendicular base film yield pressure.

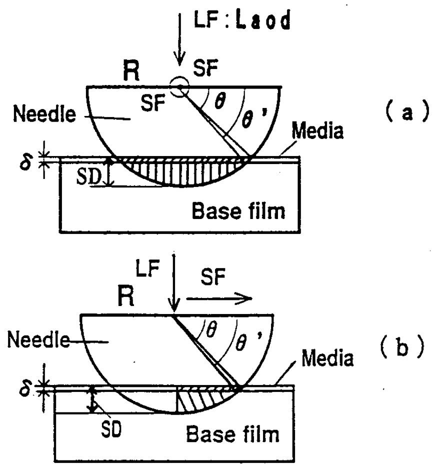


Fig. 1 Disk structure scratched with a needle.
(a) Front view (b) Side view

## RESULTS AND DISCUSSION

**Seek durability test**

Seek durability results for the disks are shown in Table 1. The seek durability strongly depends on disk preparation and film construction. The seek durability pass numbers range from $25\times10^4$ passes to $200\times10^4$passes. In CoCrTa film disks without the underlayer, the seek resistance for disk A is smaller than that for disk B. Many shallow scratches parallel to the recording track were observed on the surface of disk A at around $40\times10^4$ passes. However, no scratches were observed on disk B prepared by high sputtering power Pw, up until $90\times10^4$ passes. The seek durability at $200\times10^4$ passes was obtained for disk C with Si underlayer. The durability value is two times greater than that for disk B. The seek durability for disk D with $Al_2O_3$/Cr underlayer was $25\times10^4$ passes, but there was no improvement in the seek resistance. However, the seek durability is increased by forming the Si underlayer on the base film. The seek durability for the disk E of CoCr media was $20\times10^4$ passes, which is less than that for CoCrTa media prepared under the same sputtering conditions.

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Table 1. Flexible disk construction and seek durability pass number.

| Disk | Media | under-layer | Pw ($W/cm^2$) | durability ($\times 10^4$) |
|---|---|---|---|---|
| A | CoCrTa | - | 0.4 | 40 |
| B | CoCrTa | - | 0.8 | 90 |
| C | CoCrTa | $Al_2O_3$ | 0.8 | 25 |
| D | CoCrTa | Si | 0.8 | 200 |
| E | CoCr | - | 0.8 | 20 |

Scratch test

In order to clarify the seek durability differences for test disks, scratch resistances were examined. Figure 2 shows disk scratch depths versus scratch needle load force. In the low load force region (<20g), scratch depth(SD)/load force(LF) values for all test disks are almost the same, due to the protective layer effect against head scratch force. However, in the greater load force region, SD/LF values differ from disk to disk. The disk seek durability increases with the SD/LF value decrease.

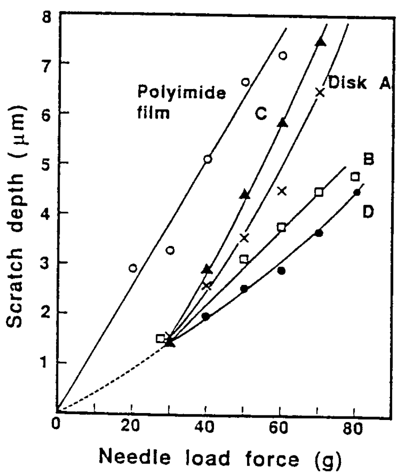


Fig. 2 Disk scratch depths versus scratch needle load force.

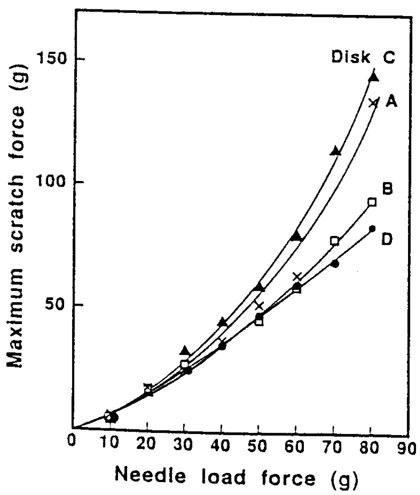


Fig. 3 Maximum scratch force values for test disks versus needle load force.

Figure 3 shows maximum scratch force values for the disks versus needle load force. The scratch force values depend on SD/LF values for individual disk. Disk D with Si underlayer has the lowest scratch force value among the disks. On the other hand, the scratch force for disk C with $Al_2O_3$/Cr underlayer is the greatest. Figure 4 shows scratch force variation (amplitude) versus needle load force for the disks. The scratch force variation is due to scratch depth variation. In the 0 to 20 g load force range, variation amplitudes are almost the same, because there are no scratches on the disk surfaces. However, at 30g load force, scratch force variation peaks for disks A, B and C are observed. This is explained by considering that protective layers begin to be broken with scratch needle at around 30g load force. In the great load force region(>30g), disks A and C with low seek durabilities have large scratch force variations. On the other hand, disks B and D show a stable scratch force variation and the variation values are also small.

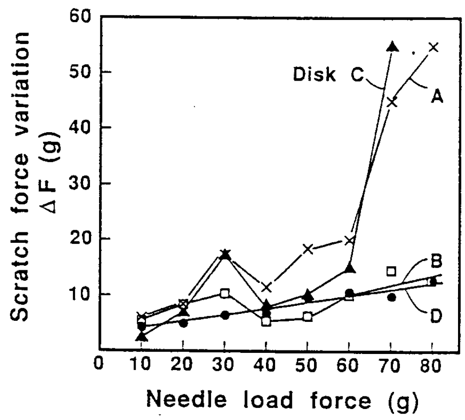


Fig. 4 Scratch force variation (amplitude) versus needle load force for test disks.

Disk media yield pressure

Scratch force is determined by a horizontal yield pressure for an entire disk media including a base film, an underlayer, a magnetic film and a protective overlayer. Disk horizontal yield pressure, in Eq.(1), is calculated for the test disks. Figure 5 shows the disk horizontal yield pressure versus needle load force. Horizontal yield pressure magnitudes are in the order:

Disk D > Disk B > Disk A > Disk C > Polyimide film

The yield pressure magnitudes correspond to those for the disk seek durability. Figure 6 shows the disk perpendicular

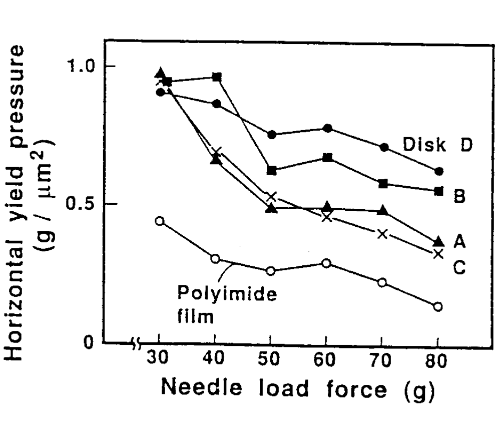


Fig. 5 Disk horizontal yield pressure versus needle load force.

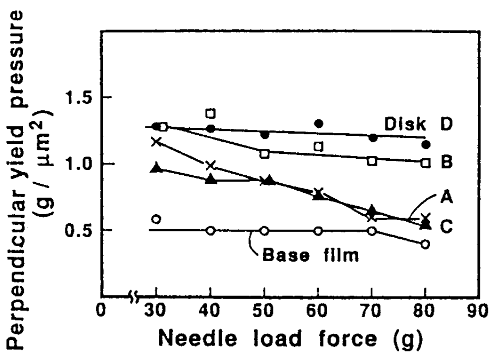


Fig. 6 Disk perpendicular yield pressure versus needle load force.

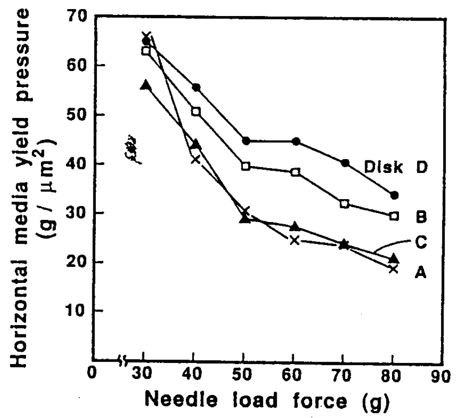


Fig. 7 Media yield pressure versus needle load force.

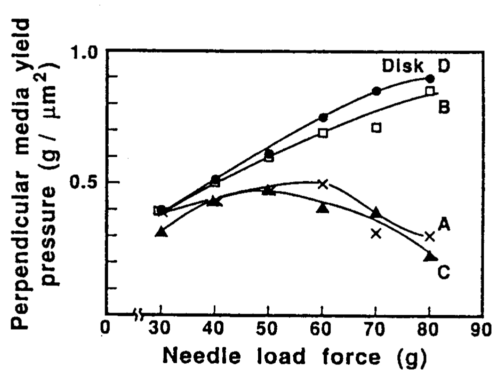


Fig. 8 Media perpendicular yield pressure versus needle load force.

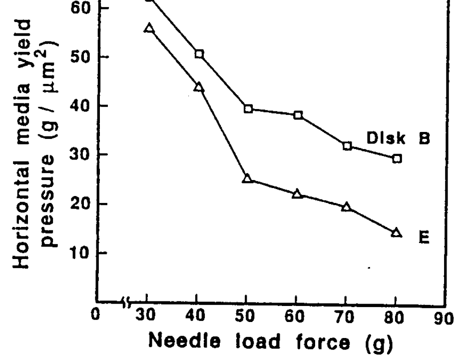


Fig. 9 Horizontal media yield pressure versus needle load force for test disks B and E.

yield pressure of Eq.(2) versus needle load force. The perpendicular yield pressure magnitude order for the disks is the same as that for the horizontal yield pressure.

A media yield pressure, except for a base film yield pressure, was evaluated by using Eq.(4) and Eq.(5). Figure 7 shows the horizontal media yield pressure versus needle load force. The relation of media yield pressure to needle load force shows in Fig.5 a tendency similar to that for an entire disk yield pressure. This result shows that the media yield pressure determines the entire disk yield pressure. Figure 8 shows the perpendicular media yield pressure versus needle load force. Disks B and D, with high seek durabilities, have high perpendicular media yield pressures. The Si underlayer increases the horizontal and perpendicular media yield pressures. However, disk C with $Al_2O_3$ underlayer has less seek durability. This is considered to be due to insufficient Cr film adhesion between the underlayer and the polyimide film. On the other hand, Disk A, prepared under low sputtering power, has half the seek durability for disk B prepared at a high sputtering power. The durability deterioration is due to a lowering of the media yield pressure, especially the perpendicular media yield pressure.

In order to evaluate the effect of adding Ta to the CoCr media, the horizontal media yield pressures for disks B and E were examined. Figure 9 shows the horizontal media yield pressure versus needle load force for disks B and E indicating that the horizontal yield pressure for disk B is two times greater than that for disk E without Ta. The addition of Ta increases the mechanical strength for the CoCr film [7]. Therefore, a high media yield pressure is needed to obtain a high seek resistance. These results show that mechanical strength of disk medium is a very important factor, which determines seek durability and that a seek durability of $200\times10^4$ passes can be attained by using appropriate conditions and a hard underlayer.

## CONCLUSION

The seek durability for CoCrTa perpendicular flexible disks was studied using a conventional 3.5" double-sided FDD. The seek durability strongly depends on the CoCrTa film preparation conditions. The durability is strengthen by adding a Si underlayer to a CoCrTa film and by addition of Ta to a CoCr film. The mechanical strength increase is attributed to an increase in the media yield pressure. A high media yield pressure leads to a high seek durability. $200\times10^4$ seek operations were attained for the following media construction: protective overlayer/CoCrTa film/Si underlayer/base film.

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