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DOWNSIZING OF SPUTTERED MAGNETIC DISK

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1. INTRODUCTION

A full line of hard disk drives (HDD), from high capacity, high-speed units to small, low-cost units, about which the external storage devices of information processing systems are centered, is available. Because of their easy maintenance, reliability, and low bit cost, they have much advantage over other external storage devices and are growing rapidly. Due to the popularity of the personal computer and the larger capacity and diversity of software, small sized HDD have shown an annual growth of more than 30%.

The trend of small sized HDD is summarized and what kind of sputtered magnetic disk is necessary in the future is considered.

2. TECHNICAL TRENDS OF HDD AND SPUTTERED MAGNETIC DISK

2.1 Large capacity, high-speed HDD

Fourteen inch, 10.5 inch, and other large capacity HDD used as the external storage device of host computers are being replaced by 5.25 inch and 3.5 inch HDD. A large capacity and high-speed HDD is constructed by arraying multiple HDD mounting the high recording density 5.25 inch and 3.5 inch sputtered magnetic disk. Making the substrate thinner is effective for mounting multiple sputtered magnetic disk. For 5.25 inch disk, 1.27 mm thin substrate disk is used and for 3.5 inch disk, 0.8 mm thin substrate disk is used. This class have the highest recording density in all HDD. But the thinner substrate is easy to be distorted. So, the advanced level of precision machining, surface roughness and flatness, and low surface defects are demanded as compared with thick substrate sputtered magnetic disk.

Table 1 Production series classification by disk size

Thickness (mm) / Diameter (inch)	0.381	0.4445	0.508	0.635	0.80	0.89	1.27	1.905
5.25							○	○
3.5					○		○	
2.5		◇		△		○		
1.89	◇	◇	◇	☆				
1.3	◇	◇	◇	◇				

○: Mass Production ☆: Pre Production
△: Trial Production ◇: Research & Development

2.2 Low height HDD

Miniaturization of the personal computer and the popularity of the laptop computer has accelerated downsizing of the HDD, especially reducing its thickness. A thin 0.8 mm substrate has been used for the sputtered magnetic disk mounted in 3.5 inch HDD with 1 inch (25.4 mm) height.

2.3 Miniaturized HDD

In recent years, the notebook type personal computer, which is recording good sales, has given rise to a new need for miniaturization of the HDD. Since the notebook type personal computer is based on the precept that it is carried, compared to the handy type with multiple floppy disk drives, its popularity is concentrated on models with an HDD capable of storing all the programs and private data. The HDD installed in the notebook type personal computer, small sized magnetic disk, such as 2.5 inch, 1.89 inch, and 1.3 inch, are used. Use of the miniaturized HDD as a external storage device for individual use is expected to grow substantially. However, taking into account competition with flush memory and other types of semiconductor memory, it is necessary not only miniaturization but also large capacity and lower cost.

2.4 Downsizing of sputtered magnetic disk

From the demand trend for miniaturized HDD, the characteristics desired as sputtered magnetic disk were small diameter, thin substrate, and high capacity and low cost. These trend are proved with the increasing of downsized HDD, with thinner sputtered magnetic disk.

With this market trend as the background, Fuji Electric has been mass producing 5.25 inch with 1.27 mm thickness downsized disk media since 1988 and has been mass producing 3.5 inch with 0.8 mm thickness disk since 1989 and 2.5 inch disk since 1990. Preproduction of 1.89 inch downsized disk was started in 1992. The production series classified by disk size is sohwn in *Table 1*.

Fig 1 Cross section profile and data zone range of sputtered magnetic disk

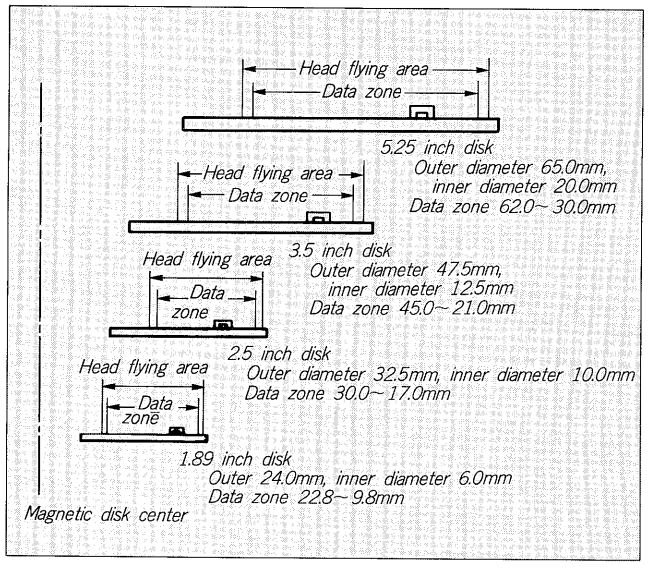
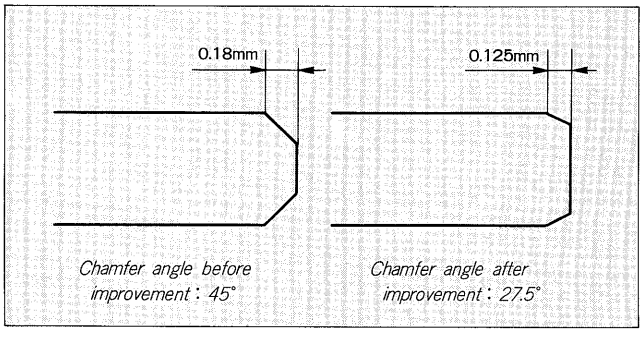


Fig. 2 Chamfer form



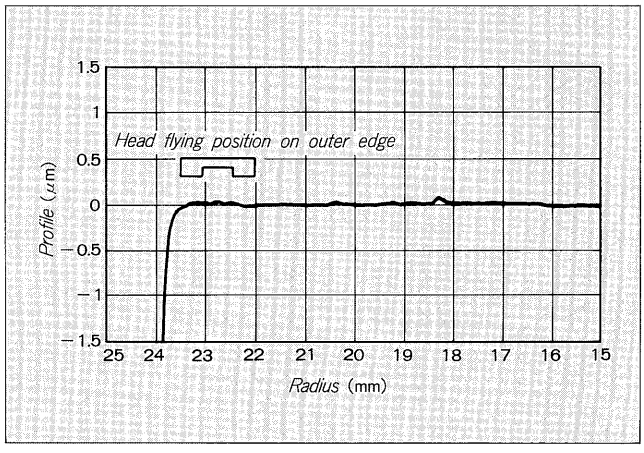
3. DEVELOPMENT OF TECHNOLOGY ESSENTIAL FOR MINIATURIZATION AND DOWNSIZING

The technology essential to deal with smaller and thinner sputtered magnetic disk is described as follows (1) small diameter, thin disk, (2) new substrate material, (3) memory capacity increasing technology, (4) lower cost.

3.1 Precision machining in substrate miniaturization and downsizing

In the past, the central area in radius of the sputtered magnetic disk, where high machining precision is possible and distortion stress and deformation are small, was used as the data zone. It must be used up to the dimensional limit, which means the inner and outer area not used in the past, to realize smaller size and higher capacity. *Figure 1* shows the cross section profile and data zone range of the sputtered magnetic disk. When almost the entire surface of the sputtered magnetic disk can be used like this, it is demanded the advanced precision machining and handling. Specific improvement made in the development of actual 1.89 inch sputtered magnetic disk are described below.

Fig. 3 Rolloff measurement results



3.1.1 Improvement of chamfer form

The flying stability of the head at the outer edge is largely governed by the format of the outer edge of the sputtered magnetic disk. Therefore, the rolloff was improved and the edge distortion stress was minimized by changing the chamfer form from 0.18 mm length 45° angle to 0.125 mm length, 27.5° angle as shown in *Fig. 2*. The outer edge head flying characteristic was improved and a flying height of 2 μ inch (0.05 μ) at an area of 0.5 mm from the outer edge was achieved by means of this. *Figure 3* shows an example of measurement result of rolloff at outer edge.

3.1.2 Sputter shadow area reduction

To use both side of the sputtered magnetic disk, vertical type with horizontally facing electrodes sputtering equipment is used. A groove is provided in the tray and the sputtered magnetic disk is stood up perpendicularly when passing by. The sputter shadow can be suppressed to 0.40 mm or less by making the depth of this groove 0.25 mm, the minimum dimension required to hold the substrate.

3.1.3 Suppression of substrate deformation

When there is a difference in the plating thickness of Ni-P layer between both sides of substrate, substrate heating during the sputtering process causes stress relaxation and the substrate is deformed. This has a greater affect as the substrate becomes thinner. For 1.89 inch substrate, the thickness difference is kept 0.35 μm compared to 0.4 μm for conventional disks and the sputter heating temperature is kept at a suitable value. The disk flatness can be made with in 8 μm or less.

3.1.4 Clamping system investigation

The manufacture of the disk consists of numerous-machinning and testing processes which clamp the inside edge and rotate the disk. Whereas the inner diameter of a small 1.89 inch substrate is an extremely small 12 mm, the clamping area is narrow because of the need for a wide data zone. In order to increase machining precision, in particular, the surface runout had to be made small and a new clamping system was necessary.

(1) Texturing equipment

Since texture irregularities were generated by sliding of the substrate at the inner circle edge chuck in the past, chucking was changed to an inner circumference surface chuck system and the surface precision was controlled more severe.

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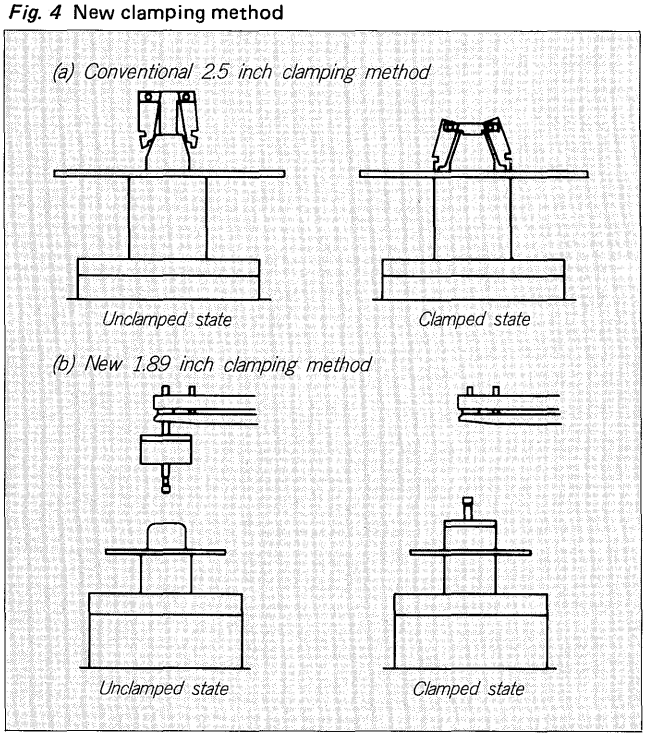
(2) Test process

The generation of numerous errors at the inner circumference was a problem. This problem was playback waveform abnormalities caused by substrate distortion stress during clamping. The clamping method was changed from the conventional umbrella opening clamping method to a cap method, which holds the entire substrate as shown in *Fig. 4*, as an improvement measure. With these improvements, the 1.89 inch sputtered magnetic disk meets the target specification and preproduction is being carried out.

Fig. 4 New clamping method



3.2 New substrate material

Recently, the new substrate materials shown in *Table 2* have been selected as research objectives as alternate substrates. The glass substrate has already been commercialized. The glass substrate features:

(1) Excellent flatness
(2) Excellent thermal stability
(3) Since it is very hard, it can be made thin.

On the other hand, its problems are:

(1) Texturing is necessarily for current product process.
(2) A metal layer is required to apply bias.
(3) Cost is high.

Fig. 5 Large capacity technology

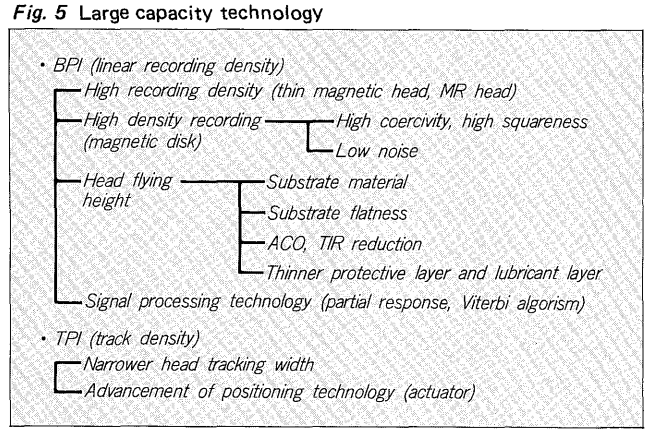


Table 2 New substrate materials

(a) Features of alternate substrates

Glass	Ceramics	Titanium	Carbon
• Hardness • Flatness, smooth surface • Thermal stability • Low thermal expansion	• Thermal stability • Hardness • Precision machining • Low thermal expansion	• Thinness • Thermal stability • NiP plating unnecessary	• Flatness • Thermal stability • Light weight • Electrical conductivity

(b) Comparison of material physical properties

Physical property	Unit	Aluminum		Glass			Ceramics		Titanium	Carbon
		Al	Ni-P	Soda-lime glass	Aluminosilicate glass	Glass ceramics	GGA	ZrO_2		
Specify gravity	g/cm³	2.7		2.5	2.52	2.6	3.9	6.05	4.5	1.8
Young s modulus	GPa	71		74	84	90	370	216	103	–
Poisson s ratio	–	0.33		0.22	0.23	0.23	0.24	0.31	0.34	–
Tensile strength Bending strength	MPa	255		386	592	241	350	1,370	276	180
Surface hardness	GPa	0.64	4.9	6.5	6.6	6.4	16.2	12.7	–	5.9
Specific heat	J/gK	0.96		0.76	0.83	0.84	0.8	0.5	0.53	0.85
Heat conductivity	W/mK	117		1.09	1.28	1.28	33	3.8	17	10.0
Thermal expansion	10^{-6}/K	24.2		8.0	9.1	12.0	7.2	10.5	8.4	3.0

When these thickness of alternate substrate is 0.5 mm or less, the development of precision machining technology and lower cost are expected to become future problems, the same as for aluminum substrate.

3.3 Large capacity technology

The items shown in *Fig. 5* are considered as technologies for increasing the capacity of sputtered magnetic disk. In relation to this, in regard to high coercivity and low noise disk technology, refer to the article "High-coercivity, low-noise sputtered magnetic disk" and in regard to head flying technology and CSS characteristics, refer to the article "Low flying height and high CSS durability techniques" of this special issue.

Regarding small diameter HDD, improvement of the magnetic head is demanded. Since the voltage induced by electromagnetic induction is used to playback recording by magnetic head, if the diameter is small and the peripheral speed is slow, the desired playback output is not obtained. Therefore, when the diameter is small, an MR (Magnetic Resistance) element whose resistance value is changed by magnetic flux changes is used and the MR head, which provides constant output regardless of peripheral speed, has a promising future. A head of smaller size 50% to 70% size than the conventional one is used so that a wide recording zone is obtained.

3.4 Lower cost

Miniaturization and downsizing reduce the amount of material used, but since single disk processings such as texturing and testing are included, lower cost cannot be achieved by only improving conventional devices. Therefore, reduction of the clean room space used by the single disk processes for 1.80 inch and smaller sputtered magnetic disk by arraying special small equipment and the simultaneous establishment of a mass production system are considered to be important.

4. AFTERWORD

We feel that miniaturization and downsizing of the sputtered magnetic disk installed in miniaturized HDD will accelerate in the future. A 1.3 inch HDD has already been placed on the market and is viewed as a spur to downsizing mainly in 2.5 inch or 1.89 inch HDD. Since miniaturized HDD are considered as products aimed at the individual and at the home, volume-wise, it is expected to grow tremendously. However, the demands placed on cost and quality will become more severe. To meet these demands, mass production technology must be strengthened further and throughput improved.