

Master disk for magnetic duplication and a method for manufacturing the master disk

5 Technical field of the invention

The present invention relates to a master disk for magnetic duplication and a fabrication method thereof. In particular, the invention relates to a method to write servo signals for positioning a head for reading and writing the data from and to a magnetic recording disk surface, or to write special data by using a magnetic duplication technique in a hard disk drive (hereinafter also referred to as "HDD"). The HDD uses a magnetic film as a recording material and is a major device of external storage equipment for computers at present.

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Background of the invention

Recording and readout of data in the HDD are performed by a magnetic head flying over the surface of a rotating magnetic recording medium by a levitation mechanism called slider keeping a distance of a few tens of nanometers above the disk surface. Bits of information on a magnetic recording medium are stored on data tracks arranged concentric on the medium surface. A magnetic head is quickly moved and positioned at a target data track on the medium surface and records or readout data.

Positioning signals (or servo signals) for detecting relative position between the magnetic head and the data track are written concentric on the surface of the magnetic recording medium. The magnetic head detects its own position at intervals while recording and reading out data. In order to avoid the center of the written servo signals being off-centered from the medium center or the center of the running course of the magnetic head, the servo signals are written after installing the magnetic recording medium into the HDD by using a dedicated apparatus called a servo writer. Recording density has currently reached as high as 100 G bits / in² in a development phase, and the recording capacity is increasing at a rate of 60 % a year. Consequently, the density of the servo signals for detecting the position of the head has necessarily increased, resulting in increase in the time for writing the servo signals year after year. The prolonged time for writing the servo signals is becoming a severe factor that lowers productivity of the HDD and raises its cost.

Recently, a magnetic duplication technique is being developed where whole servo signals are magnetically transcribed at one time in place of a method to write servo signals using a signal writing head of the above-mentioned servo writer. This technique is expected to substantially shorten the time for writing the servo information.

Figs. 11(a), 11(b), 11(c) and Figs. 12(a), 12(b) illustrate the

magnetic duplication technique in which the servo signals are written at one time using a signal writing head. (See the permanent magnet 110 in Figs. 12(a) and 12(b).)

5 Figs. 11(a), 11(b), and 11(c) show the magnetic duplication process between a master disk 1 and a magnetic recording medium 100.

10 In the initial homogeneous magnetization process illustrated in Fig. 11(a), the curved arrow on a magnetic recording medium 100 comprising a magnetic layer 102 formed on a substrate 101 shows the movement path of a permanent magnet for magnetic duplication. Magnetic layer 102 is homogeneously magnetized in circumferential direction.

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 In the positioning process illustrated in Fig. 11(b), the master disk 1 for magnetic duplication is disposed in position on the magnetic recording medium 100.

20 In the step of transferring signal patterns in Fig. 11(c), the master disk is put in contact with the magnetic recording medium 100, and the permanent magnet 110 for magnetic duplication is moved along the path depicted by the curved arrow to perform magnetic duplication.

Figs. 12(a) and 12(b) illustrate outline of the magnetic duplication for the magnetic recording medium 100.

Fig. 12(a) is a cross sectional view showing an initial
5 homogeneous magnetization process where a permanent magnet 110
is moved over the magnetic recording medium 100 with a constant
gap less than 1 mm.

The magnetic film deposited on the substrate is not magnetized
10 in one direction in the beginning and is magnetized in this initial
homogeneous magnetization process in one direction by leakage flux
in the gap of the permanent magnet 110. The arrows depicted in the
magnetic film in Figs. 12(a) and 12(b) indicate the direction of
magnetization.

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The step of transferring signal pattern shown in Fig.12 (b)
illustrates magnetic duplication process. The master disk 1
comprises soft magnetic film 10, a cobalt-based soft magnetic film for
example, embedded on the surface portion of a silicon substrate 1a
20 opposite to the medium surface.

The permanent magnet 110 generates leakage magnetic field for
writing duplication signals, the direction of which is reversed from
the direction of the magnetic filed in the initial homogeneous

magnetization process. In the arrangement where the master disk 1 having a pattern of embedded soft magnetic films 10 is intervening between the permanent magnet 110 and the magnetic recording medium 100, leakage magnetic field from the permanent magnet 110 penetrates through the silicon substrate 1a and magnetizes magnetic layer 102 in the region without the soft magnetic films 10, while in the position of soft magnetic films 10 in the pattern, the leakage flux flows within the soft magnetic films 10 because the magnetic flux takes the path of minimum reluctance.

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Accordingly, the leakage magnetic flux through the silicon substrate 1a is small in the position of the soft magnetic films 10, thus, magnetization is not newly written in the magnetic recording medium.

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Patterns on the master disk 1 are conventionally not product servo patterns 20 as shown in Fig. 13, but are reference servo patterns 30 as shown in Fig. 14 that serve a base for self-generating the product servo patterns in a hard disk.

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The reference servo pattern 30 is imposed with the following restrictions in order that the magnetization can be securely reversed in the process of magnetic duplication using a master disk 1 by the external field in the portion of the magnetic recording medium 100

that just opposes to the location of the master disk 1 at which a soft magnetic film 10 is absent. Here, the minimum line width of the reference servo pattern 30 is about 1.5 μm , while that of the product servo pattern 20 is 0.35 μm .

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1) Patterns other than the burst pattern, for example a preamble pattern, don't change in the radial direction (R direction) and only change in the circumferential direction (θ direction) that is the direction along a track.

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2) The burst pattern 5 is an isolated pattern that is composed of isolated magnetic films.

The following describes problematic points in magnetic

15 duplication using a master disk 1 on which a reference servo pattern 30 is formed.

1) Errors in the process of forming the reference servo pattern 30 affect the product servo pattern 20, which is not a situation suited for high density recording.

2) The effect of magnetic duplication would be enhanced if the magnetic duplication pattern could include OS and contents in addition to the reference servo pattern 30.

Relating to the point 2), in particular, recording of only the servo pattern is sufficient in an externally installed hard disk, while hard disks installed within an apparatus, for example a personal computer in these days, are equipped with pre-installed OS and application software at the time of shipment. It will be very effective to magnetically duplicate those types of software, too. Thus, a technique is expected to be developed that allows magnetic duplication of the product servo pattern and the data pattern.

The product servo patterns 20 as shown in Fig. 13 used in conventional HDDs can be classified into the three patterns that are described below and enlarged views thereof are shown in Figs. 15 through 18.

1) Fig. 15 shows a pattern that does not change in the radial direction (R direction) and changes only in the circumferential direction (θ direction). A typical pattern of this type is a preamble pattern 2 that performs amplitude adjustment of readout signals and clock extraction from the readout signals.

2) Fig. 16 shows an isolated pattern composed of isolated magnetic films. A burst pattern 5 is this type of pattern. The burst pattern detects the position of the magnetic head.

3) Fig. 17 and Fig. 18 show other patterns than the above two types of patterns.

5 The pattern of Fig. 17 corresponds to irregular patterns including servo detection pattern 3 and patterns for the servo address information (track number 4a and sector number 4b). The pattern of Fig. 18 corresponds to an entirely irregular pattern such as a contents pattern.

10 The area surrounded by closed lines in Figs. 15 through 18 is the zone where soft magnetic film 10 is formed in the master disk 1.

Japanese Unexamined Patent Application Publication No. 2001-283433 discloses a technique for avoiding detection error of a readout
15 signal by correcting pulse shift of the readout signal that is detected corresponding to the soft magnetic pattern of the master carrier.

Japanese Unexamined Patent Application Publication No. 2002-216343 discloses a technique to prevent occurrence of signal loss by
20 enhancing intimate contact between a slave medium and a master carrier. The intimate contact is made possible by forming air suction paths, which in turn is formed by the pattern of protrusions and recesses in the master carrier with the width of the protrusions smaller than the track pitch.

Problem to be solved by the invention

Magnetic duplication can be carried out without problem for the preamble pattern 2 and the burst pattern 5 of the three types of product patterns 20. However, in the patterns except for the above
5 two types of patterns, an area surrounded by a soft magnetic film 10 as shown in Figs. 19(a), 19(b) and 19(c) (hereinafter, such an area is referred to as a special region A) cannot be magnetically duplicated.

Although Fig. 12 is a cross-sectional view of magnetic duplication,
10 the magnetic flux actually flows in a three-dimensional space and take a path of minimum reluctance.

In the patterns of Figs. 19(a), 19(b) and 19(c), it is ideally desired that in the special region A, in which soft magnetic film 10 is absent,
15 all the magnetic flux from the external field would flow in the magnetic recording medium 100 intimately contacting with the master disk 1. However, the magnetic flux actually tends to flow in the adjacent soft magnetic film 10 that exhibits less reluctance. As a
20 result, only a small fraction of the magnetic flux from the external field can flow in the magnetic recording medium 100 intimately contacting with the master disk 1.

In a case of small duplication field, in particular, the special region A surrounded by the pattern of the soft magnetic film 10 as

shown in Figs. 19(a), 19(b) and 19(c) has a problem that the reversal of magnetization as shown in Fig. 12(b) cannot be performed. As a result, so-called bit loss occurs in the readout signals from the magnetic recording medium 100 with the transferred magnetic pattern from the master disk 1. Thus, ideal duplication can be hardly performed.

More specific description will be made below.

Fig. 10 is an enlarged top plan view of a master disk 1. The special region A (marked by hatching) surrounded by a pattern of soft magnetic film 10 is an area where reversal of magnetization is difficult. This special region A of difficult magnetization reversal has a relatively small area and is surrounded by a soft magnetic film 10 in close proximity. In magnetic duplication process using a permanent magnet 110 as shown in Fig. 12(b), the applied magnetic field collectively flows in the surrounding soft magnetic film 10 and is not lead to the special region A in the central region.

Because a soft magnetic film 10 does not exist in special region A, properly large magnetic flux should be applied to the magnetic recording medium 100 in the location that is opposing the special region A and magnetically transferred from that area. Nevertheless, the special region A is surrounded by the soft magnetic film 10 in close proximity, so enough magnetic flux can not be applied.

Since properly large magnetic flux is not lead to the slave magnetic recording medium 100 at the location opposing the special region A, reversal of magnetization is not performed, resulting in incorrect magnetic duplication.

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Because of incorrect magnetic duplication according to the technique of magnetic duplication, some information data that is to be recorded on the magnetic recording medium 100 as a correct value of "1" may be recorded as a wrong value of "0". Thus, there is a
10 problem that highly reliable magnetic duplication is impossible.

Accordingly, an object of the present invention is to provide a master disk for magnetic duplication allowing highly reliable magnetic duplication technique, and another object is to provide a
15 method for manufacturing such a master disk. A master disk and a manufacturing method according to the invention allow eliminating bit loss in a magnetic recording medium having a magnetic pattern transferred from the master disk. For achieving this, a region is provided where reversal of magnetization by transferring field is
20 secured, even in the area surrounded by a surrounding shape pattern of soft magnetic film.

Means to solve the problem

One aspect of the present invention is a master disk for magnetic

duplication comprising duplication patterns that is magnetically duplicated to a magnetic recording medium, and a pattern of soft magnetic films embedded in the master disk arranged in a radial direction and a circumferential direction surrounding a special region
5 that has an area equal to an area of a division of one record pixel, the special region being a magnetic transfer region consisting of a magnetization reversible area that is magnetically transferred and a magnetization irreversible area that is not magnetically transferred.

10 The magnetization reversible area is formed in a central region of the division of a record pixel and a magnetic flux of an externally applied magnetic field is collectively lead to the magnetization reversible area with very little influence of the pattern of soft magnetic films, and the magnetization reversible area constitutes a
15 part of a magnetic path having a minimum reluctance for the magnetic flux of an externally applied magnetic field. The magnetization irreversible area is formed around the magnetization reversible area and the externally applied magnetic field is not lead to the magnetization irreversible area with influence of the pattern of
20 soft magnetic films, and the magnetization irreversible area constitutes a magnetic path having a larger reluctance for the magnetic flux of the externally applied magnetic field than the reluctance of the magnetic path including of the magnetization reversible area.

Each soft magnetic film of the pattern of soft magnetic films surrounding the magnetization reversible area and the magnetization irreversible area of the magnetic transfer region preferably has a width in the radial direction smaller than a track pitch.

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Each soft magnetic film in the pattern of soft magnetic films surrounding the magnetization reversible area and the magnetization irreversible area of the magnetic transfer region preferably has a width in the circumferential direction smaller than a line pitch.

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Each soft magnetic film of the pattern of soft magnetic films preferably has the width in the radial direction of about half the track pitch or the width in the circumferential direction of about half the line pitch.

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The pattern of soft magnetic films is preferably embedded along the line of the radial direction and the circumferential direction in the duplication pattern other than a burst pattern used for positioning of the magnetic head.

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Another aspect of the present invention is a method for manufacturing a master disk for magnetic duplication having duplication patterns that are magnetically duplicated to a magnetic recording medium and a pattern of soft magnetic films, the

duplication patterns and the pattern of soft magnetic films being embedded in the master disk.

The method comprises a step of arranging the pattern of soft
5 magnetic films in a radial direction and a circumferential direction
surrounding a special region that has an area equal to an area of a
division of one record pixel; a step forming a magnetization reversible
area in a central region of the division of a record pixel, wherein a
magnetic flux of an externally applied magnetic field is collectively
10 lead to the magnetization reversible area without influence of the
pattern of soft magnetic films, and the magnetization reversible area
constitutes a part of a magnetic path having a minimum reluctance
for the magnetic flux of an externally applied magnetic field; and a
step of forming a magnetization irreversible area around the
15 magnetization reversible area, wherein the externally applied
magnetic field is not lead to the magnetization irreversible area with
influence of the pattern of soft magnetic films, and the magnetization
irreversible area constitutes a magnetic path having a larger
reluctance for the magnetic flux of the externally applied magnetic
20 field than the reluctance of the magnetic path including the
magnetization reversible area.

Brief description of drawings

Fig. 1 is a plan view showing surrounding shape patterns of soft

magnetic films on a master disk of the first aspect of embodiment according to the present invention. Surrounding shape patterns according to prior art are also shown for comparison.

Fig. 2 is a plan view of an enlarged pattern of soft magnetic films according to the present invention.

Fig. 3(a) through Fig. 3(e) show a process for manufacturing a master disk to form a pattern of soft magnetic films according to the present invention.

Fig. 4 illustrates a relationship between a burst pattern and data tracks.

Fig. 5(a) through Fig. 5(d) illustrate waveforms obtained on detecting the patterns by a magnetic head.

Fig. 6 is a flow chart showing signal processing of detected waveform.

Fig. 7(a) illustrates readout signals from a soft magnetic film of a pattern of soft magnetic films according to a prior art and Fig. 7(b) illustrates readout signals from a soft magnetic film of a pattern of soft magnetic films according to the present invention.

Fig. 8 is a plan view showing one variation of a pattern of soft magnetic films in which a length in the circumferential direction is not restricted, in the second aspect of embodiment according to the present invention.

Fig. 9 is a plan view showing another variation of a pattern of soft magnetic films in which a length in the radial direction is not

restricted, in the second aspect of embodiment according to the present invention.

Fig. 10 illustrates surrounding shape patterns of soft magnetic films according to a prior art.

5 Fig. 11(a) through Fig. 11(c) illustrate a magnetic duplication process of a magnetic recording medium.

Fig. 12(a) and Fig. 12(b) illustrate outline of a magnetic duplication process of a magnetic recording medium.

Fig. 13 illustrates a product servo pattern.

10 Fig. 14 illustrates a reference servo pattern.

Fig. 15 illustrates a pattern that does not vary in the radial direction and only varies in the circumferential direction: an example of a preamble pattern.

15 Fig. 16 illustrates an isolated pattern: an example of a burst pattern.

Fig. 17 illustrates a type of entirely irregular pattern: a servo pattern.

Fig. 18 illustrates another type of entirely irregular pattern: a contents pattern.

20 Fig. 19(a) through Fig. 19(c) illustrate examples of patterns that are difficult to be magnetically duplicated.

Aspect of embodiment of the invention

Some aspects of preferred embodiments according to the present

invention will be described in detail below with reference to accompanying drawings.

First Example

5 The first aspect of embodiment of the invention will be described referring to Figs. 1 through 7.

Structure of a master disk

Structure of master disk 1 will be described.

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Fig. 1 shows patterns on a master disk 1.

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The master disk has patterns of soft magnetic films 50 according to the invention embedded on the surface region thereof. For comparison with a prior art, the disk surface also includes illustration of conventional patterns of soft magnetic films 10 that are difficult to be magnetically duplicated. Burst pattern 5 is also illustrated in Fig. 1. Patterns other than the pattern of the soft magnetic films 50 are the same as the patterns illustrated in Fig. 13 and Fig. 14.

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Fig. 2 is an enlarged illustration of the region in Fig. 1 in which the patterns of soft magnetic films 50 are formed.

The soft magnetic film 50 of the pattern has a rectangular shape,

a side length in the radial direction being half the track pitch and a side length in the circumferential direction being half the line pitch.

5 A plurality of soft magnetic films 50 of the pattern (seven or eight films in this example) are arranged along the radial direction and the circumferential direction and around the special regions P and Q having a combined area equal to the area of a division for one record pixel, thereby composing a surrounding shape pattern 40 around the special regions.

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The special region P that is surrounded by a surrounding shape pattern 40 and has an area equal to the area of a division for one record pixel, forms as an area that allows reliable magnetization reversal in the special region P by transferring magnetic field.

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The special region P is positioned at the central portion of the division for one record pixel and is a magnetization reversible area in which magnetization can be reversed by the transferring magnetic field.

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The special region Q is positioned in the peripheral portion around the magnetization reversible area and is a magnetization irreversible area in which magnetization is not reversed by the transferring magnetic field.

In this example of embodiment of the invention, magnetic duplication process from the master disk 1 to the magnetic recording medium 100 is the same as the previously described one referring to Figs. 11(a), 11(b), 11(c) and Figs. 12(a), 12(b). That is, the process in the example also employs a technique of magnetic duplication using a signal transferring head such as a permanent magnet 110.

Principle of magnetic duplication

The principle of magnetic duplication using the master disk 1 will be described.

In Fig. 1, the solid lines in the radial direction indicate the center of the data track and the dotted lines indicate the positions $\pm TP/4$ apart from the center of the data track. The solid lines along the radial direction show the position of line change and the dotted lines shows $\pm LP/2$ position relative to the position of line change. Here, TP represents a track pitch, and the LP the line pitch.

A conventional pattern of soft magnetic films 10 is formed with TP and LP as unit lengths. In contrast, a pattern of soft magnetic films 50 according to the invention is formed with $TP/2$ and $LP/2$ as lengths of the unit of the magnetic films, the periods of the unit being TP and LP. Regions without the magnetic film with side lengths of $TP/2$ and $LP/2$ are provided between the units of magnetic films. As a

result, the magnetic films are isolated each other.

Fig. 2 illustrates flow of magnetic flux based on physics in the special regions P and Q surrounded by a pattern of the soft magnetic films 50 shown in Fig. 1.

The black rectangular areas in Fig. 2 represent soft magnetic films 50.

10 The area with hatching positioned in the center represents the special region P, which was conventionally hard to be magnetically duplicated. (See the special region A in Fig. 10.) The special region P in the present invention is a magnetization reversible area that allows magnetic duplication.

15 Special regions Q are formed around the special region P, that is, in the neighboring area of the magnetization reversible area. The special regions Q are magnetization irreversible areas that cannot be magnetically duplicated. The region having at least the special
20 region P of magnetization reversible area and the special regions Q of magnetization irreversible areas as a whole is referred to as a magnetization transfer region.

When an external field for magnetic duplication is applied by a

permanent magnet 110 as shown in Fig. 12 (b), a unidirectional magnetic field is applied in Fig. 2 in the circumferential (θ) direction. The magnetic flux of the external field tends to take a path of minimum reluctance according to the law of physics.

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The reluctance is inversely proportional to the cross sectional area and directly proportional to the length of the path of magnetic flux flow. Because the special region P positioned in the central region is apart from the soft magnetic films 50, the flow of the magnetic flux of the external field is hardly affected by the soft magnetic films 50. Consequently, the magnetic flux is lead to the central region without significant disturbance.

Now, examining magnetic flux flow from the point A to the point B in Fig. 2, the three paths can be assumed: the first path $A \rightarrow C \rightarrow B$ through the special region P, the second path $A \rightarrow D \rightarrow B$ through the special region Q, and the third path $A \rightarrow E \rightarrow F \rightarrow B$ through the special region Q and a soft magnetic film. The reluctance of each path can be represented as follows.

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Because the reluctance of R_d of the soft magnetic film 50 is far smaller than the reluctance R_c of magnetic film 101 of the magnetic recording medium 100, R_d of the R_{AEFB} can be neglected.

path	reluctance
A→C→B	$R_{ACB} = 2 \times R_a$
A→D→B	$R_{ADB} = 2 \times R_b$
A→E→F→B	$R_{AEFB} = 2 \times R_c + R_d = 2 \times R_c$

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Since the magnitude of the reluctances R_a , R_b , and R_c of the magnetic layer 101 of the magnetic recording medium 100 is proportional to the distance in the magnetic circuit as shown in Fig. 2, the path exhibiting smallest reluctance is the path A→C→B.

- 10 Consequently, magnetic flux flows in the special region P (indicated by hatching) where magnetic duplication was conventionally difficult, even through the soft magnetic films 50 exist around the special region. External field can be applied to the magnetic recording medium 100 in contact with the master disk 1, thereby allowing the
- 15 reversal of magnetization as in the transferring process shown in Fig. 12(b) in this special region P of the magnetization transfer region.

Therefore, the special regions P and Q can be defined as follows.

- 20 The special region P (a magnetization reversible area) is an area where the magnetic flux of external field flows with very little influence of the pattern of soft magnetic films 50 and is collectively lead to the central region. The special region P is formed as a part of the magnetic path of minimum reluctance against magnetic flux flow.

On the other hand, the special region Q (a magnetization irreversible area) is an area where the magnetic flux of external field tends to flow to the soft magnetic films 50 with smaller reluctance affected by the pattern of soft magnetic films 50 and ^{do not} is not lead to the
5 special region Q. The special region Q is formed as a magnetic path having greater reluctance than a magnetic path including the magnetization reversible area.

Manufacturing method

10 A manufacturing method of the master disk 1 will be described below.

Fig. 3 shows the manufacturing process of a master disk 1 that is used in the magnetic duplication of servo signals by a mechanism
15 shown in Fig. 12.

In the first step shown in Fig. 3(a), a resist film 61 having thickness of 1.2 μm is applied onto the surface of a silicon substrate about 500 μm thick using a spin coater. Then, in the second step
20 shown in Fig. 3(b), patterning is conducted to the resist film by means of photolithography similar to a manufacturing method of usual silicon semiconductors.

The resist film is used as a mask for etching in the third step.

Since the resist film is made of novolac, which is not very resistant to etching, it is important for the resist film to have sufficient thickness not to melt out.

5 In the third step shown in Fig. 3(c), the silicon substrate 60 is processed by dry etching to a depth of 500 nm employing reactive plasma etching using a reactive gas of methyl trichloride, to form grooves.

10 In the fourth step shown in Fig. 3(d), soft magnetic film 50 is deposited to a thickness of 500 nm by means of a sputtering method leaving the resist film 61, to embed the soft magnetic films 50 in the grooves.

15 Patterns of soft magnetic films 50 are formed with the unit lengths of half the track pitch in the radial direction and half the line pitch in the line direction having the soft magnetic films isolated each other as shown in Fig. 1 except for the isolated pattern such as burst pattern 5 and the patterns, such as preamble pattern 2, that are
20 invariable in the radial direction and only variable in the circumferential direction out of the three types of the magnetic patterns formed on the magnetic recording medium 100.

In the fifth step shown in Fig. 3(e), the silicon substrate 60 is

immersed in a solvent that dissolves the resist film after deposition of the magnetic films 50, while ultrasonic is also applied as required. As a result, the resist films 61 between the soft magnetic films 50 and the silicon substrate 60 are dissolved and removed.

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A master disk produced by the above-described manufacturing method allows perfectly avoiding bit loss in a magnetic recording medium having magnetic patterns transferred from the master disk. That means the bit error rate of the medium is zero.

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Readout process of information

Readout process of information recorded on a magnetic recording medium 100 that is duplicated using the master disk 1 is described referring to Fig. 4 through Fig. 7.

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Fig. 4 shows a relationship between a burst pattern 5 and data tracks.

The figure shows the positions of the tracks Trk 0 through Trk 7 in the case of the data plane servo system. The burst pattern 5 of A, B, C, and D indicates the position of the magnetic head 200 relative to the track center.

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Fig. 5(a) through Fig. 5(d) show the waveforms obtained on

detecting the pattern by the magnetic head 200. Fig. 6 is a flow chart showing signal processing of a detected waveform

In step S1, the magnetic head 200 is moved on the burst pattern
5 A through D shown in Fig. 5(a) in the circumferential direction to detect pattern signals.

In steps 2 and 3, the detected signals are amplified and passed through a low-pass filter to read out the signal waveforms shown in
10 Fig. 5(b).

In step S4, the read out waveform is processed by full wave rectification to obtain a rectified waveform of the signal shown in Fig. 5(c).
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In step S5, the rectified waveform of the signal is integrated to obtain the integrated waveform of Fig. 5(d), wherein the integration is reset between the pattern B and the pattern C.

20 In step S6, sampling is executed at four points from the integrated waveform of the signal, to extract sampling signals corresponding to the values of A, A+B, C, and C+D.

In step S7, the values of the four sampling signals are computed

by a computing element to calculate $A \cdot B$ and $C \cdot D$.

$A \cdot B$ is output if $C \cdot D > 0$ and $-(A \cdot B)$ is output if $C \cdot D \leq 0$. Thus, a position signal detected by the magnetic head 200 is generated in a form of analogue voltage over the whole width of one track.

As described above, the data track is determined by the burst pattern 5, and generally, a track pitch TP is equal to a length of the burst pattern 5 in the radial direction. The line pitch LP is equal to the line width in the circumferential direction of the preamble pattern 2 that generates clock frequency, and usually same as the line width of the burst pattern in the circumferential direction.

The pattern of soft magnetic films 50 according to the present invention is applied to patterns other than the isolated patterns such as the burst pattern 5 and the patterns, such as the preamble pattern 2, which are invariable in the radial direction and only variable in the circumferential direction.

As a result, the magnitude of the read out waveform of the signals differs between the readout signal 300 from the pattern of the soft magnetic films 10 of Fig. 7(a) where the invention is not applied and the readout signal 301 from the pattern of the soft magnetic film 50 of Fig. 7(b) where the invention is applied. The difference,

however, can be complied with by a measure using an appropriate electronic circuit described below.

1) The problem that the pulse interval of the read out signals from
5 the magnetic head 200 is halved due to half length in the circumferential direction of the magnetized region is solved by doubling the sampling frequency just in that region.

2) The problem that the amplitude of the read out signals from the
10 magnetic head 200 is halved due to half length in the radial direction of the magnetized region is solved by doubling the gain of the AGC (Auto Gain Control) amplifier just in that region.

Second Example

15 The second aspect of embodiment of the invention will be described referring to Fig. 8 and Fig. 9.

This Example shows some variations of the pattern of soft magnetic films 50. The soft magnetic films 50 in the First Example
20 described above have a square shape with the lengths in the radial direction and the circumferential direction being half the each pitch. However, the shape of the soft magnetic film is not limited to this configuration.

In the example of Fig. 8, the length in the radial direction is limited to half the track pitch, but no limitation is imposed to the length in the circumferential direction.

5 In the example of Fig. 9, the length in the circumferential direction is limited to half the line pitch, but no limitation is imposed to the length in the radial direction.

As shown in the examples, the configuration of the pattern of the
10 soft magnetic films 50 is not limited to a special form, as long as the region surrounded by a surrounding shape pattern of soft magnetic films 50 in the radial direction and in the circumferential direction includes a region with an area of a division of one record pixel consisting of a special region P (of a magnetization reversible area
15 that can be magnetically transferred) and a special region Q (of a magnetization irreversible area that cannot be magnetically transferred).

Advantageous Effect of the invention

20 As described so far, a master disk for magnetic duplication according to the present invention is provided with a special region consisting of a magnetization reversible area and a magnetization irreversible area around the magnetization reversible area in a region that is surrounded by a surrounding shape pattern of soft magnetic

films and has an area corresponding to one record pixel. The special region allows securing reversal of magnetization by a transferring magnetic field.

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Claims

1. A master disk for magnetic duplication comprising:
duplication patterns that is magnetically duplicated to a
magnetic recording medium; and

5 a pattern of soft magnetic films embedded in the master disk
arranged in a radial direction and a circumferential direction
surrounding a special region that has an area equal to an area of a
division of one record pixel, the special region being a magnetic
transfer region consisting of a magnetization reversible area that is
10 magnetically transferred and a magnetization irreversible area that
is not magnetically transferred, wherein

the magnetization reversible area is formed in a central region of
the division of a record pixel and a magnetic flux of an externally
applied magnetic field is collectively lead to the magnetization
15 reversible area, and the magnetization reversible area constitutes a
part of a magnetic path having a minimum reluctance for the
magnetic flux of an externally applied magnetic field, and

the magnetization irreversible area is formed around the
magnetization reversible area and the externally applied magnetic
20 field is not lead to the magnetization irreversible area, and the
magnetization irreversible area constitutes a magnetic path having a
larger reluctance for the magnetic flux of the externally applied
magnetic field than the reluctance of the magnetic path including the
magnetization reversible area.

2. A master disk for magnetic duplication according to claim 1,
wherein each magnetic film forming the pattern of soft magnetic
films surrounding the magnetization reversible area and the
magnetization irreversible area of the magnetic transfer region has a
5 width in the radial direction smaller than a track pitch.

3. A master disk for magnetic duplication according to claim 1,
wherein each soft magnetic film in the pattern of soft magnetic films
surrounding the magnetization reversible area and the magnetization
10 irreversible area of the magnetic transfer region has a width in the
circumferential direction smaller than a line pitch.

4. A master disk for magnetic duplication according to claim 2,
wherein each soft magnetic film in the pattern of soft magnetic films
15 has the width in the radial direction of about half the track pitch.

5. A master disk for magnetic duplication according to claim 3,
wherein each soft magnetic film in the pattern of soft magnetic films
has the width in the circumferential direction of about half the line
20 pitch.

6. A master disk for magnetic duplication according to claim 1,
wherein the pattern of soft magnetic films is embedded along a line of
the radial direction and along a line of the circumferential direction

in the duplication pattern other than a burst pattern used for positioning of the magnetic head.

7. A master disk for magnetic duplication according to claim 2,
5 wherein the pattern of soft magnetic films is embedded along a line of the radial direction and along a line of the circumferential direction in the duplication pattern other than a burst pattern used for positioning of the magnetic head.

10 8. A master disk for magnetic duplication according to claim 3, wherein the pattern of soft magnetic films is embedded along a line of the radial direction and along a line of the circumferential direction in the duplication pattern other than a burst pattern used for positioning of the magnetic head.

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9. A master disk for magnetic duplication according to claim 4, wherein the pattern of soft magnetic films is embedded along a line of the radial direction and along a line of the circumferential direction in the duplication pattern other than a burst pattern used for
20 positioning of the magnetic head.

10. A method for manufacturing a master disk for magnetic duplication having duplication patterns that are magnetically duplicated to a magnetic recording medium and a pattern of soft

magnetic films, the duplication patterns and the pattern of soft magnetic films being embedded in the master disk, the method comprising:

5 a step of arranging the pattern of soft magnetic films in a radial direction and a circumferential direction surrounding a special region that has an area equal to an area of a division of one record pixel;

forming a magnetization reversible area in a central region of the division of a record pixel, wherein a magnetic flux of an externally applied magnetic field is collectively lead to the magnetization
10 reversible area, and the magnetization reversible area constitutes a part of a magnetic path having a minimum reluctance for the magnetic flux of an externally applied magnetic field; and

forming a magnetization irreversible area around the magnetization reversible area, wherein the externally applied
15 magnetic field is not lead to the magnetization irreversible area and the magnetization irreversible area constitutes a magnetic path having a larger reluctance for the magnetic flux of the externally applied magnetic field than the reluctance of the magnetic path including the magnetization reversible area.

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