



METHOD OF MAGNETIC TRANSFER TO MAGNETIC
RECORDING MEDIUM INCLUDING TWO RECORDING LAYERS
AND THE MAGNETIC RECORDING MEDIUM

Field of the Invention

5 The present invention relates to a method of writing servo data for
positioning a magnetic head for writing and reading data to the surface of a
magnetic recording medium in a hard disk drive by employing the magnetic
transfer technique. The hard disk drive using a magnetic film for the
recording stuff thereof (hereinafter referred to as the "HDD") is now used for
10 an external storage of most computers. Specifically, the present invention
relates to a method of magnetic transfer to a magnetic recording medium
including two recording layers and the magnetic recording medium
including two recording layers.

15 Prior Art

A new servo writing technique, that magnetically transfers servo data
for positioning a magnetic head for writing and reading data to a magnetic
recording medium, has been attracting much attention. For facilitating the
new servo writing technique, the servo data is written in the form of soft
20 magnetic patterns, shaped with lines or islands and embedded in the
surface portion of a master disk. The new servo writing technique
magnetically transfers the servo data to the surface of the magnetic
recording medium by positioning the master disk in tight contact with or in
close proximity to the magnetic recording medium and by applying a
25 magnetic field from the outside. Since the new servo writing technique
transfers the position data (servo pattern) for controlling the magnetic head
of the HDD to a hard disk efficiently in a very short time, the new servo
writing technique has been expected to drastically reduce the
manufacturing costs of the HDD, to improve the recording density of the

HDD and to create new additional values for the HDD.

Fig. 7(a) is a cross sectional view showing a step of the conventional magnetic transfer. Fig. 7(b) is another cross sectional view showing another
5 step of the conventional magnetic transfer.

Referring now to Fig. 7(a), a magnetic recording medium (magnetic disk) 1 is magnetized uniformly to the right hand side of the figure (circumference direction of the magnetic recording medium) 6 by an external magnetic field H_{ex} , much higher than the coercive force H_c of the magnetic
10 recording medium 1 and applied from a permanent magnet 4 moving in the circumference direction 6 of the magnetic recording medium 1 with a certain spacing kept therebetween (the step of initial magnetization). In Fig. 7(a), a yoke 5 made of a soft magnetic material is shown. The yoke 5 and the permanent magnet 4 constitute a ring head.

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Referring now to Fig. 7(b), a master disk 3 is positioned in close proximity to or in close contact with the magnetic recording medium 1 magnetically initialized. The master disk 3 includes magnetic layers 3a (Co soft magnetic layers) scattered and embedded in the surface portion 3b of
20 the master disk 3. Magnetic transfer is conducted by applying an external magnetic field H_{ex} to the direction 7 opposite to the direction 6 of the external magnetic field H_{ex} applied for the initial magnetization from the permanent magnet 4 moving above the master disk 3 positioned in close proximity to or in close contact with the magnetic recording medium 1.

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The magnetic transfer process will be described below more in detail.

The leakage magnetic field (the direction thereof is the same with the direction of the magnetic field for magnetic transfer and opposite to the direction of the magnetic field for initial magnetization) from the moving
30 permanent magnet 4 reaches the magnetic layer in the surface portion of

the magnetic recording medium 1 through the surface portion 3b of the master disk 3. The leakage magnetic field, that has reached the surface portion of the magnetic recording medium 1, inverts the initial magnetization, resulting in recorded magnetization with a high coercive
5 force. In the embedded magnetic layers 3a, the leakage magnetic field expands in parallel to the surface of the master disk 3, i.e. along the paths with low magnetic resistance. Since the leakage magnetic field hardly reaches the magnetic layer in the magnetic recording medium 1 through the embedded magnetic layers 3a, the initial magnetization remains without
10 being inverted in the portions of the magnetic layer in the magnetic recording medium 1 below the embedded magnetic layers 3a. Thus, a negative pattern of the embedded magnetic layers 3a is transferred to the magnetic recording medium 1. The magnetic transfer technique described above does not utilize the leakage magnetic fields from the embedded
15 magnetic layers 3a for magnetizing the magnetic recording medium 1 but utilizes the embedded magnetic layers 3a as a mask for interrupting the leakage magnetic field from the permanent magnet 4. In short, the leakage magnetic field from the permanent magnet 4 selectively magnetizes the magnetic recording medium 1 through the surface portion 3b of the master
20 disk 3 (cf. Japanese Unexamined Laid Open Patent Application 2001-34939).

Now the relation between the strength H_{ex} of the external magnetic field for magnetic transfer and the coercive force H_c of the magnetic
25 recording medium 1 will be described below.

As described above, fine soft magnetic patterns 3a are embedded in the surface of the master disk 1. Fig. 8(a) shows cross sectional views describing the distribution of the magnetic field around the soft magnetic patterns 3a.
30 Fig. 8(b) is a graph describing the distributions of the parallel components

of the magnetic fluxes on the magnetic recording medium 1.

As described in Fig. 8(a), the magnetic fluxes converge to the soft magnetic patterns 3a in the regions, therein the soft magnetic patterns 3a are located. The magnetic fluxes, once converged to the soft magnetic patterns 3a, diverge from the soft magnetic patterns 3a into the regions, therein any soft magnetic pattern 3a is not located. Therefore, the magnetic field H_a beneath the central portion of the soft magnetic pattern 3a is low, since the magnetic fluxes converge beneath the central portion of the soft magnetic pattern 3a. The magnetic field H_b at both ends of the soft magnetic pattern 3a is the highest, since the magnetic fluxes converged to both ends of the soft magnetic pattern 3a are applied to the magnetic recording medium 1. The magnetic field H_g at the center of the region between the adjacent soft magnetic patterns 3a is lower than the magnetic field H_b at both ends of the soft magnetic pattern 3, since the magnetic fluxes once converged diverge well at the center of the region between the adjacent soft magnetic patterns 3a.

Fig. 8(b) plots the relations between the external magnetic field H_{ex} and the above described magnetic fields H_a , H_b and H_g . Due to the existence of the soft magnetic patterns 3a, the magnetic fields H_b and H_g increase with increasing magnetic field H_{ex} always keeping higher values than that of the corresponding external magnetic field H_{ex} . Therefore, the curves for the magnetic fields H_b and H_g are always above the broken line, the gradient thereof is 1, on the graph. In contrast, the magnetic field H_a is always lower than the corresponding external magnetic field H_{ex} due to the existence of the soft magnetic patterns 3a. The curve for the magnetic field H_a is always below the broken line, the gradient thereof is 1. The reference symbol H_t in Fig. 8(b) designates the magnetic field strength, thereat the soft magnetic patterns 3a saturate magnetically. Therefore, the magnetic

field H_a applied to the magnetic recording medium 1 beneath the soft magnetic patterns 3a increases sharply, when the external magnetic field H_{ex} applied is higher than the magnetic field H_t .

5 Therefore, magnetic transfer to the magnetic recording medium 1, the coercive force thereof is H_c , is facilitated by applying an external magnetic field H_{ex} , that makes the following relations hold, to the magnetic recording medium 1: $H_b \gg H_c$, $H_g \gg H_c$, and $H_a \ll H_c$.

10 Problems to be solved by the Invention

 The conventional magnetic transfer technique described above is effective for the magnetic transfer to a magnetic recording medium including only one recording layer.

15 However, it is impossible for the conventional magnetic transfer technique to transfer the soft magnetic patterns embedded in a master disk independently to two recording layers included in a magnetic recording medium.

20 In view of the foregoing, it is an object of the invention to provide a method of magnetic transfer, that facilitates transferring magnetic signals independently to two recording layers included in a magnetic recording medium. It is another object of the invention to provide a magnetic recording medium, including two recording layers, that facilitates
25 transferring different magnetic signals independently to the respective recording layers.

Means for solving the Problems

 According to the invention, there is provided a method of magnetically
30 transferring data to a magnetic recording medium including a first magnetic

recording layer and a second magnetic recording layer below the first magnetic recording layer, the method including the steps of: applying an initializing magnetic field in parallel to the magnetic recording medium to magnetically initialize the magnetic recording medium; positioning a first master disk in close proximity to or in close contact with the magnetic recording medium, the master disk including a nonmagnetic substrate including soft magnetic layers embedded in the surface portions thereof and shaped with respective line patterns or respective island patterns indicating first data; and applying a first transfer magnetic field to the first master disk and the magnetic recording medium in opposite to the initializing magnetic field to transfer the first data from the first master disk to the second magnetic recording layer.

Advantageously, the method further includes the step of applying a second transfer magnetic field to the first master disk and the magnetic recording medium in the direction same with the direction of the initializing magnetic field to transfer the first data from the first master disk to the first magnetic recording layer.

Advantageously, the method further includes the step of positioning a second master disk in substitution for the first master disk, the second master disk being positioned in close proximity to or in close contact with the magnetic recording medium, the second master disk including a nonmagnetic substrate including soft magnetic layers embedded in the surface portion thereof and shaped with respective line patterns or respective island patterns indicating second data; and the step of applying a second transfer magnetic field to the second master disk and the magnetic recording medium in the direction same with the direction of the initializing magnetic field to transfer the second data from the second master disk to the first magnetic recording layer.

Advantageously, the strength of the first transfer magnetic field and the strength of the second transfer magnetic field are different from each other.

5 Advantageously, the coercive force of the first magnetic recording layer and the coercive force of the second magnetic recording layer are different from each other.

10 Advantageously, the coercive force H_{c1} of the first magnetic recording layer, the coercive force H_{c2} of the second magnetic recording layer, the strength H_{ex2} of the first transfer magnetic field and the strength H_{ex1} of the second transfer magnetic field are set at the respective values, which makes the following relations hold: $H_{c1} \ll H_{c2}$, $H_{ex1} \ll H_{ex2}$, $H_{c1} \ll H_{ex2}$, and $H_{ex1} \ll H_{c2}$.

15 Advantageously, the first data are servo signals, and the patterns of the soft magnetic layers in the first master disk and the patterns of the soft magnetic layers in the second master disk are different from each other such that the servo signals recorded in the second magnetic recording layer
20 are not erased during recording the second data in the first magnetic recording layer.

25 Advantageously, the magnetic recording medium further includes one or more isolation layers disposed between the first magnetic recording layer and the second magnetic recording layer and made of a nonmagnetic material.

Brief Description of the Drawing Figures

Fig. 1 shows graphs explaining how the soft magnetic patterns embedded in the master disk are transferred independently to two recording layers included in a magnetic recording medium, the coercive forces thereof
5 Hc1 and Hc2 are different from each other, when external magnetic fields Hex1 and Hex2, different from each other, are applied to the magnetic recording medium.

Figs. 2(a) through 2(c) are schematic cross sectional views explaining the principle of magnetic transfer, that combines the coercive forces Hc1 and
10 Hc2 of two recording layers included in a magnetic recording medium and the external magnetic fields Hex1 and Hex2 for transferring the soft magnetic patterns embedded in the master disks independently to the respective recording layers.

Figs. 3(a) and 3(b) are cross sectional views describing the steps of
15 magnetic transfer according to the first embodiment of the invention.

Figs. 4(a) through 4(c) are cross sectional views describing the steps of magnetic transfer according to the second embodiment of the invention.

Figs. 5(a) through 5(c) are cross sectional views describing the steps of magnetic transfer according to the third embodiment of the invention.

20 Fig. 6 is a cross sectional view of a magnetic recording medium including two recording layers according to the fourth embodiment of the invention.

Fig. 7(a) is a cross sectional view showing a step of the conventional magnetic transfer.

25 Fig. 7(b) is another cross sectional view showing another step of the conventional magnetic transfer.

Fig. 8(a) shows cross sectional views describing the distribution of the magnetic field around the soft magnetic patterns.

30 Fig. 8(b) is a graph describing the distributions of the parallel components of the magnetic fluxes on the magnetic recording medium.

Modes for carrying out the Invention

Now the invention will be described hereinafter in detail with reference to the accompanied drawing figures which illustrate the preferred embodiments of the invention.

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First, how magnetic transfer is effected when external magnetic fields, the strengths H_{ex1} and H_{ex2} thereof are different from each other, are applied to a magnetic recording medium including two recording layers, the coercive forces thereof H_{c1} and H_{c2} are different from each other, will be described below.

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Here, it is assumed that the relations $H_{c1} \ll H_{c2}$, $H_{ex1} \ll H_{ex2}$, $H_{c1} \ll H_{ex2}$, and $H_{ex1} \ll H_{c2}$ hold, and that H_{c1} , H_{c2} , H_{ex1} , and H_{ex2} are located as described on the transfer maps of Fig. 1.

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(1) Magnetic transfer to the recording medium, the coercive thereof is H_{c1} , by an external magnetic field H_{ex1}

The initialization step conducted in advance to magnetic transfer magnetizes a magnetic recording medium in one direction until the magnetization thereof saturates. As shown in the graph (A) in Fig. 1, excellent magnetic transfer is facilitated, since the following relations hold between the recording magnetic fields H_a , H_b and H_g generated by the magnetic field H_{ex1} applied to the master disk and the magnetic recording medium and the coercive force H_{c1} : $H_b \gg H_{c1}$, $H_g \gg H_{c1}$, and $H_a \ll H_{c1}$.

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As described with reference to Figs. 8(a) and 8(b), H_a designates the recording magnetic field beneath the central portion of the soft magnetic pattern 3a, H_b the recording magnetic field at both ends of the soft magnetic pattern 3a, and H_g the recording magnetic field at the center of the region between the adjacent soft magnetic patterns 3a.

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(2) Magnetic transfer to the recording medium, the coercive thereof is H_{c2} , by an external magnetic field H_{ex2}

As shown in the graph (B) in Fig. 1, excellent magnetic transfer is facilitated, since the following relations hold between the recording magnetic fields H_a , H_b and H_g generated by the magnetic field H_{ex2} applied to the master disk and the magnetic recording medium and the coercive force H_{c2} : $H_b \gg H_{c2}$, $H_g \gg H_{c2}$, and $H_a \ll H_{c2}$.

(3) Magnetic transfer to the recording medium, the coercive thereof is H_{c1} , by an external magnetic field H_{ex2}

As shown in the graph (H) in Fig. 1, the following relations hold between the recording magnetic fields H_a , H_b and H_g generated by the magnetic field H_{ex2} applied to the master disk and the magnetic recording medium and the coercive force H_{c1} : $H_b \gg H_{c1}$, $H_g \gg H_{c1}$, and $H_a \gg H_{c1}$. Therefore, the magnetization in the magnetic recording medium aligned by the initial magnetization below the soft magnetic patterns 3a is also inverted by the magnetic transfer. When the external magnetic field H_{ex} much higher than the coercive force H_c is applied to the master disk 3, the transfer signals can not be written in the magnetic recording medium 1, since the magnetic recording medium 1 is magnetized uniformly in opposite to the initial magnetization direction even if the master disk 3 is on the magnetic recording medium 1.

(4) Magnetic transfer to the recording medium, the coercive thereof is H_{c2} , by an external magnetic field H_{ex1}

As shown in the graph (G) in Fig. 1, the following relations hold between the recording magnetic fields H_a , H_b and H_g generated by the magnetic field H_{ex1} applied to the master disk and the magnetic recording medium and the coercive force H_{c2} : $H_b \ll H_{c2}$, $H_g \ll H_{c2}$, and $H_a \ll H_{c2}$. Therefore, the magnetization in the magnetic recording medium aligned by

the initial magnetization is not inverted in the portion of the magnetic recording medium below the soft magnetic patterns 3a nor in the portion of the magnetic recording medium, above which any soft magnetic pattern 3a is not existing. In other words, the transfer signals can not be written in the magnetic recording medium 1, since the initial magnetization is retained uniformly throughout the magnetic recording medium 1.

By appropriately combining the coercive forces H_{c1} and H_{c2} and the external magnetic fields H_{ex1} and H_{ex2} , the soft magnetic patterns embedded in the master disk are transferred independently to two recording layers included in the magnetic recording medium. The principle of the magnetic transfer will be described below with reference to Figs. 2(a) through 2(c). In the following, the relations between the coercive force H_{c1} , the coercive force H_{c2} , the external magnetic field H_{ex1} , and the external magnetic field H_{ex2} are the same with those described above.

Fig. 2(a) is a cross sectional view of the simplified magnetic recording medium describing the step of initial magnetization. The magnetic recording medium 1 includes an upper recording layer 1a, the coercive force thereof is H_{c1} , and a lower recording layer 1b, the coercive force thereof is H_{c2} . In the step of initial magnetization, the upper recording layer 1a and the lower recording layer 1b are initialized simultaneously by an applied external magnetic field H_{ex2} much higher than the coercive forces H_{c1} and H_{c2} .

Fig. 2(b) is a cross sectional view describing the step of first magnetic transfer. Referring now to Fig. 2(b), a first master disk 3 is positioned above or on the magnetic recording medium 1. An external magnetic field H_{ex2} , the direction thereof is opposite to that of the initializing magnetic field, is applied to the magnetic recording medium 1. The upper recording layer 1a, the coercive force thereof is H_{c1} , is magnetized uniformly in the opposite

direction to that of the initial magnetization as described in the foregoing paragraph (3) "Magnetic transfer to the recording medium, the coercive thereof is Hc1, by an external magnetic field Hex2". The soft magnetic patterns on the first master disk 3 are transferred exclusively to the lower recording layer 1b, the coercive force thereof is Hc2, as described in the foregoing paragraph (2) "Magnetic transfer to the recording medium, the coercive thereof is Hc2, by an external magnetic field Hex2".

Fig. 2(c) is a cross sectional view describing the step of second magnetic transfer. Referring now to Fig. 2(c), a second master disk 2 is positioned, preferably, above or on the magnetic recording medium 1. An external magnetic field Hex1, the direction thereof is the same with that of the initializing magnetic field, is applied to the magnetic recording medium 1. The soft magnetic patterns on the second master disk 2 are transferred exclusively to the upper recording layer 1a, the coercive force thereof is Hc1, as described in the foregoing paragraphs (1) "Magnetic transfer to the recording medium, the coercive thereof is Hc1, by an external magnetic field Hex1". Any soft magnetic pattern on the second master disk 3 is not transferred by the external magnetic field Hex1 to the lower recording layer 1b, the coercive force thereof is Hc2, and the magnetization aligned before the second step of magnetic transfer is retained in the lower recording layer 1b as described in the foregoing paragraph (4) "Magnetic transfer to the recording medium, the coercive thereof is Hc2, by an external magnetic field Hex1".

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In summary, the magnetic transfer method described above includes the following steps:

- ① the step of preparing a magnetic recording medium including an upper recording layer 1a, the coercive force thereof is Hc1, and a lower recording layer 1b, the coercive force thereof is Hc2;

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- ② the step of setting the coercive forces H_{c1} and H_{c2} such that $H_{c1} \ll H_{c2}$;
- ③ the first transfer step of applying an external magnetic field H_{ex2} , that makes the following relations hold between the recording magnetic fields H_a , H_b and H_g generated on the magnetic recording medium by the applied external magnetic field H_{ex2} and the coercive forces H_{c1} and H_{c2} such that $H_b \gg H_{c2}$, $H_g \gg H_{c2}$, $H_a \ll H_{c2}$, $H_b \gg H_{c1}$, $H_g \gg H_{c1}$, and $H_a \gg H_{c1}$ to transfer the soft magnetic patterns on a first master disk not to the upper recording layer 1a but exclusively to the lower recording layer 1b and to magnetize the upper recording layer 1a uniformly in opposite to the initial magnetization direction; and
- ④ the second transfer step of applying an external magnetic field H_{ex1} , that makes the following relations hold between the recording magnetic fields H_a , H_b and H_g generated on the magnetic recording medium by the applied external magnetic field H_{ex1} and the coercive forces H_{c1} and H_{c2} such that $H_b \ll H_{c2}$, $H_g \ll H_{c2}$, $H_a \ll H_{c2}$, $H_b \gg H_{c1}$, $H_g \gg H_{c1}$, and $H_a \ll H_{c1}$ to transfer the soft magnetic patterns on a second master disk exclusively to the upper recording layer 1a and to retain the magnetization in the lower recording layer 1b without being affected by the application of the external magnetic field H_{ex1} .

Thus, the soft magnetic patterns embedded in the master disks are transferred independently to the recording layers of a magnetic recording medium.

Embodiments

Now the invention will be described more in detail below in connection with the embodiments thereof.

First embodiment

Figs. 3(a) and 3(b) are cross sectional views describing the steps of magnetic transfer according to a first embodiment of the invention.

Magnetic transfer is conducted on a magnetic recording medium 1 including an upper recording layer 1a, the coercive force H_{c1} thereof is 3000 Oe, and a lower recording layer 1b, the coercive force H_{c2} thereof is 6000 Oe. According to the first embodiment, the soft magnetic patterns on a master disk 3 are transferred only to the lower recording layer 1b. In the initializing step shown in Fig. 3(a), the upper recording layer 1a and the lower magnetic layer 1b are magnetically initialized by applying an external initializing magnetic field of around 7000 Oe to the magnetic recording medium 1.

In the transfer step shown in Fig. 3(b), the magnetic transfer is conducted by an external magnetic field H_{ex} of 6000 Oe applied in opposite to the initializing magnetic field. The external magnetic field H_{ex} magnetizes the upper recording layer 1a uniformly and transfers the soft magnetic patterns 3a on the master disk 3 only to the lower recording layer 1b. The soft magnetic patterns 3a on the master disk 3 are from 0.5 to 3 μ m in line width, and the soft magnetic layers are 500 nm in thickness. The master disk includes a single crystal silicon substrate. The soft magnetic patterns are made of pure cobalt.

Second embodiment

Figs. 4(a) through 4(c) are cross sectional views describing the steps of magnetic transfer according to a second embodiment of the invention.

Magnetic transfer is conducted on a magnetic recording medium 1 including an upper recording layer 1a, the coercive force H_{c1} thereof is 3000 Oe, and a lower recording layer 1b, the coercive force H_{c2} thereof is 6000 Oe. According to the second embodiment, the soft magnetic patterns on a master

disk 3 are transferred independently to the lower recording layer 1b through the first step of magnetic transfer and to the upper recording layer 1a through the second step of magnetic transfer.

5 Referring now to Fig. 4(a) describing the initializing step, the recording layers 1a and 1b are magnetically initialized by an external initializing magnetic field of around 7000 Oe.

Referring now to Fig. 4(b) describing the first step of magnetic transfer,
10 an external magnetic field of 6000 Oe is applied in opposite to the initial magnetization direction in the first step of magnetic transfer. The upper recording layer 1a is magnetized uniformly in opposite to the initial magnetization direction, and the soft magnetic patterns 3a on a master disk 3 are transferred only to the lower recording layer 1b.

15 Referring now to Fig. 4(c) describing the second step of magnetic transfer, an external magnetic field of 3000 Oe is applied in the same direction with the initial magnetization direction. The magnetization in the lower recording layer 1b is unaffected, and the soft magnetic patterns 3a on a
20 master disk 3 are transferred only to the upper recording layer 1a. According to the second embodiment, the same master disk is used in the first and second steps of magnetic transfer.

Third embodiment

25 Figs. 5(a) through 5(c) are cross sectional views describing the steps of magnetic transfer according to a third embodiment of the invention. According to the third embodiment, different master disks including different soft magnetic patterns embedded therein are used in the first and second steps of magnetic transfer.

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According to the third embodiment, magnetic transfer is conducted on a magnetic recording medium 1 including an upper recording layer 1a, the coercive force H_{c1} thereof is 3000 Oe, and a lower recording layer 1b, the coercive force H_{c2} thereof is 6000 Oe.

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Referring now to Fig. 5(a) describing the initializing step, the recording layers 1a and 1b are magnetically initialized by an external initializing magnetic field of around 7000 Oe.

10 Referring now to Fig. 5(b) describing the first step of magnetic transfer, an external magnetic field of 6000 Oe is applied in opposite to the initial magnetization direction in the first step of magnetic transfer. The upper recording layer 1a is magnetized uniformly in opposite to the initial magnetization direction, and the soft magnetic patterns 2a on a master disk 2
15 are transferred only to the lower recording layer 1b.

Referring now to Fig. 5(c) describing the second step of magnetic transfer, the master disk 2 for the first step of magnetic transfer is replaced by a master disk 3, and an external magnetic field of 3000 Oe is applied in
20 the same direction with the initial magnetization direction in the second step of magnetic transfer. The magnetization in the lower recording layer 1b is unaffected, and the soft magnetic patterns 3a on a master disk 3 are transferred only to the upper recording layer 1a.

25 By using different master disks in the first and second steps of magnetic transfer, the upper recording layer 1a in the magnetic recording medium 1 is employable, for example, for a data recording layer and the lower recording layer 1b for a servo signal storing layer storing the servo signals written therein without being erased during writing data in the
30 upper recording layer 1a.

Fourth embodiment

Fig. 6 is a cross sectional view of a magnetic recording medium including two recording layers according to a fourth embodiment of the invention.

5 Referring now to Fig. 6, the magnetic recording medium according to the fourth embodiment includes a substrate 9 made of aluminum or glass, and a first nonmagnetic undercoating layer 10 of 10 nm in thickness formed by sputtering on the substrate 9. The first nonmagnetic undercoating layer 10 is formed to control the easy axes of magnetization in the recording
10 layers. The first nonmagnetic undercoating layer 10 is made of an alloy such as CoCr, CoW and CoTi.

The magnetic recording medium according to the fourth embodiment further includes a lower recording layer 11 formed on the first nonmagnetic
15 undercoating layer 10. The lower recording layer 11 is a magnetic metal layer containing, for example, Co as the main component thereof and from several % to several teen % of an appropriate combination of Pt, Cr, Ta, and B added thereto (e.g. a magnetic alloy layer such as a CoCrPtTa layer and a CoCrPtB layer). (The lower recording layer 11 corresponds to the lower
20 recording layer 1b in Figs. 2(a) through 5(c).)

The magnetic recording medium according to the fourth embodiment further includes a nonmagnetic isolation layer 12 containing Co as the main component thereof such as a CoCr layer, a CoW layer, and a CoTi layer, and
25 a second nonmagnetic undercoating layer 13 containing Co as the main component thereof such as a CoCr layer, a CoW layer, and a CoTi layer. Although the second nonmagnetic undercoating layer 13 and the nonmagnetic isolation layer 12 are alloy layers containing Co as the main components thereof, the compositions and the contents thereof are different
30 from each other.

The magnetic recording medium according to the fourth embodiment further includes an upper recording layer 14 (corresponds to the upper recording layer 1a in Figs. 2(a) through 5(c).) formed on the second undercoating layer 13. Although the upper recording layer 14 contains, Co
5 as the main component thereof and an appropriate combination of Pt, Cr, Ta, and B added thereto in the same manner as the lower recording layer 11, the compositions of the metals added are different from those in the lower recording layer 11 to provide the upper recording layer 14 with a coercive force lower than that of the lower recording layer 11.

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The magnetic recording medium according to the fourth embodiment further includes a carbon layer (carbon protection layer) 15 on the upper recording layer 14 to protect the upper recording layer 14 against corrosion or against wear caused by the friction with the magnetic head for writing
15 data and for reading data.

Advantageous Effects of the Invention]

As described above, the method of magnetic transfer according to the invention facilitates transferring different magnetic signals independently
20 to two recording layers included in a magnetic recording medium. Therefore, the method of magnetic transfer according to the invention facilitates expanding the application fields of the magnetic printing technique in such a way that the upper recording layer is used for a data recording layer and the lower recording layer for a servo signal storage layer, that keeps storing
25 the servo signals written therein without being erased during writing data in the upper recording layer.

What is claimed is:

1. A method of magnetically transferring data to a magnetic recording medium comprising a first magnetic recording layer and a second magnetic recording layer below the first magnetic recording layer, the method
5 comprising the steps of:
 - applying an initializing magnetic field in parallel to the magnetic recording medium, whereby to magnetically initialize the magnetic recording medium;
 - positioning a first master disk in close proximity to or in close contact
10 with the magnetic recording medium, the master disk comprising a nonmagnetic substrate comprising soft magnetic layers embedded in the surface portions thereof and shaped with respective line patterns or respective island patterns indicating first data; and
 - applying a first transfer magnetic field to the first master disk and the
15 magnetic recording medium in opposite to the initializing magnetic field, whereby to transfer the first data from the first master disk to the second magnetic recording layer.
2. The method according to Claim 1, further comprising the step of applying a second transfer magnetic field to the first master disk and the
20 magnetic recording medium in the direction same with the direction of the initializing magnetic field, whereby to transfer the first data to the first magnetic recording layer.
3. The method according to Claim 1, further comprising the step of positioning a second master disk in substitution for the first master disk,
25 the second master disk being positioned in close proximity to or in close contact with the magnetic recording medium, the second master disk comprising a nonmagnetic substrate comprising soft magnetic layers embedded in the surface portion thereof and shaped with respective line

patterns or respective island patterns indicating second data; and the step of applying a second transfer magnetic field to the second master disk and the magnetic recording medium in the direction same with the direction of the initializing magnetic field, whereby to transfer the second data to the
5 first magnetic recording layer.

4. The method according to Claim 2, wherein the strength of the first transfer magnetic field and the strength of the second transfer magnetic field are different from each other.

5. The method according to Claim 3, wherein the strength of the first
10 transfer magnetic field and the strength of the second transfer magnetic field are different from each other.

6. The method according to Claim 1, wherein the coercive force of the first magnetic recording layer and the coercive force of the second magnetic recording layer are different from each other.

7. The method according to Claim 4, wherein the coercive force Hc1 of the first magnetic recording layer, the coercive force Hc2 of the second magnetic recording layer, the strength Hex2 of the first transfer magnetic field and the strength Hex1 of the second transfer magnetic field are set at the respective values, which make the following relations hold:

20 $Hc1 \ll Hc2$, $Hex1 \ll Hex2$, $Hc1 \ll Hex2$, and $Hex1 \ll Hc2$.

8. The method according to Claim 5, wherein the coercive force Hc1 of the first magnetic recording layer, the coercive force Hc2 of the second magnetic recording layer, the strength Hex2 of the first transfer magnetic field and the strength Hex1 of the second transfer magnetic field are set at the
25 respective values, which make the following relations hold:

$Hc1 \ll Hc2$, $Hex1 \ll Hex2$, $Hc1 \ll Hex2$, and $Hex1 \ll Hc2$.

9. The method according to Claim 8, wherein the first data are servo signals, and the patterns of the soft magnetic layers in the first master disk and the patterns of the soft magnetic layers in the second master disk are different from each other such that the servo signals recorded in the second
5 magnetic recording layer are not erased during recording the second data in the first magnetic recording layer.

10. The magnetic recording medium described in Claim 1, further comprising one or more isolation layers between the first magnetic recording
10 layer and the second magnetic recording layer, the one or more isolation layers comprising a nonmagnetic material.

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