

METHOD OF MAGNETIC TRANSFER

BACKGROUND OF THE INVENTION

Field of the Invention

5 This invention relates to a method of magnetic transfer for transferring information to a magnetic recording medium (slave medium) from a master information carrier carrying thereon a magnetic layer pattern representing the information to be transferred to the magnetic recording medium.

10 Description of the Related Art

 With an increase in information quantity, there is a demand for a magnetic recording medium which is high in capacity, low in cost and preferably requires a short time to read out a necessary part of data (a magnetic recording medium which
15 allows so-called high-speed access). As an example of such a magnetic recording medium, there has been known a high recording density magnetic medium such as a hard disc or a flexible disc. To realize the high capacity, so-called servo tracking technology for causing a magnetic head to accurately
20 trace narrow data tracks plays an important role. To perform the servo tracking, a servo tracking signal, an address information signal, a reproduction clock signal and the like are recorded on the disc at certain intervals as so-called preformat.

25 As a method of recording the preformat accurately and efficiently, there has been proposed, for instance, in

Japanese Unexamined Patent Publication Nos. 63(1988)-183623,
U.S. Patent No. 6,347,016, a magnetic transfer method in which
a pattern which is formed on a master information carrier and
represents servo information is copied to a magnetic recording
5 medium (a slave medium) by magnetic transfer.

In the magnetic transfer, a master information carrier
having thereon an irregularity pattern (a pattern of
protruding portions and recessed portions) representing
information (e.g., servo information) to be transferred to a
10 slave medium (a magnetic recording medium such as a magnetic
disc) and a magnetic layer formed at least on the protruding
portions is brought into a close contact with the slave medium
and a transfer magnetic field is applied to the master
information carrier and the slave medium in a close contact
15 with each other, whereby a magnetization pattern corresponding
to the information represented by the irregularity pattern is
magnetically transferred from the master information carrier
to the slave medium. Accordingly, the information carried by
the master information carrier can be statically recorded on
20 the slave medium with the relative position between the master
information carrier and the slave medium kept constant. Thus,
according to the magnetic transfer, the preformat recording
can be performed accurately and the time required for the
preformat recording is very short.

25 We, this applicant, have proposed in Japanese Unexamined
Patent Publication No. 2001-14667 a method of magnetic

transfer in which the magnetic layer of the slave medium is initially magnetized in one direction of the recording tracks and a transfer magnetic layer is applied to the slave medium in the direction opposite to the direction of the
5 initial-magnetization with the slave medium held in close contact with the master information carrier. By this method, a very good magnetic transfer can be effected.

The intensity of the transfer magnetic field should be substantially the same as the coercive force H_c of the slave
10 medium and the intensity of the initial DC magnetic field should be stronger than that of the transfer magnetic field and preferably not weaker than about twice the intensity of the transfer magnetic field (i.e., the coercive force H_c of the slave medium).

15 At present, the coercive force H_c of the slave medium tends to increase under the demands for magnetic recording medium of higher capacity, higher recording/reproducing accuracy or the like. As the coercive force H_c of the slave medium becomes stronger, it is necessary to increase the
20 intensity of the transfer magnetic field and the initial magnetic field. However since the intensity of a magnetic field generated by a magnetic field generator is limited, it is important how to efficiently use a magnetic field of an intensity which can be currently generated.

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SUMMARY OF THE INVENTION

Embodiments of the present invention provide an improved method of magnetic transfer in which the initial DC magnetic field and the transfer magnetic field can be efficiently applied to the slave medium.

5 In accordance with an aspect of the present invention, there is provided a method of magnetic transfer for magnetically transferring information represented by a pattern of a magnetic layer formed on a master information carrier to a magnetic layer of a slave medium comprising the steps of

10 applying an initial DC magnetic field to the slave medium by a magnetic field generator to initially magnetize the magnetic layer of the slave medium in one direction of recording tracks and

 applying a transfer magnetic field to the slave medium

15 and the master information carrier by a magnetic field generator in the direction opposite to the direction of the initial-magnetization with the initially-magnetized magnetic layer of the slave medium held in close contact with the magnetic layer on the master information carrier, wherein the

20 improvement comprises that

 the initial DC magnetic field is applied to the slave medium with the slave medium supported from one side thereof so that the other side of the slave medium is directly opposed to the magnetic field generator, and

25 the transfer magnetic field is applied to the slave medium and the master information carrier held in close contact

with each other so that the initially-magnetized magnetic layer of the slave medium held in close contact with the magnetic layer on the master information carrier by a holder, which covers both the sides of the slave medium/master information carrier assembly, with the magnetic field generator positioned to oppose both the sides or one side of the slave medium/master information carrier assembly so that the magnetic field generated by the magnetic field generator is applied to the slave medium and the master information carrier through the holder.

That is, in accordance with embodiments of the present invention, the transfer magnetic field is applied to the slave medium through the holder by the magnetic field generator and the initial DC magnetic field is directly applied to the slave medium without a holder intervening between the magnetic field generator and the slave medium.

The slave medium may be provided with the magnetic layer on one side thereof or on both the sides thereof. When the slave medium is provided with the magnetic layer on both the sides and information is to be transferred on both the sides of the slave medium at one time, the "slave medium/master information carrier assembly" comprises a slave medium and a pair of master information carriers on the respective sides of the slave medium.

The expression "to transfer information" means to pattern the arrangement of magnetization of the magnetic layer

of the slave medium according to the information.

The intensity of the initial DC magnetic field is preferably not lower than the coercive force of the magnetic layer of the slave medium, more preferably not lower than 1.2
5 times the coercive force of the same and most preferably not lower than about twice the coercive force of the same.

The intensity of the transfer magnetic field is preferably not lower than about 0.6 times the coercive force of the magnetic layer of the slave medium and not higher than
10 about 1.3 times the coercive force of the magnetic layer of the slave medium.

As the magnetic field generator for applying the initial DC magnetic field and the transfer magnetic field, for instance, an electromagnet unit or a permanent magnet unit may be
15 employed.

In accordance with an embodiment of the method of magnetic transfer of the present invention, since the initial DC magnetic field is directly applied to the slave medium without a holder intervening between the magnetic field generator and the slave
20 medium, the magnetic field generator can be disposed in the vicinity of the surface of the slave medium and a sufficiently strong magnetic field can be applied to the magnetic layer of the slave medium. This is especially useful when the coercive force of the slave medium is strong and an initial DC magnetic
25 field whose intensity is not weaker than about twice the coercive force of the slave medium is to be applied to the slave

medium. Whereas, since the slave medium and the master information carrier(s) are held in close contact with each other by the holder when the transfer magnetic field is applied, the transfer magnetic field can be uniformly applied to the
5 slave medium/master information carrier assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a fragmentary perspective view showing an important part of the initial magnetization system employed in a magnetic transfer apparatus for carrying out a method of
10 magnetic transfer in accordance with a first embodiment of the present invention,

Figure 2 is a fragmentary perspective view showing an important part of the transfer magnetic field application system of a magnetic transfer apparatus for carrying out a
15 method of magnetic transfer in accordance with a second embodiment of the present invention,

Figure 3 is an exploded perspective view of the holder,

Figures 4A to 4C are views for illustrating basic steps of magnetic transfer,

20 Figure 5 is a fragmentary perspective view showing an important part of the initial magnetization system employed in a magnetic transfer apparatus for carrying out a method of magnetic transfer in accordance with a second embodiment of the present invention, and

25 Figure 6 is a perspective view showing a modification of the magnetic field generator employed in the initial

magnetization system shown in Figure 5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A pair of pieces of information are transferred to opposite sides (upper and lower sides 2b and 2c) of a slave medium (magnetic recording medium) 2 by a method of magnetic transfer in accordance with a first embodiment of the present invention from a pair of master information carriers 3 and 4. The slave medium 2 is a disc-like magnetic recording medium such as a hard disc, a flexible disc or the like. That is, in this particular embodiment, the slave medium 2 is a double-sided magnetic recording medium comprising a disc-like base sheet and magnetic layers formed on upper and lower sides 2b and 2c of the base sheet.

As shown in Figure 3, the master information carriers 3 and 4 are like a disc in shape and comprises substrates 3a and 4a having on their one sides irregularity patterns (patterns of protruding portions and recessed portions) representing information to be transferred to the magnetic layers of the magnetic recording media (slave media) and soft magnetic layers 3b and 4b provided on the surface of the substrates 3a and 4a. The irregularity patterns respectively carried by the master information carriers 3 and 4 represent information to be transferred to the lower magnetic layer 2c and the upper magnetic layer 2b of the slave medium 2. The information carried by the master information carriers 3 and 4 may be transferred to opposite sides 2b and 2c of the slave

medium 2 either simultaneously or in sequence.

The slave medium 2 is first applied with an initial DC magnetic field H_{in} by an initial magnetization system 1 shown in Figure 1 and the magnetic layer 2c and/or 2b of the slave medium 2 is initially magnetized in one direction of recording tracks. The initial magnetization system 1 shown in Figure 1 comprises a support table 5 which supports the slave medium 2 from the lower side 2c thereof, an electromagnet unit 50 held in the vicinity of the upper side 2b of the slave medium 2, and a rotating means (not shown) which rotates the support table 5 relatively to the electromagnet unit 50 in the direction of arrow A. In this initial magnetization system 1, the slave medium 2 is directly opposed to the magnetic poles of the electromagnet unit 50, and accordingly, the magnetic field generated by the electromagnet unit 50 is directly applied to the slave medium 2.

The electromagnet unit 50 comprises a core 52 having a gap 51 which radially extends at least from an innermost track to an outermost track of the slave medium 2 and a winding 53 wound around the core 52.

The electromagnet unit 50 generates an initial DC magnetic field H_{in} across the gap 51 in parallel to the direction of the recording tracks. Accordingly, by rotating the slave medium 2 once or more relatively to the initial DC magnetic field H_{in} , the initial DC magnetic field H_{in} parallel to the concentric recording tracks can be applied to over the

entire recording track area.

In this particular embodiment, the width w_1 of the gap 51 is set to be not larger than half of the radius of the innermost recording track and the distance h_1 between the gap 51 and the upper surface of the slave medium is set to be not larger than 5mm (preferably 3mm) so that the initial DC magnetic field applied to the slave medium is not weaker than twice the coercive force of the magnetic layer of the slave medium 1 on both the sides of the slave medium 2. For example, when the radius of the innermost recording track is 20mm, the width w_1 of the gap 51 is set to be not larger than 10mm (preferably not larger than 5mm).

After the magnetic layers on the upper and lower sides 2b and 2c are thus initially magnetized, the slave medium 2 together with the lower and upper master information carriers 3 and 4 held in close contact with the lower and upper side of the slave medium 2 is applied with a transfer magnetic field H_{du} (Figure 2) by a transfer magnetic field application system 11 shown in Figure 2. The transfer magnetic field application system 11 comprises a holder 10 which holds the slave medium 2 and the master information carriers 3 and 4 in close contact with each other covering the upper and lower sides of the slave medium/master information carrier assembly, a magnetic field generator 60 having upper and lower electromagnet units 60a and 60b respectively opposed to the upper and lower sides 2b and 2c of the slave medium 2 and a rotating means (not shown)

which rotates the holder 10 in the direction of arrow A relatively to the magnetic field generator 60. That is, in this transfer magnetic field application system 11, the slave medium 2, and the master information carriers 3 and 4 are
5 accommodated in the holder 10, and the transfer magnetic field H_{du} is applied to the slave medium 2, and the master information carriers 3 and 4 through the holder 10.

Each of the upper and lower electromagnet units 60a and 60b of the magnetic field generator 60 comprises a core 62
10 having a gap 61 which radially extends at least from an innermost track to an outermost track of the slave medium 2 and a winding 63 wound around the core 62, and the upper and lower electromagnet units 60a and 60b generate magnetic fields parallel to the direction of the tracks in the same directions
15 on opposite sides of the slave medium 2. It is not necessary to provide an electromagnet on each side of the slave medium but an electromagnet may be provided only on one side of the slave medium 2.

In the transfer magnetic field application system 11,
20 the intensity of the transfer magnetic field is set to be not lower than about 0.6 times the coercive force H_c of the magnetic layer of the slave medium and not higher than about 1.3 times the coercive force of the magnetic layer of the slave medium (preferably $0.8H_c$ to $1.2H_c$ and more preferably $1H_c$ to $1.1H_c$)
25 on both the sides of the slave medium 2.

Figure 3 is an exploded perspective view of the holder

10.

As shown in Figure 3, the holder 10 comprises a lower holder member 8 having a lower correcting member 6 which holds the lower master information carrier 3, for transferring the information to the lower magnetic layer (the magnetic layer on the lower side 2c) of the slave medium 2, under suction force and forces it flat and an upper holder member 9 having an upper correcting member 7 (the same as the lower correcting member 6 in structure) which holds the upper master information carrier 4, for transferring the information to the upper magnetic layer (the magnetic layer on the upper side 2b) of the slave medium 2, under suction force and forces it flat. The upper and lower holder members 9 and 8 presses the upper and lower master information carriers 4 and 3 respectively against the upper and lower magnetic layers of the slave medium 2 with the centers of the upper and lower master information carriers 4 and 3 and the slave medium 2 aligned with each other, thereby holding the upper and lower master information carriers 4 and 3 and the slave medium 2 in close contact with each other.

The lower and upper master information carriers 3 and 4 are respectively held under suction by lower and upper holder members 8 and 9 on the side opposite to the magnetic layer 3b and 4b carrying thereon the information to be transferred. In order to strengthen the close contact with the slave medium 2, small through holes extending from one side of the master

information carrier to the other side may be formed in the master information carrier so that air trapped between the slave medium 2 and the master information carrier is purged therethrough at portions where the through holes do not
5 interfere with the irregularity pattern representing the information to be transferred and do not communicate with suction holes (to be described later) of the correcting members 6 and 7.

The lower correcting member 6 is like a disc in shape
10 and is sized according to the size of the master information carrier 3. The surface of the lower correcting member 6 which is brought into contact with the master information carrier 3 is formed into a suction face 6a whose surface is about 0.01 to 0.1 μ m in centerline mean surface roughness Ra. About 25
15 to 100 suction holes 6b not larger than about 2mm in diameter uniformly open in the suction face 6a. Though not shown, each of the suction holes 6b is connected to a vacuum pump through a vacuum passage which is led outside the lower holder member 8 through the lower correcting member 6. The back side
20 (opposite to the magnetic layer) of the lower master information carrier 3 is forced flat along the suction face 6a under the suction force applied thereto through the suction holes 6b and thus the flatness of the lower master information carrier 3 is corrected. The upper correcting member 7 is the
25 same as the lower correcting member 6 in structure, and will not be described here.

The lower and upper holder member 8 and 9 are like a disc in shape and one or both of them is movable in the axial direction toward and away from each other. The lower and upper holder member 8 and 9 are opened and closed by an opening/closing mechanism (a pressing mechanism, a fastener mechanism or the like) not shown, and pressed against each other at a predetermined pressure when closed. The lower and upper holder member 8 and 9 are provided with flanges 8a and 9a on their outer peripheries which are brought into abutment against each other to close its inside in an air-tight fashion when the lower and upper holder member 8 and 9 are closed. A locator pin 8 which engages with the central opening of the slave medium 2 to locate the slave medium 2 is erected at the center of the lower holder member 8.

Magnetic transfer of information to the slave medium 2 by a method of magnetic transfer in accordance with a first embodiment of the present invention using the initial magnetization system 1 shown in Figure 1 and the transfer magnetic field application system 11 shown in Figure 2 will be described, hereinbelow.

The slave medium 2 is first placed on the support table 5 of the initial magnetization system 1 and an initial DC magnetic field H_{in} is generated across the gap 51 of the electromagnet unit 50. The magnetic field H_{in} is parallel to a tangent of the recording tracks, and the initial DC magnetic field is applied to over the entire area of the recording tracks

by rotating the support table 5 (or the slave medium 2) relatively to the magnetic field once or more in the direction of arrow A by rotating means (not shown). In order to initially magnetize the upper and lower magnetic layers of the slave medium 2 at one time, it is necessary for the intensity of the magnetic field H_{in} on the upper and lower sides 2b and 2c of the slave medium 2 to be not weaker than the coercive force H_c of the slave medium 2. When the strength of the magnetic field H_{in} on the lower side of the slave medium 2 is insufficient, it is necessary to turn over the slave medium 2 and to initially magnetize the magnetic layers on the opposite sides of the slave medium 2 in sequence.

Then, the master information carriers 3 and 4 and the slave medium 2 are set in the holder 10 with the lower master information carrier 3 and the upper master information carrier 4 respectively in close contact with the lower and upper magnetic layers of the slave medium 2 and the holder 10 is set to the transfer magnetic field application system 11. Each of the electromagnet units 60a and 60b opposed to the upper and lower surfaces of the holder 10 generates a transfer magnetic field H_{du} in a direction opposite to the initial DC magnetic field. The transfer magnetic field H_{du} is applied to over the entire area of the recording tracks by rotating the holder 10 relatively to the magnetic field once or more in the direction of arrow A, whereby the information represented by the irregularity patterns on the master

information carriers 3 and 4 are magnetically transferred to the slave medium 2.

The magnetic transfer will be described in more detail with reference to Figures 4A to 4C, hereinbelow. In Figures 5 4A to 4C, only the lower magnetic layer 2b and the lower master information carrier 3 are shown.

An initial DC magnetic field H_{in} is applied to the slave medium 2 to magnetize the magnetic layers 2b and 2c of the slave medium 2 in a direction parallel to the recording tracks as 10 shown in Figure 3A.

Thereafter, the magnetic layer 3b of the lower master information carrier 3 and the magnetic layer 4b of the upper master information carrier 4 are brought into close contact with the lower and upper magnetic layers of the slave medium 15 2 by the holder 10. In this state, the holder 10 together with the slave medium 2 and the master information carriers 3 and 4 in close contact with opposite sides of the slave medium 2 is positioned in place between the upper and lower electromagnet units 60a and 60b of the transfer magnetic field 20 application system 11 each generating a transfer magnetic field H_{du} in a direction opposite to the initial DC magnetic field as shown in Figure 3B, thereby effecting magnetic transfer. As a result, the information represented by the irregularity pattern on each of the upper and lower master 25 information carriers 3 and 4 is recorded on each of the magnetic layers 2b and 2c of the slave medium 2 as a magnetization pattern

as shown in Figure 4C.

In the case where the irregularity pattern representing information to be transferred is a negative pattern reverse to the positive pattern shown in Figures 4A to 4C, the
5 information can be magnetically transferred to the slave medium 2 by reversing the directions of the initial DC magnetic field H_{in} and the transfer magnetic field H_{du} .

Figure 5 is a fragmentary perspective view showing an initial magnetization system 1' employed in a magnetic
10 transfer apparatus for carrying out a method of magnetic transfer in accordance with a second embodiment of the present invention. The initial magnetization system 1' shown in Figure 5 differs from that 1 shown in Figure 1 in that a pair of permanent magnets 70a and 70b is employed as a magnetic field
15 generator in place of an electromagnet unit 50.

That is, the initial magnetization system 1' has a magnetic field generator 70 comprising a pair of permanent magnets 70a and 70b which are magnetized in a direction substantially perpendicular to the upper side 2b of the slave
20 medium 2 and radially extend from an innermost track to an outermost track of the slave medium 2 so that opposite poles of the respective permanent magnets 70a and 70b are opposed to the surface of the slave medium 2. Also, in this initial magnetization system 1', the permanent magnets 70a and 70b are
25 directly opposed to the slave medium 2 and the magnetic field generated between the permanent magnets 70a and 70b is directly

applied to the slave medium 2.

The permanent magnets 70a and 70b generates an initial DC magnetic field H_{in} in parallel to the direction of the recording tracks. Accordingly, by rotating the slave medium
5 2 once or more relatively to the permanent magnets 70a and 70b, the initial DC magnetic field H_{in} can be applied to over the entire area of the slave medium 2.

As in the first embodiment described above, the intensity of the initial DC magnetic field H_{in} applied to the slave medium
10 2 is set to be not weaker than twice the coercive force H_c of the magnetic layer of the slave medium 2.

This can be realized, for instance, by setting the distance w_2 between the permanent magnets 70a and 70b to be not larger than 10mm and the distance h_2 between the upper side
15 of the slave medium 2 and the permanent magnets 70a and 70b to be not larger than 5mm (preferably 3mm).

A third permanent magnet 71 magnetized in a direction perpendicular to the direction of magnetization of the permanent magnets 70a and 70b may be inserted between the
20 permanent magnets 70a and 70b so that the third permanent magnet 71 generates a magnetic field directed in the same direction as the magnetic field generated by the permanent magnets 70a and 70b, as in a magnetic field generator 70' shown in Figure 6. The magnetic field generated by the third permanent magnet
25 71 enhances the magnetic field generated by the permanent magnets 70a and 70b.

Though, in the embodiments described above, the slave medium (or the holder) is rotated relatively to the magnetic field generator to apply the magnetic field to over the entire area of the slave medium 2, it is possible to rotate the latter
5 relatively to the former.

Further, though, in the embodiments described above, the surface of the slave medium (or the slave medium/master information carrier assembly) is held horizontal but the surface may be held vertical with the magnetic field generator
10 opposed to the surface.

What is claimed is;

1. A method of magnetic transfer for magnetically transferring information represented by a pattern of a magnetic layer formed on a master information carrier to a magnetic layer of a slave medium comprising the steps of
 - 5 applying an initial DC magnetic field to the slave medium by a magnetic field generator to initially magnetize the magnetic layer of the slave medium in one direction of recording tracks and
 - 10 applying a transfer magnetic field to the slave medium and the master information carrier by a magnetic field generator in the direction opposite to the direction of the initial-magnetization with the initially-magnetized magnetic layer of the slave medium held in close contact with the magnetic layer on the master information carrier, wherein the
 - 15 improvement comprises that
 - the initial DC magnetic field is applied to the slave medium with the slave medium supported from one side thereof so that the other side of the slave medium is directly opposed
 - 20 to the magnetic field generator, and
 - the transfer magnetic field is applied to the slave medium and the master information carrier held in close contact with each other so that the initially-magnetized magnetic layer of the slave medium held in close contact with the magnetic layer on the master information carrier by a holder,
 - 25 which covers both the sides of the slave medium/master

information carrier assembly, with the magnetic field generator positioned to oppose both the sides or one side of the slave medium/master information carrier assembly so that the magnetic field generated by the magnetic field generator is applied to the slave medium and the master information carrier through the holder.

2. A method of magnetic transfer as defined in Claim 1 in which the intensity of the initial DC magnetic field is set to be not lower than the coercive force of the magnetic layer of the slave medium.

3. A method of magnetic transfer as defined in Claim 2 in which the intensity of the initial DC magnetic field is set to be not lower than 1.2 times the coercive force of the magnetic layer of the slave medium.

4. A method of magnetic transfer as defined in Claim 3 in which the intensity of the initial DC magnetic field is set to be not lower than twice the coercive force of the magnetic layer of the slave medium.

5. A method of magnetic transfer as defined in any one of Claims 1 to 4 in which the intensity of the transfer magnetic field is set to be not lower than about 0.6 times the coercive force of the magnetic layer of the slave medium and not higher than about 1.3 times the coercive force of the magnetic layer of the slave medium.

6. A method of magnetic transfer as defined in any one of Claims 1 to 5 in which the magnetic field generator comprises

an electromagnet unit.

7. A method of magnetic transfer as defined in any one of Claims 1 to 5 in which the magnetic field generator comprises a permanent magnet unit.