TITLE OF THE INVENTION

METHOD AND APPARATUS FOR MAGNETIC TRANSFER

BACKGROUND OF THE INVENTION

The present invention relates to a method for recording a large amount of information on a magnetic recording medium at one time, and in particular, to a method for transferring a recording information to a magnetic recording medium of large capacity and high recording density.

With rapid development and progress in the utilization of digital image, amount of information to be handled in personal computers and other devices has extensively increased. Because of the increase of the amount of information, there are now strong demands on a magnetic recording medium, which has larger capacity to record the information and can be manufactured at low cost and requires shorter time for writing and reading operations.

In a high density recording medium such as hard disk or in a high density floppy disk type magnetic recording medium represented by ZIP (Iomega Inc.), information recording area has narrower track compared with the floppy disk now commonly used. In order that magnetic head can scan over narrow track width and signals can be recorded or reproduced with high S/N ratio, it is necessary to perform accurate scanning by the tracking servo technique.

In a large capacity magnetic recording medium such as a hard disk or a removable type magnetic recording medium,

servo signal for tracking or address information signal, reproduction clock signal, etc. are recorded with a certain spacing between them within one turn of the disk. This is the so-called pre-format.

By reading this pre-formatted signal and by correcting its own position, the magnetic head can run accurately on the track.

In the mode of pre-formatting currently in practice, disks are recorded one by one and track by track using a special-purpose servo recorder. However, there are problems in that the servo recorder are expensive and long time is required for the preparation of the pre-format and this means longer time for manufacture and higher manufacturing cost.

In this respect, a method has been proposed to perform magnetic transfer without carrying out pre-format for each track. For example, a transfer technique is described in Japanese Patent Publications Laid-Open 63-183623, 10-40544, and 10-269566. However, none of these inventions provides a proposal suitable for practical applications. There has been no disclosure on concrete means or conditions such as the condition of magnetic field to be applied at the magnetic transfer in the method for magnetic transfer or the means for generating the magnetic field.

To solve the problems as described above, the following method has been proposed in Japanese Patent Publications Laid-Open 63-183623 and 10-40544: On the surface of the substrate, surface irregularities (i.e.

recesses and projections; concave portions and convex portions) corresponding to information signals are formed. The surface of the master carrier for magnetic transfer where ferromagnetic thin film is formed at least on the projections is brought into contact with the surface of sheet-type or disk-type magnetic recording medium where ferromagnetic thin film or ferromagnetic powder coating layer is formed. Or, AC bias magnetic field or DC magnetic field is applied to excite ferromagnetic material which constitutes the surface of the projections. As a result, magnetized pattern to match the surface irregularities is recorded on the magnetic recording medium.

According to this method, the surface of the projected portions of the master carrier for magnetic transfer is brought closely together to the magnetic recording medium to be pre-formatted, i.e. the slave medium, and the ferromagnetic material which constitutes the projected portions is excited. As a result, the desired format is formed on the slave medium. By this method, recording can be carried out statically without changing relative positions of the master carrier for magnetic transfer and the slave medium, and accurate pre-format recording can be performed. Also, the time required for the recording is very short. Specifically, in the method for recording from the magnetic head as described above, the time of several minutes to several tens of minutes is normally required, while magnetic transfer can be completed within one second regardless of the recording capacity or recording density

in this magnetic transfer method.

Now, description will be given on the transfer of pattern for pre-format in the master carrier for magnetic transfer referring to Fig. 1. Fig. 1 (A) is a schematical plan view to explain magnetic layer surface of the master carrier for magnetic transfer, and Fig. 1 (B) is a cross-sectional view to explain the process of transfer.

On a certain area of the track of the master carrier 1 for magnetic transfer, a pre-format region 2 and a data region 3 where patterns of servo signals and address signal for tracking to be transferred are formed. By bringing the master carrier 1 for magnetic transfer and the slave medium 4 closely together and by applying an external magnetic field 6 for transfer in track direction 5, the pre-format information can be transferred to the slave medium as a recording information 7. Thus, the slave medium can be manufactured with high efficiency.

However, it has been made clear that, when magnetic transfer is performed according to this method, the quality of information signal may be deteriorated, and that servo action may be inaccurate.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method and an apparatus for stable magnetic transfer by bringing a master carrier for magnetic transfer and a slave medium closely together and by transferring a pre-format pattern through application of an external magnetic field

in order to prevent inaccurate servo operation of the slave medium.

The present invention provides a method for magnetic transfer by bringing a master carrier for magnetic transfer together with a slave medium and by applying magnetic field for transfer, said master carrier having a magnetic layer formed on surface of a substrate corresponding to an information signal, and said slave medium comprising a magnetic recording medium where the information is to be transferred, said method comprising the steps of:

arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between, and disposing the slave medium perpendicularly to the axis of the magnetic pole,

rotating the slave medium or the permanent magnet in track direction; and

applying magnetic field in track direction on the surface of the slave medium, whereby:

after initial DC magnetization has been formed on the slave medium in advance in track direction, the master carrier for magnetic transfer and the slave medium processed by said initial DC magnetization are brought closely together, and a magnetic field for transfer in reverse direction to the direction of the initial DC magnetization on the surface of the slave medium is applied in track direction, and magnetic transfer is performed.

Also, the present invention provides a method for

magnetic transfer by bringing a master carrier for magnetic transfer together with a slave medium, said master carrier having a magnetic layer formed on surface of a substrate corresponding to an information signal, and said slave medium comprising a magnetic recording medium where the information is to be transferred, and by applying magnetic field for transfer, said method comprising the steps of:

arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between;

arranging said magnets obliquely in such manner that a distance between the permanent magnets at one end in the track direction is different from a distance at the other end, and turning the magnetic field intensity distribution in track direction to asymmetrical;

rotating the magnets or the slave medium arranged in track direction; and

applying magnetic field approximately in track direction on the surface of the slave medium, whereby:

after initial DC magnetization of the slave medium has been performed in advance in track direction, the master carrier for magnetic transfer and the slave medium processed by said initial DC magnetization are brought closely together, and magnetic transfer is performed, and a magnetic field for transfer in reverse direction to the direction of the initial DC magnetization on the surface of the slave medium is applied in track direction.

Further, the present invention provides a method for magnetic transfer by bringing a master carrier for magnetic transfer together with a slave medium and by applying magnetic field for transfer, said master carrier having a magnetic layer formed on surface of a substrate corresponding to an information signal, and said slave medium comprising a magnetic recording medium where the information is to be transferred, said method comprising the steps of:

applying a magnetic field in track direction on the surface of the slave medium, bringing the master carrier for magnetic transfer and the slave medium processed by said initial DC magnetization closely together after initial DC magnetization of the slave medium has been performed in track direction in advance;

arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between;

turning magnetic field intensity distribution in tracking direction to asymmetrical by arranging in such manner that a distance between said permanent magnets on one end in the track direction is different from a distance at the other end;

rotating said arranged magnets or a collective unit of the master carrier for magnetic transfer with the slave medium in track direction;

applying a magnetic field for transfer in track

direction reverse to the direction of the initial DC magnetization, and magnetic transfer is performed.

Also, the present invention provides the method for magnetic transfer as described above, wherein permanent magnets are arranged with the same polarities facing to each other and with the slave medium interposed between, said permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged in such manner that axis of the magnetic pole runs perpendicularly to the surface of the slave medium, and magnetic field intensity distribution in track direction of the magnetic field generated is such that there is at least one point having magnetic field intensity higher than coercive force (Hcs) of the slave medium at a position in the track direction.

Further, the present invention provides the method for magnetic transfer as described above, wherein permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged with the same polarities facing to each other and with the slave medium interposed between, said permanent magnets are arranged obliquely so that a distance between the permanent magnets at one end in tracking direction is different from a distance at the other end, and magnetic field intensity distribution in track direction is turned to asymmetrical, whereby the magnetic field intensity in the track direction of the magnetic field generated is such that there is a portion with magnetic intensity higher than coercive force of the slave medium only in one direction at a position in the

track direction, and magnetic field intensity in reverse direction has a value lower than coercive force (Hcs) of the slave medium even at any position in the track direction.

Also, the present invention provides the method for magnetic transfer as described above, wherein permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged with the same polarities facing to each other and with the slave medium interposed between, magnetic field intensity distribution in tracking direction is turned to asymmetrical by arranging the magnets obliquely in such manner that a distance between said permanent magnets at one end in track direction is different from a distance at the other end, whereby magnetic field intensity distribution in track direction of the magnetic field generated is such that magnetic field intensity higher than the maximum value of optimal transfer magnetic field intensity range is present at none of the position in track direction, there is at least one point where magnetic field intensity is within the optimal transfer magnetic field intensity in one track direction, and magnetic field intensity in the tracking direction in direction reverse thereto is lower than the minimum value of the optimal transfer magnetic field intensity range at any position in the track direction.

Further, the present invention provides the method for magnetic transfer as described above, wherein the optimal transfer magnetic field intensity is 0.6 × Hcs to 1.3 ×

Hcs to the coercive force (Hcs) of the slave medium.

Also, the present invention provides an apparatus for magnetic transfer for applying magnetic field for transfer, wherein a magnetic layer is formed on a portion of surface of a substrate corresponding to an information, and a master carrier for magnetic transfer and a slave medium comprising a magnetic recording medium where information is to be transferred are brought closely together, said apparatus comprising initial DC magnetizing means for arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between so that an axis of the magnetic pole runs perpendicularly to the surface of the slave medium, for rotating said slave medium or said permanent magnets in track direction, and for performing initial DC magnetization in track direction of the slave medium in advance by applying magnetic field in track direction on the surface of the slave medium, combining means for combining the master carrier for magnetic transfer with the slave medium processed by initial DC magnetization, and transfer magnetic field applying means for applying a magnetic field for transfer in reverse direction to the direction of the initial DC magnetization on the surface of the slave medium in track direction by turning the collective unit thus combined or the permanent magnets in track direction.

Further, the present invention provides an apparatus

for magnetic transfer for applying magnetic field for transfer, wherein a magnetic layer is formed on a portion of surface of a substrate corresponding to an information, and a master carrier for magnetic transfer and a slave medium comprising a magnetic recording medium where information is to be transferred are brought closely together, said apparatus comprising initial DC magnetizing means for performing initial DC magnetization of the slave medium in track direction in advance by arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between, for arranging the magnets obliquely so that a distance between said permanent magnets at one end in the track direction is different from a distance at the other end, for rotating the permanent magnets where magnetic field intensity distribution in track direction is turned to asymmetrical or the slave medium is rotated in the track direction, and magnetic field is applied in the track direction on the surface of the slave medium, combining means for combining the master carrier for magnetic transfer with the slave medium processed by initial DC magnetization closely together, and transfer magnetic field applying means for applying a magnetic field for transfer in reverse direction to the direction of the initial DC magnetization on the surface of the slave medium in track direction.

Also, the present invention provides an apparatus for magnetic transfer for applying magnetic field for transfer,

wherein a magnetic layer is formed on a portion of surface of a substrate corresponding to an information, and a master carrier for magnetic transfer and a slave medium comprising a magnetic recording medium where information is to be transferred are brought closely together, said apparatus comprising combining means for combining the master carrier for magnetic transfer with the slave medium processed by initial DC magnetization, and transfer magnetic field applying means consisting of permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with said combined unit interposed between, and arranging said permanent magnets obliquely so that a distance between said permanent magnets at one end in the track direction is different from a distance at the other end, and rotating means for rotating at least one of said combined unit or the transfer magnetic field applying means.

Further, the present invention provides the apparatus for magnetic transfer as described above, wherein, in said initial DC magnetizing means, when permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged with the same polarities at opposed position with the slave medium interposed between so that the axis of the magnetic pole runs perpendicularly to the surface of the slave medium, the magnetic field intensity distribution in the track direction of the magnetic field generated is such that there is at least one point in track direction where magnetic field intensity is higher than coercive

force (Hcs) of the slave medium.

Also, the present invention provides the apparatus for magnetic transfer as described above, wherein said initial DC magnetizing means comprises permanent magnets, said permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between, said permanent magnets arranged obliquely so that a distance between said permanent magnet at one end in the track direction is different from a distance at the other end, and magnetic field intensity distribution is turned to asymmetrical in the track direction, the magnetic field intensity distribution in the track direction is such that a point where magnetic field intensity is higher than coercive force (Hcs) of the slave medium is present only in one direction at a position in the track direction, and the magnetic field intensity in reverse direction is lower than the coercive force (Hcs) of the slave medium at a position in the track direction.

Further, the present invention provides the apparatus for magnetic transfer as described above, wherein permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged with the same polarities facing to each other and with the slave medium interposed between, said permanent magnets arranged obliquely so that a distance between said permanent magnets at one end in the track direction is different from a distance at the other end, and magnetic field intensity distribution is turned to

asymmetrical in the track direction, the magnetic field intensity distribution in the track direction of the magnetic field thus generated is such that magnetic field intensity higher than the maximum value of the optimal transfer magnetic field intensity range is not present at any position in the track direction, magnetic field intensity within the optimal transfer magnetic field intensity range is present at least at one point in one track direction, and magnetic field intensity in the track direction reverse thereto is lower than the minimum value in the optimal transfer magnetic field intensity range at any track direction in any track direction.

Also, the present invention provides the apparatus for magnetic transfer as described above, wherein the optimal transfer magnetic field intensity is 0.6 × Hcs to 1.3 × Hcs.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a drawing to explain transfer of a pattern for pre-format in a master carrier for magnetic transfer;

Fig. 2 is a drawing to explain a method for applying a magnetic field using two permanent magnets facing to each other and;

Fig. 3 is a drawing to explain another method for applying a magnetic field; and

Fig. 4 is a drawing to explain still another method for applying a magnetic field.

DESCRIPTION OF THE PREFERRED EMBODIMENT

When a master carrier for magnetic transfer and a slave medium are brought closely together and a magnetic field for transfer is applied from outside, magnetic transfer operation is unstable and a portion with signals of poor quality is produced as the result of transfer. Having found that the quality of signals is decreased because the magnetic field applied at the time of transfer is not adequate, the present inventors have conceived the present invention.

In the magnetic transfer from the master carrier for magnetic transfer to the slave medium, it has been believed in the past that, when an external magnetic field higher than the coercive force Hcs of the slave medium is applied, the slave medium is magnetized all in applied direction, and this is the reason why the pattern to be transferred is not recorded. For example, in Japanese Patent Publication Laid-Open 10-40544, it is described in the paragraph 0064 that it is preferable to have coercive force equal to or lower than the coercive force of the magnetic recording medium.

However, the present inventors have found the following principle after elaborate study. The principle of magnetic transfer according to the present system is as follows: As shown in Fig. 1, in a convex portion of a magnetic layer of a master carrier 1 for magnetic transfer, which is substantially in contact with a slave medium 4, an external magnetic field 6 for transfer is turned to a

magnetic field 6a which is absorbed to the convex portion, and the recordable magnetic field intensity is not attained on the magnetic layer of the slave medium 4 in contact. However, on the magnetic layer of the slave medium 4 corresponding to a concave portion of the master carrier 1 for magnetic transfer not in contact with the slave medium 4, the recordable magnetic field intensity is attained. As shown by reference numeral 7 in the figure, magnetization occurs in a direction of the external magnetic field 6 for transfer, and a pattern for pre-format of the master carrier 1 for magnetic transfer can be transferred to the slave medium 4 as a recording information 7.

Therefore, when transfer is performed from the master carrier for magnetic transfer to the slave medium, in the portion in contact with the slave medium, most of the magnetic field enters the pattern portion of the master carrier for magnetic transfer, and it appears that no inversion occurs even when transfer magnetic field higher than the coercive force Hcs of the slave medium is applied. By applying magnetic field for transfer having intensity in specific relation to the coercive force Hcs of the slave medium, it is possible to obtain a slave medium with the signal of high quality.

In order to achieve clear and distinct transfer in any type of pattern, initial DC magnetization should be performed on the slave medium in advance with sufficiently high magnetic field to magnetize to higher than the coercive force Hcs, or more preferably, to more than 1.2

times of Hcs. And magnetic field for transfer with specific intensity, i.e. a magnetic field within optimal transfer magnetic field intensity range, should be applied. The preferable magnetic field for transfer is given as:

$$0.6 \times Hcs \leqq \text{Magnetic field for transfer} \leqq 1.3 \times Hcs$$

It should be applied in a direction reverse to the direction of the initial DC magnetization.

More preferably, the magnetic field for transfer has coercive force of 0.8 - 1.2 Hcs, or most preferably, 1 - 1.1 Hcs.

The magnetic recording medium for performing pre-format for servo is a disk-type recording medium, and information is recorded along a track, which is formed concentrically from the center of rotation. To apply the magnetic field to transfer a radial pattern in the disk-type magnetic recording medium as described above, the magnetic field is applied in the direction of the track on the slave medium surface, i.e. in tangential direction of a circular arc at a position in arbitrary track direction, and initial DC magnetization is performed in track direction of the slave medium.

Next, the master carrier for magnetic transfer and the slave medium processed by the initial DC magnetization are brought closely together, and the magnetic field for transfer is applied in the direction of track on the slave medium surface. In this case, the direction of the initial DC magnetization when magnetic field is applied in the direction of track on the slave medium must be reverse to

the direction of the magnetic field for transfer applied for magnetic transfer on the slave medium surface.

Therefore, in order to apply the magnetic field under the above condition for applying magnetic field all over the entire surface of the disk-type medium, a magnetic field of such magnetic field intensity distribution that magnetic field intensity is higher than the coercive force Hcs of the slave medium at least at one point on a position in track direction is generated on a part of the track direction. By rotating the slave medium or the magnetic field by one turn in the track direction, the initial DC magnetization can be achieved.

Also, a magnetic field with such magnetic field intensity distribution is generated on a portion in the track direction that it has a portion with magnetic field intensity of higher than the coercive force Hcs of the slave medium only in one direction at a position in the track direction and that magnetic field intensity in reverse direction is lower than the coercive force Hcs of the slave medium at any position of the track direction. By rotating the slave medium or the magnetic field by one turn in the track direction, a magnetic field for initial DC magnetization can be applied in the track direction of the slave medium in advance.

Further, a magnetic field with such magnetic field intensity distribution is generated on a portion of the track direction that magnetic field intensity higher than the maximum value of the optimal transfer magnetic field

intensity range is not present at any position in the track direction and the portion with magnetic field within the optimal transfer magnetic field intensity range is present at least at one point in one track direction and magnetic field intensity reverse to the track direction is lower than the minimum value in the optimal transfer magnetic intensity range at any position of the track direction. The master carrier for magnetic transfer and the slave medium subjected to the initial DC magnetization are brought closely together, and this is rotated in the track direction or the magnetic field is rotated in the track direction. Thus, by applying the magnetic field for transfer in the track direction on the slave medium surface, this can be accomplished.

In the method of the present invention, transfer magnetic field may be applied by tilting the axis of magnetic pole of the permanent magnet obliquely with respect to the slave medium surface. In this case, the optimal value of the tilting of the axis of the magnetic pole varies according to the shape of the magnet. In case of a permanent magnet in form of a parallelepiped, it is preferable that an angle θ between a plane perpendicular to the axis of the magnetic pole and the surface of the slave medium is 5° to 70° , or more preferably 20° to 55° .

The permanent magnet used for the initial DC magnetization and magnetic transfer is preferably in such size as to be equal to or longer than the distance from a track on one end of the slave medium to a track on the

other end. In case of a disk-type slave medium, it is preferable that it is in such size as to be equal to or longer than the radial distance from the outermost track to the innermost track of the slave medium. When a permanent magnet of such size is used, it is possible to apply uniform magnetic field on the slave medium surface simply by moving the slave medium or the closely fitted group or the collective unit of the slave medium and the master carrier for magnetic transfer or the permanent magnet in one direction all over the total length of the track or by rotating by one turn.

Also, the magnetic field intensity to be applied using the permanent magnet must be uniform at any position all over the track. Its variation is preferably within ±5% at any position over the entire track, or more preferably within ±2.5%.

In the following, description will be given on a method for transfer and an apparatus for transfer.

Fig. 2 is to explain a method for applying magnetic field using two permanent magnets arranged at two opposed positions. Fig. 2 (A) shows an example where permanent magnets 8a and 8b each symmetrically magnetized with respect to the axis of the magnetic pole are arranged at opposite positions on upper and lower surfaces of the salve medium 4 respectively. The slave medium is rotated with the same polarities of magnetic poles facing to each other.

From each of the permanent magnets 8a and 8b arranged on upper and lower surfaces of the slave medium 4

respectively, a magnetic field 9 is applied to the surface of the slave medium 4 as shown in Fig. 2 (B).

Fig. 2 (C) is a diagram showing magnetic field intensity to be applied on the slave medium. In the magnetic field applied on the slave medium, a peak value higher than the coercive force Hcs of the slave medium is present. By rotating the slave medium or the magnet, initial DC magnetization can be performed on the slave medium.

Fig. 3 is to explain another method for applying the magnetic field.

Fig. 3 (A) is to explain a method for applying an asymmetrical magnetic field, and Fig. 3 (B) is to explain intensity of the magnetic field when the magnetic field of Fig. 3 (A) is applied.

Permanent magnets 8c and 8d each magnetized symmetrically with respect to the axis of the magnetic pole are arranged at opposite positions with the slave medium 4 interposed between them and with the same polarities facing to each other. The magnets are arranged obliquely so that a distance 11a between the ends of the permanent magnets on one end in the track direction is different from a distance 11b between the ends of the permanent magnets on the other end in the track direction, and distribution of magnetic field intensity in the track direction is turned to asymmetrical. An asymmetrical magnetic field 12 is given asymmetrically with respect to the surface of the slave medium 4. By rotating the slave medium 4 or the tilted

permanent magnets 8c and 8d in the track direction with respect to the central axis of the slave medium 1 and by applying the asymmetrical magnetic field to the entire surface of the slave medium, initial DC magnetization can be achieved.

In the asymmetrical magnetic field, a peak value 13 with lower intensity gives no influence on the initial DC magnetization to the slave medium, and only a peak value 14 with higher intensity exerts action on the initial DC magnetization.

Fig. 4 is to explain still another method for applying a magnetic field.

Fig. 4 (A) is to explain application of an asymmetrical magnetic field on a collective unit of the slave medium and the master carrier for magnetic transfer. Fig. 4 (B) is to explain intensity of a magnetic field given when the magnetic field shown in Fig. 4 (A) is applied.

To the surface of a collective unit 15 comprising the slave medium 4 processed by initial DC magnetization and the master carrier 1 for magnetic transfer, permanent magnets 8c and 8d each magnetized symmetrically with respect to the axis of the magnetic pole are arranged at opposite positions with the collective unit 15 interposed between them and with the same polarities facing to each other. It is designed in such manner that a distance 11a between the ends of the permanent magnets at one end in the track direction is different from a distance 11b between

the ends of the permanent magnets on the other end in the track direction, and the magnets are arranged obliquely to turn the magnetic field intensity distribution in the track direction to asymmetrical. By applying the asymmetrical magnetic field 12 to the surface of the slave medium 4, or by rotating the collective unit 15 or at least one of the tilted permanent magnets 8c and 8d in the track direction with respect to the central axis of the collective unit 15, a magnetic field in reverse direction to the magnetizing direction of the initial DC magnetization can be applied on the entire surface of the collective unit 15.

In the asymmetrical magnetic field, a peak value 13 with lower intensity gives no influence on the transfer of the pattern from the master carrier for magnetic transfer to the slave medium, and only a peak value 14 with higher intensity contributes to the magnetic transfer.

When a magnetic field in the optimal transfer magnetic field intensity range is given from the master carrier for magnetic transfer to the slave medium, the peak value 14 with higher intensity can form a good pattern regardless of the shape of the pattern.

The apparatus to be used in the method for magnetic transfer as shown in Fig. 2 to Fig. 4 has such a mechanism that the distance between the slave medium surface and the permanent magnet can be adjusted as desired. By adjusting the distance between the slave medium and the permanent magnet, the magnetic field intensity as desired can be obtained on the slave medium surface.

In an apparatus shown in Fig. 3 and Fig. 4, in addition to the mechanism to adjust the distance, there is provided a mechanism for adjusting tilt angle of the permanent magnet as desired, and this makes it possible to adjust the magnetic intensity reverse to initial DC magnetization and the magnetic field for magnetic transfer to the desired magnetic field intensity.

The method shown in Fig. 3 and Fig. 4 simply shows an example, in which magnetic field distribution at a position in the track direction is turned to asymmetrical using two permanent magnets. As a result, it is possible to change the shape of the permanent magnet on the slave medium side, or to combine a plurality of small permanent magnets into one block. Further, using a non-homogeneous material as the magnetic material in the permanent magnets, the magnetic field distribution can be turned to asymmetrical. Thus, it is possible to form a magnetic field pattern with asymmetrical intensity distribution similar to the examples shown in Fig. 3 and Fig. 4.

Now, description will be given on a method to manufacture the master carrier for magnetic transfer to be used in the magnetic transfer of the present invention.

As a substrate for the master carrier for magnetic transfer, a planar member with flat and smooth surface, which is made of silicon, quartz plate, glass, non-magnetic metal such as aluminum or alloy, ceramics, synthetic resin, etc., and which has enough resistance to processing environment such as temperature in etching and film forming

processes may be used.

On a substrate with flat and smooth surface, photoresist is coated, and light exposure or development is performed using a photo mask to match the pattern of pre-format. Or, the photoresist is directly marked, and a pattern corresponding to the pre-format information is formed.

Next, in the etching process, etching of the substrate is performed corresponding to the pattern by etching means such as reactive etching, physical etching using argon plasma, or etching using liquid.

The depth of the hole to be formed by the etching should be a depth corresponding to thickness of a magnetic layer formed as a transfer information recording portion. It is preferably 20 - 1000 nm. If it is too thick, spreading width of the magnetic field becomes too large, and this is not desirable.

The holes to be formed have preferably uniform depth so that bottom surface can be formed with a surface plane which runs in parallel to the surface of the substrate.

Also, the hole has preferably such a shape that its cross-section in the track direction perpendicular to the surface is of rectangular shape.

Next, the magnetic material is processed by vacuum film forming means such as vacuum deposition method, sputtering method, ion plating method, and a film of magnetic material is formed up to the surface of the substrate in thickness to correspond to the formed hole.

Magnetic characteristics of the transfer information recording portion are as follows: coercive force (Hcs) not more than 2500 Oe, or more preferably, 5 - 1500 Oe; saturation magnetic flux density (Bs) not less than 0.3 T (Tesla), or more preferably, not less than 0.5 T.

Then, photoresist is removed by lift-off method. The surface is polished, and burrs are removed if any, and the surface is flattened.

In the above, description has been given on the method to form holes on the substrate and to form a film of magnetic material in the holes thus formed. It may be designed in such manner that the film of magnetic material is formed at predetermined points on the substrate by photo-fabrication method to make convex portions on the transfer information recording portion, and non-magnetic material is the formed in film or is filled between the convex portions, and the surface may be made on the same level as the non-magnetic material portion of the transfer information recording portion.

As the magnetic material to be used in the magnetic layer, cobalt, iron or their alloys having high magnetic flux density may be used. More concretely, Co, CoPtCr, CoCr, CoPtCrTa, CoPtCrNbTa, CoCrB, CoNi, Fe, FeCo, FePt, etc. may be used.

The thickness of the magnetic layer is preferably 20 - 1000 nm, or more preferably, 30 - 500 nm. If it is too thick, resolution of recording is decreased.

In particular, it is preferable for the purpose of

providing clear transfer that magnetic flux density is high and it is in the same direction as the slave medium, e.g. in intra-surface direction in case of intra-surface recording, and to have magnetic anisotropy in vertical direction in case of vertical recording. It is preferable that the magnetic material has a structure of fine magnetic particles or amorphous structure because sharp edge can be produced.

In order to provide magnetic anisotropy on the magnetic material, it is preferable to have a non-magnetic underlayer, and crystal structure and lattice constant should be the same as those of the magnetic layer. More concretely, Cr, CrTi, CoCr, CrTa, CrMo, NiAl, Ru, etc. may be used to form the film by sputtering.

A protective film such as a diamond-like carbon film may be formed on the magnetic layer, and lubricant may be provided. As the protective film, it is more preferable that diamond-like carbon film of 5 - 30 nm and lubricant are present. The reason why lubricant must be provided is as follows: When deviation is caused during the contact process with the slave medium and this deviation is to be corrected, friction occurs, and if there is no lubricant layer, durability may be decreased.

The master carrier for magnetic transfer according to the present invention can be used not only in the transfer of magnetic recording information to a disk-type magnetic recording medium such as hard disk, large capacity removable type magnetic recording medium, etc. but also in

the transfer of magnetic recording information to a card-type magnetic recording medium or a tape-type magnetic recording medium.

In the following, description will be given in detail on the present invention by referring to examples.

[Example 1 and Comparative example 1]

(Preparation of master carrier for magnetic transfer)

In a vacuum film-making apparatus, pressure was reduced to 10^{-7} Torr at room temperature, and argon was then introduced to turn the pressure to 3×10^{-3} Torr. Then, a film of FeCo of 200 nm in thickness was formed on a silicon substrate, and this was used as the master carrier for magnetic transfer.

It had coercive force Hc of 100 Oe and magnetic flux density (Ms) of 23000 Gauss.

A disk-like pattern was formed by radial lines extending from the center of the disk to a position of 20 - 40 mm in radial direction with equal spacing of 10 μ in width. The spacing of the lines was set to 10 μm at the innermost position, i.e. 20 mm in radial direction.

(Preparation of the slave medium)

In a vacuum film-making apparatus, pressure was reduced to 10^{-7} Torr at room temperature, and argon was then introduced to turn the pressure to 3×10^{-3} Torr. Then, a glass plate was heated up to 200℃, and a disk-type magnetic recording medium of 3.5 inches in diameter was prepared, which had CoCrPt of 25 nm, Ms of 4500 Gauss, and coercive force (Hcs) of 2500 Oe.

(Initial DC magnetization method)

Permanent magnets were arranged as shown in Fig. 2 so that peak magnetic field intensity on the surface of the slave medium was to be 5000 Oe, i.e. two times as much as the coercive force Hcs of the slave medium, and initial DC magnetization of the slave medium was performed.

(Magnetic transfer test method)

The slave medium under initial DC magnetization and the master carrier for magnetic transfer were brought closely together. Using an apparatus with the permanent magnets tilted as shown in Fig. 4, magnetic field was applied in reverse direction to the magnetization of the slave medium, and magnetic transfer was performed. In Fig. 4, tilt angle of the permanent magnets to the slave medium given as θ was 35°. To bring the master carrier for magnetic transfer and the slave medium closely together, these were squeezed with a rubber plate interposed between them, and pressure was applied on an aluminum plate.

(Method to evaluate electromagnetic transfer characteristics)

An electromagnetic transfer characteristics measuring system (manufactured by Kyodo Electronics; SS-60) was used to evaluate transfer signal of the slave medium. An MR head with the following performance data was used: reproducing head gap 0.3 μm; reproduction track width 2.7 μm; recording head gap 0.45 μm; and recording track width 3.3 μm.

Reading signal was processed by a spectro-analyzer for

frequency analysis, and a difference (C/N) between peak intensity of primary signal (C) and extrapolated medium noise (N) was determined. In the values of C/N at each magnetic field intensity, relative value of ΔC/N was evaluated with the maximum value at 0 dB. The results are shown in Table 1. When the value of C/N was not more than -20 dB, signal quality of magnetic transfer did not reach the level for practical use, and this was indicated with the mark *.

Table 1

Hcs of slave medium: 2500 Oe

Peak intensity of magnetic field for transfer (Oe)	Ratio to Hcs	ΔC/N (dB)
750	0.3	*
1,250	0.5	-12.3
1,500	0.6	-4.2
2,000	0.8	-1.3
2,250	0.9	-0.4
2,500	1.0	0.0
2,750	1.1	-0.3
3,000	1.2	-0.8
3,250	1.3	-4.9
3,500	1.4	-9.6
3,750	1.5	-16.9
4,000	1.6	*
5,000	2.0	*

(Example 2 and Comparative example 2)

To a slave medium having coercive force (Hcs) of 2500 Oe, magnetic transfer was carried out by the same procedure as in Example 1 except that initial DC magnetization of the slave medium was performed with peak magnetic field intensity of 3000 Oe, i.e. magnetic field intensity 1.2 times as high as the coercive force (Hcs) of the slave medium. Then, the slave medium under initial DC magnetization and the master carrier for magnetic transfer were brought closely together and magnetic transfer was performed. The magnetic transfer pattern was developed by the same procedure as in Example 1, and measurement was made. The results are summarized in Table 2.

Table 2

Hcs of slave medium: 2500 Oe

Peak intensity of magnetic field for transfer (Oe)	Ratio to Hcs	ΔC/N (dB)
750	0.3	*
1,250	0.5	-12.3
1,500	0.6	-2.8
2,000	0.8	-0.2
2,250	0.9	0.0
2,500	1.0	-0.1
2,750	1.1	-1.6
3,000	1.2	-1.1

3,250	1.3	-4.8
3,500	1.4	-9.6
3,750	1.5	-15.9
4,000	1.6	*
5,000	2.0	*

(Comparative example 3)

To a slave medium having coercive force (Hcs) of 2500 Oe, magnetic transfer was performed by the same procedure as in Example 1 except that initial DC magnetization was performed with peak magnetic field intensity of 2000 Oe, i.e. with magnetic intensity 0.8 time as high as the coercive force (Hcs) of the slave medium. Then, the slave medium processed by initial DC magnetization and the master carrier for magnetic transfer were closely brought together, and magnetic transfer was performed. By the same procedure as in Example 1, the magnetic transfer pattern was developed, and measurement was made. The results are shown in Table 3.

Table 3

Hcs of slave medium: 2500 Oe

Peak intensity of magnetic field for transfer (Oe)	Ratio to Hcs	ΔC/N (dB)
750	0.3	*
1,250	0.5	*
1,500	0.6	*

2,000	0.8	*
2,250	0.9	*
2,500	1.0	*
2,750	1.1	*
3,000	1.2	*
3,250	1.3	*
3,500	1.4	*
3,750	1.5	*
4,000	1.6	*
5,000	2.0	*

(Example 3 and Comparative example 4)

To a slave medium having coercive force (Hcs) of 2500 Oe, initial DC magnetization of the slave medium was performed using the permanent magnets shown in Fig. 3 so that peak magnetic field intensity was to be 5000 Oe, 3000 Oe and 2000 Oe. Then, this was brought closely together with the master carrier for magnetic transfer processed by initial DC magnetization. Magnetic field was applied using the permanent magnets shown in Fig. 4, and magnetic transfer was performed.

Then, the result similar to the case of the system with permanent magnets of Fig. 2 was obtained.

(Example 4 and Comparative example 5)

To a slave medium having coercive force (Hcs) of 2000 Oe prepared by the same procedure as in Example 1, magnetic transfer was performed by the same procedure as in Example 1 except that initial DC magnetization of the slave medium

was performed with peak magnetic field intensity of 4000 Oe, i.e. magnetic field intensity 2 times as high as the coercive force (Hcs) of the slave medium, and the slave medium processed by initial DC magnetization was brought together closely with the master carrier for magnetic transfer, and magnetic transfer was performed using a system shown in Fig. 4. Then, the magnetic transfer pattern was developed, and measurement was made. The results are shown in Table 4.

Table 4

Hcs of slave medium: 2000 Oe

Peak intensity of magnetic field for transfer (Oe)	Ratio to Hcs	ΔC/N (dB)
600	0.3	*
1,000	0.5	-12.8
1,200	0.6	-3.4
1,600	0.8	-0.6
1,800	0.9	-0.3
2,000	1.0	0.0
2,200	1.1	-0.6
2,400	1.2	-2.8
2,600	1.3	-3.4
2,800	1.4	-9.6
3,000	1.5	-17.6
3,200	1.6	*
4,000	2.0	*

(Example 4 and comparative example 5)

To a slave medium having coercive force (Hcs) of 2000 Oe, magnetic transfer was performed by the same procedure as in Example 5 except that initial DC magnetization of the slave medium was performed with peak magnetic field intensity of 2400 Oe, i.e. magnetic field intensity 1.2 times as high as the coercive force (Hcs) of the slave medium, and the slave medium processed by initial DC magnetization was brought closely together with the master carrier for magnetic transfer. Then, the magnetic transfer pattern was developed by the same procedure, and measurement was made. The results are shown in Table 5.

Table 5

Hcs of slave medium: 2000 Oe

Peak intensity of magnetic field for transfer (Oe)	Ratio to Hcs	ΔC/N (dB)
600	0.3	*
1,000	0.5	-12.4
1,200	0.6	-4.8
1,600	0.8	-0.6
1,800	0.9	-0.5
2,000	1.0	0.0
2,200	1.1	-0.3
2,400	1.2	-1.8
2,600	1.3	-2.4

2,800	1.4	-9.3
3,000	1.5	-16.9
3,200	1.6	*
4,000	2.0	*

(Comparative example 6)

To a slave medium having coercive force (Hcs) of 2000 Oe prepared by the same procedure as in Example 1, magnetic transfer was performed by the same procedure as in Example 1 except that initial DC magnetization of the slave medium was performed with peak magnetic field intensity of 1600 Oe, i.e. with magnetic field intensity 0.8 time as high as the coercive force (Hcs) of the slave medium, and the slave medium processed by initial DC magnetization was brought closely together with the master carrier for magnetic transfer, and magnetic transfer was performed using a system shown in Fig. 4. Then, the magnetic transfer pattern was developed, and measurement was made. The results are summarized in Table 6.

Table 6

Hcs of slave medium: 2000 Oe

Peak intensity of magnetic field for transfer (Oe)	Ratio to Hcs	ΔC/N (dB)
600	0.3	*
1,000	0.5	*
1,200	0.6	*

1,600	0.8	*
1,800	0.9	*
2,000	1.0	*
2,200	1.1	*
2,400	1.2	*
2,600	1.3	*
2,800	1.4	*
3,000	1.5	*
3,200	1.6	*
4,000	2.0	*

In the magnetic transfer from the master carrier for magnetic transfer to the slave medium, by applying magnetic field for transfer with a specific intensity to the coercive force (Hcs) of the slave medium, it is possible to obtain a transfer pattern with excellent quality on the slave medium regardless of position or configuration of the pattern.

WHAT WE CLAIM IS:

1. A method for magnetic transfer by bringing a master carrier for magnetic transfer together with a slave medium and by applying magnetic field for transfer, said master carrier having a magnetic layer formed on surface of a substrate corresponding to an information signal, and said slave medium comprising a magnetic recording medium where the information is to be transferred, said method comprising the steps of:

arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between, and disposing the slave medium perpendicularly to the axis of the magnetic pole,

rotating the slave medium or the permanent magnets in track direction; and

applying magnetic field in track direction on the surface of the slave medium, whereby:

after initial DC magnetization has been formed on the slave medium in advance in track direction, the master carrier for magnetic transfer and the slave medium processed by said initial DC magnetization are brought closely together, and a magnetic field for transfer in reverse direction to the direction of the initial DC magnetization on the surface of the slave medium is applied in track direction, and magnetic transfer is performed.

2. A method for magnetic transfer by bringing a master carrier for magnetic transfer together with a slave medium



and by applying magnetic field for transfer, said master carrier having a magnetic layer formed on surface of a substrate corresponding to an information signal, and said slave medium comprising a magnetic recording medium where the information is to be transferred, said method comprising the steps of:

arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between;

arranging said magnets obliquely in such manner that a distance between the permanent magnets at one end in the track direction is different from a distance at the other end, and turning the magnetic field intensity distribution in track direction to asymmetrical;

rotating the magnets or the slave medium arranged in track direction; and

applying magnetic field approximately in track direction on the surface of the slave medium, whereby:

after initial DC magnetization of the slave medium has been performed in advance in track direction, the master carrier for magnetic transfer and the slave medium processed by said initial DC magnetization are brought closely together, and magnetic transfer is performed, and a magnetic field for transfer in reverse direction to the direction of the initial DC magnetization on the surface of the slave medium is applied in track direction.

3. A method for magnetic transfer by bringing a master



carrier for magnetic transfer together with a slave medium and by applying magnetic field for transfer, said master carrier having a magnetic layer formed on surface of a substrate corresponding to an information signal, and said slave medium comprising a magnetic recording medium where the information is to be transferred, said method comprising the steps of:

applying a magnetic field in track direction on the surface of the slave medium, bringing the master carrier for magnetic transfer and the slave medium processed by said initial DC magnetization closely together after initial DC magnetization of the slave medium has been performed in track direction in advance;

arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between;

turning magnetic field intensity distribution in tracking direction to asymmetrical by arranging in such manner that a distance between said permanent magnets on one end in the track direction is different from a distance at the other end;

rotating said arranged magnets or a collective unit of the master carrier for magnetic transfer with the slave medium in track direction;

applying a magnetic field for transfer in track direction reverse to the direction of the initial DC magnetization, and magnetic transfer is performed.

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4. A method for magnetic transfer according to claim 1, wherein permanent magnets are arranged with the same polarities facing to each other and with the slave medium interposed between, said permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged in such manner that axis of the magnetic pole runs perpendicularly to the surface of the slave medium, and magnetic field intensity distribution in track direction of the magnetic field generated is such that the magnetic field intensity is higher than coercive force (Hcs) of the slave medium at least at one point at a position in the track direction.

5. A method for magnetic transfer according to claim 2, wherein permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged with the same polarities facing to each other and with the slave medium interposed between, said permanent magnets are arranged obliquely so that a distance between the permanent magnets at one end in tracking direction is different from a distance at the other end, and magnetic field intensity distribution in track direction is turned to asymmetrical, whereby the magnetic field intensity in the track direction of the magnetic field generated is such that there is a portion with magnetic intensity higher than coercive force of the slave medium only in one direction at a position in the track direction, and magnetic field intensity in reverse direction has a value lower than coercive force (Hcs) of the slave medium even at any position in the track

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direction.

6. A method for magnetic transfer according to claim 3, wherein permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged with the same polarities facing to each other and with the slave medium interposed between, magnetic field intensity distribution in tracking direction is turned to asymmetrical by arranging the magnets obliquely in such manner that a distance between said permanent magnets at one end in track direction is different from a distance at the other end, whereby magnetic field intensity distribution in track direction of the magnetic field generated is such that magnetic field intensity higher than the maximum value of optimal transfer magnetic field intensity range is present at none of the position in track direction, there is at least one point where magnetic field intensity is within the optimal transfer magnetic field intensity in one track direction, and magnetic field intensity in the tracking direction in direction reverse thereto is lower than the minimum value of the optimal transfer magnetic field intensity range at any position in the track direction.

7. A method for magnetic transfer according to claim 6, wherein the optimal transfer magnetic field intensity is 0.6 × Hcs to 1.3 × Hcs to the coercive force (Hcs) of the slave medium.

8. An apparatus for magnetic transfer for applying magnetic field for transfer, wherein a magnetic layer is formed on a portion of surface of a substrate corresponding

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to an information, and a master carrier for magnetic transfer and a slave medium comprising a magnetic recording medium where information is to be transferred are brought closely together, said apparatus comprising initial DC magnetizing means for arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between so that the axis of the magnetic pole runs perpendicularly to the surface of the slave medium, for rotating said slave medium or said permanent magnets in track direction, and for performing initial DC magnetization in track direction of the slave medium in advance by applying magnetic field in track direction on the surface of the slave medium, combining means for combining the master carrier for magnetic transfer with the slave medium processed by initial DC magnetization, and transfer magnetic field applying means for applying a magnetic field for transfer in reverse direction to the direction of the initial DC magnetization on the surface of the slave medium in track direction by turning the collective unit thus combined or the permanent magnets in track direction.

9. An apparatus for magnetic transfer for applying magnetic field for transfer, wherein a magnetic layer is formed on a portion of surface of a substrate corresponding to an information, and a master carrier for magnetic transfer and a slave medium comprising a magnetic recording medium where information is to be transferred are brought

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closely together, said apparatus comprising initial DC magnetizing means for performing initial DC magnetization of the slave medium in track direction in advance by arranging permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the slave medium interposed between, for arranging the magnets obliquely so that a distance between said permanent magnets at one end in the track direction is different from a distance at the other end, for rotating the permanent magnets where magnetic field intensity distribution in track direction is turned to asymmetrical or the slave medium is rotated in the track direction, and magnetic field is applied in the track direction on the surface of the slave medium, combining means for combining the master carrier for magnetic transfer with the slave medium processed by initial DC magnetization closely together, and transfer magnetic field applying means for applying a magnetic field for transfer in reverse direction to the direction of the initial DC magnetization on the surface of the slave medium in track direction.

10. An apparatus for magnetic transfer for applying magnetic field for transfer, wherein a magnetic layer is formed on a portion of surface of a substrate corresponding to an information, and a master carrier for magnetic transfer and a slave medium comprising a magnetic recording medium where information is to be transferred are brought closely together, said apparatus comprising combining means

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for combining the master carrier for magnetic transfer with the slave medium processed by initial DC magnetization, and transfer magnetic field applying means consisting of permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with said combined unit interposed between, and arranging said permanent magnets obliquely so that a distance between said permanent magnets at one end in the track direction is different from a distance at the other end, and rotating means for rotating at least one of said combined unit or the transfer magnetic field applying means.

11. An apparatus for magnetic transfer according to claim 8, wherein, in said initial DC magnetizing means, when permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged with the same polarities at opposed position with the slave medium interposed between so that the axis of the magnetic pole runs perpendicularly to the surface of the slave medium, the magnetic field intensity distribution in the track direction of the magnetic field generated is such that there is at least one point in track direction where magnetic field intensity is higher than coercive force (Hcs) of the slave medium.

12. An apparatus for magnetic transfer according to claim 9, wherein said initial DC magnetizing means comprises permanent magnets, said permanent magnets each magnetized symmetrically to the axis of the magnetic pole with the same polarities facing to each other and with the



slave medium interposed between, said permanent magnets arranged obliquely so that a distance between said permanent magnet at one end in the track direction is different from a distance at the other end, and magnetic field intensity distribution is turned to asymmetrical in the track direction, the magnetic field intensity distribution in the track direction is such that a point where magnetic field intensity is higher than coercive force (Hcs) of the slave medium is present only in one direction at a position in the track direction, and the magnetic field intensity in reverse direction is lower than the coercive force (Hcs) of the slave medium at a position in the track direction.

13. An apparatus for magnetic transfer according to claim 10, wherein permanent magnets each magnetized symmetrically to the axis of the magnetic pole are arranged with the same polarities facing to each other and with the slave medium interposed between, said permanent magnets arranged obliquely so that a distance between said permanent magnets at one end in the track direction is different from a distance at the other end, and magnetic field intensity distribution is turned to asymmetrical in the track direction, the magnetic field intensity distribution in the track direction of the magnetic field thus generated is such that magnetic field intensity higher than the maximum value of the optimal transfer magnetic field intensity range is not present at any position in the track direction, magnetic field intensity within the

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optimal transfer magnetic field intensity range is present at least at one point in one track direction, and magnetic field intensity in the track direction reverse thereto is lower than the minimum value in the optimal transfer magnetic field intensity range at any position in any track direction.

14. An apparatus for magnetic transfer according to claim 13, wherein the optimal transfer magnetic field intensity is 0.6 × Hcs to 1.3 × Hcs.

