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MASTER INFORMATION CARRIER FOR MAGNETIC TRANSFER

BACKGROUND OF THE INVENTION

Field of the Invention

5 This invention relates to a master information carrier carrying thereon an irregularity pattern (a pattern of protruding portions and recessed portions) representing the information to be transferred to a magnetic medium.

Description of the Related Art

10 With an increase in information quantity, there is a demand for a magnetic recording medium which is high in memory capacity, low in cost and preferably requires a short time to read out a necessary part of data (a magnetic recording medium which allows so-called high-speed access). As an example of
15 such a magnetic recording medium, there has been known a high recording density magnetic medium such as a hard disc, a zip (a flexible disc available from Iomega) and the like. In such a high recording density magnetic medium, the recording area is formed by narrow data tracks. In order to cause a magnetic
20 head to accurately trace such narrow data tracks and reproduce the data at a high S/N ratio, the so-called servo tracking technique has been employed.

 In order to perform the servo tracking, it is necessary to write servo information such as servo tracking signals for
25 positioning the data tracks, address signals for the data tracks and reproduction clock signals on the magnetic

recording medium as a preformat upon production thereof. At the present, such preformat recording is performed by the use of a specialized servo recording apparatus (a servo track writer). However, the preformat recording by the conventional
5 servo recording apparatus is disadvantageous in that it takes a long time since the servo information must be recorded on the magnetic recording medium one by one by the use of a magnetic head, which deteriorates the productivity.

As a method of recording the preformat accurately and
10 efficiently, there has been proposed, for instance, in Japanese Unexamined Patent Publication No. 63(1988)-183623 and 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
15 recording medium (a slave medium) by magnetic transfer.

In the magnetic transfer, the magnetization pattern representing the information (e.g., servo information) carried by a master information carrier is magnetically transferred from the master information carrier to a slave
20 medium by applying a transfer magnetic field to the slave medium and the master information in close contact with each other, and accordingly, the information carried by the master information carrier can be statically recorded on the slave medium with the relative position between the master
25 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.

The master information carrier used in the magnetic transfer disclosed, for instance, in U.S. Patent No. 6,347,016
5 has an irregularity pattern (a pattern of protruding portions and recessed portions) representing information to be transferred to slave media and at least the top surface of the protruding portions of the irregularity pattern is formed of magnetic material. By magnetic transfer by the use of such
10 a patterned master information carrier, a magnetization pattern corresponding to the irregularity pattern on the master information carrier is formed on the slave media.

In the magnetic transfer, the reproduction signal waveform obtained from the slave media to which the
15 magnetization pattern is transferred from the master information carrier, that is, whether the reproduction signal waveform is of a desired amplitude and a desired period, is important.

Our, these inventor's, investigation has revealed that
20 the reproduction signal waveform from a magnetic recording medium obtained by the magnetic transfer depends upon the shape of the protruding portions of the irregularity pattern on the master information carrier, the strength of the transfer magnetic field, the distance between the master information
25 carrier and the slave medium (the degree of close contact therebetween), and the like. The amplitude of the

reproduction signal waveform is related to the signal quality (S/N), and a certain strength of the transfer magnetic field is required and the distance between the master information carrier and the slave medium should be as small as possible in order to obtain a good signal quality. Various shapes of the protruding portions of the irregularity pattern on the master information carrier have been proposed in view of using conditions such as on close contact, separation and the like, manufacturing conditions, and/or the like. In any shape of the protruding portions, there is an effective width in the direction of the tracks. However, it has not been clear what effective width in the direction of the tracks provides desired periodicity to the reproduction signal waveform.

Unless the reproduction signal waveform has desired periodicity, the recording/reproducing accuracy of the magnetic recording medium is deteriorated. Especially, when the information to be transferred is a servo signal, the tracking performance deteriorate, which can result in deterioration of reliability.

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SUMMARY

A need exists to provide a master information carrier which can form a magnetization pattern on a magnetic recording medium by magnetic transfer so that a desired reproduction signal waveform can be obtained from the magnetic recording medium.

In accordance with an embodiment of the present invention, there is provided a master information carrier for magnetic transfer having on the surface thereof a concentric irregularity pattern representing information to be transferred to a disc-like magnetic recording medium, at least the top surface of the protruding portions of the irregularity pattern being formed of magnetic material, wherein the improvement comprises that

the irregularity pattern is formed so that the width L [nm] in a circumferential direction of a protruding portion at a distance R [nm] from the center satisfies the condition

$$L = \alpha (\omega \cdot \Delta T \cdot R), \quad 0.8 \leq \alpha \leq 1.4,$$

wherein ω represents in [rad/sec] the angular velocity of the magnetic recording medium when a signal is read out from the magnetic recording medium after the magnetic transfer and ΔT represents in [sec] a desired signal time width of a reproduction signal waveform in a magnetization transition region corresponding to an interval between the ends of the protruding portion in the circumferential direction.

That is, in the master information carrier for magnetic transfer of the present invention, the width L [nm] in a circumferential direction (in a direction of track) of a protruding portion is changed according to the radius of the track (the distance from the center) with the value of α selected to an optimal value within the range of 0.8 to 1.4 according to the conditions such as the shape of the protruding

portion, the strength of the magnetic field applied upon magnetic transfer, the distance between the master information carrier and the magnetic recording medium (the degree of close contact therebetween) and/or the like, so that the signal time
5 width of the reproduction waveform reproduced at an angular velocity of ω is of a desired value in all the tracks.

The "width in a circumferential direction of a protruding portion" as used here means an effective width affecting formation of the magnetization pattern (the width of the
10 magnetized area) by the protruding portion. For example, when the cross-sectional shape of the protruding portion taken along a plane extending in a direction parallel to the direction of the track in perpendicular to the surface of the master information carrier (will be simply referred to as "the
15 longitudinal cross-sectional shape", hereinbelow) is a rectangle or trapezoid, the effective width is the width in the direction of the track of the top surface of the protruding portion, whereas when the longitudinal cross-sectional shape of the protruding portion is a rectangle or trapezoid with its
20 upper portions cut away at the ends thereof, the effective width is the distance between the intersections of the extension of the upper side of the rectangle or the trapezoid and the extensions of the end lines of the rectangle or the trapezoid.

In the master information carrier of an embodiment of the present
25 invention where the width L [nm] in a circumferential direction of a protruding portion at a distance R [nm] from the center

satisfies the aforesaid condition, the reproduction signal waveform obtained from the slave media to which the magnetization pattern is transferred from the master information carrier can be of a desired amplitude and a desired
5 period. Especially, when the information to be transferred is a servo signal, the accuracy of the tracking servo is improved.

When $L/(\omega \cdot \Delta T \cdot R) (= \alpha)$ is smaller than 0.8, the longitudinal cross-sectional shape of the protruding portion
10 must be a trapezoid having sufficiently inclined end lines in order to obtain desired periodicity of the reproduction signal, which makes it geometrically difficult to ensure a predetermined depth of recessed portion between protruding portions. Further when $L/(\omega \cdot \Delta T \cdot R) (= \alpha)$ is larger than 1.4,
15 the applied magnetic field must be strengthened or the distance between the master information carrier and the slave medium must be enlarged in order to obtain desired periodicity of the reproduction signal. However when the distance between the master information carrier and the slave medium is enlarged,
20 the amplitude of the reproduction signal greatly deteriorates, that is, the signal quality greatly deteriorates.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an exploded perspective view of a double-sided slave medium and a pair of master information
25 carriers carrying thereon information to be transferred to opposite sides of the slave medium,

Figures 2A to 2C are views for illustrating basic steps of magnetic transfer,

Figure 3 is a plan view for illustrating a master information carrier in accordance with an embodiment of the present invention,

Figure 4 is a view showing the relation between the reproduction signal waveform obtained from the magnetic recording medium, the magnetization pattern of the magnetic recording medium and the irregularity pattern on the master information carrier, and

Figures 5A to 5C are views showing examples of the cross-sectional shape of the protruding portion on the master information carrier.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Magnetic transfer for transferring information on a master information carrier to a slave medium (magnetic recording medium) will be first described in brief. As shown in Figure 1, a pair of pieces of information are transferred to opposite sides of a magnetic recording medium (slave medium) 2 from a pair of master information carriers 3 and 4.

The magnetic recording medium 2 is a disc-like magnetic recording medium such as a hard disc or a flexible disc and comprises a disc-like base sheet 2a and magnetic layers 2b and 2c formed on opposite sides of the base sheet 2a.

The master information carriers 3 and 4 comprise substrates 3a and 4a having irregularity patterns (e.g., servo

signals) representing information to be transferred to the magnetic layers 2b and 2c of the magnetic recording medium 2 and soft magnetic layers 3b and 4b provided along the irregularity patterns on the base sheets 3a and 4a

5 Though the magnetic recording medium 2 is away from the master information carriers 3 and 4 in Figure 1, the magnetic layers 2b and 2c of the magnetic recording medium 2 are brought into close contact with the soft magnetic layers 3b and 4b of the master information carriers 3 and 4, or are opposed to the
10 soft magnetic layers 3b and 4b of the master information carriers 3 and 4 in the vicinity thereof, when magnetic transfer is actually carried out.

 Basic steps of magnetic transfer of information to a slave medium (magnetic recording medium) will be described
15 with reference to Figures 2A to 2C, hereinbelow. In Figures 2A to 2C, only the lower magnetic layer 2b is shown.

 An initial DC magnetic field H_{in} is first applied to the slave medium 2 in one direction parallel to the recording tracks thereof, thereby magnetizing the magnetic layer 2b of the slave
20 medium 2 in an initial DC magnetization as shown in Figure 2A. Thereafter, the magnetic layer 3b of the lower master information carrier 3 is brought into close contact with the lower magnetic layer 2b of the slave medium 2. In this state, a transfer magnetic field H_{du} is applied in the direction
25 opposite to the initial DC magnetic field H_{in} as shown in Figure 2B, thereby magnetically transferring the information on the

master information carrier 3 to the lower magnetic layer 2b of the slave medium 2. As a result, information represented by the irregularity pattern on the master information carrier 3 (e.g., a servo signal) is transferred to the lower magnetic layer 2b as shown in Figure 2C. The information represented by the irregularity patterns on a pair of master information carriers may be transferred to opposite sides of the slave medium either simultaneously or in sequence.

In the case where the irregularity pattern representing information to be transferred is a negative pattern reverse to the positive pattern shown in Figures 2A to 2C, the 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} . The intensities of the initial magnetic field and the transfer magnetic field should be determined taking into account the coercive force of the slave medium 2, the specific permeabilities of the magnetic layers of the master information carrier 3 and the slave medium 2.

The master information carrier 3 in accordance with the present invention will be described in detail with reference to Figures 3, 4 and 5A to 5C, hereinbelow.

The master information carrier 3 of the present invention is provided on its surface with an irregularity pattern representing information to be transferred to a slave medium 2. The irregularity pattern is formed so that the width L [nm]

in a circumferential direction of a protruding portion at a distance R [nm] from the center satisfies the condition

$$L = \alpha(\omega \cdot \Delta T \cdot R), \quad 0.8 \leq \alpha \leq 1.4,$$

wherein ω represents in [rad/sec] the angular velocity
5 of the magnetic recording medium when a signal is read out from
the magnetic recording medium after the magnetic transfer and
 ΔT represents in [sec] a desired signal time width of a
reproduction signal waveform in a magnetization transition
region corresponding to an interval between the ends of the
10 protruding portion in the circumferential direction. The
value of α is selected within the range of 0.8 to 1.4 so that
the width L [nm] is such as to obtain a desired ΔT from a
magnetic recording medium after magnetic transfer. The
circumferential width M of the recessed portion is a value in
15 proportion to $(\omega \cdot \Delta T \cdot R)$ and the factor of proportionality is
readily determined when the shape and the circumferential
width L of the protruding portion are determined.

In the master information carrier 3 shown in Figure 3,
the circumferential width L1 of the protruding portion formed
20 at a distance R1 from the center is $\alpha(\omega \cdot \Delta T \cdot R1)$ and the
circumferential width L2 of the protruding portion formed at
a distance R2 from the center is $\alpha(\omega \cdot \Delta T \cdot R2)$.

That is, when reading out a signal from a magnetic
recording medium, a reproduction signal is generally obtained
25 by detecting magnetization transition regions of a
magnetization pattern while rotating the magnetic recording

medium at a constant angular velocity. Accordingly, in order to obtain a predetermined reproduction signal waveform from a magnetic recording medium, it is necessary that the intervals between magnetization transition regions of the magnetization pattern are narrowed inward and broadened outward. In accordance with the present invention, the widths of the protruding portions and the recessed portions contributing to the intervals between magnetization transition regions are made to be larger as the radius of the concentric recording track is increased in order to make such intervals. Though, being illustrated as a rectangle in Figure 3, the shape of the top surface of the protruding portion need not be limited to a rectangle but may be, for instance, a parallelogram or a trapezoid.

15 In order to obtain a desired ΔT in a reproduction signal shown in the part of Figure 4 indicated at (a), it is necessary that the transition regions 20 of the magnetization pattern in the slave medium 2 is formed at intervals shown in the part of Figure 4 indicated at (b). The intervals L_0 between the transition regions 20 of the magnetization pattern in the slave medium 2 is $\omega \cdot \Delta T \cdot R$. Though the magnetization transition regions 20 in the slave medium 2 are formed according to the track direction widths (width in the track direction) of the protruding portions on the master information carrier 3, the intervals between the transition regions 20 of the magnetization pattern in the slave medium 2 do not necessarily

coincide with the track direction width of the protruding portion on the master information carrier 3 but change with various factors such as the strength of the magnetic field applied upon magnetic transfer, the distance between the master information carrier and the magnetic recording medium (the degree of close contact therebetween), the shape of the protruding portion, and the like. Accordingly, with the track direction width L of the protruding portion taken as $L=\alpha \cdot L_0$, the value of α must be set. An optimal value of α is selected within the range of 0.8 to 1.4.

Such a master information carrier can be produced by producing a plurality of master information carriers different in α within the range of 0.8 to 1.4, carrying out magnetic transfer by the use of the master information carriers, and adopting the master information carrier from which a magnetic recording medium closest to a desired signal time width ΔT in signal time width is obtained as the master information carrier to be used in an actual magnetic transfer.

The shape of the protruding portions of the irregularity pattern on the master information carrier is varied according to using conditions such as on close contact, separation and the like, manufacturing conditions, and/or the like. The "width in a circumferential direction (track direction width) of a protruding portion" as used here means an effective width affecting formation of the magnetization pattern (the width of the magnetized area) by the protruding portion. For example,

when the cross-sectional shape of the protruding portion taken along a plane extending in a direction parallel to the direction of the track in perpendicular to the surface of the master information carrier (will be simply referred to as "the longitudinal cross-sectional shape", hereinbelow) is a rectangle or trapezoid as shown in Figure 5A, the track direction width L is the width in the direction of the track of the top surface of the protruding portion, whereas when the longitudinal cross-sectional shape of the protruding portion is a rectangle or trapezoid with its upper portions cut away at the ends thereof as shown in Figure 5B, the track direction width L is the distance between the intersections of the extension of the upper side of the rectangle or the trapezoid and the extensions of the end lines of the rectangle or the trapezoid. Further, when the upper surface and the end surfaces of the protruding portion are curved as shown in Figure 5C, the track direction width L of the protruding portion is the distance between the intersections of the tangents of the upper surface and the end surfaces of the protruding portion.

Though the value of the track direction width of the protruding portion optimal to obtain a predetermined reproduction signal waveform differs with the shape of the protruding portion, a master information carrier which can provide slave media from which reproduction signals of a predetermined waveform can be obtained can be produced by selecting the value of α from the range of 0.8 to 1.4.

The substrate of the master information carrier may be formed, for instance, of nickel, silicon, a quartz plate, glass, aluminum, ceramics or synthetic resin. The soft magnetic layer may be formed, for instance, of Co, Co alloys (e.g., CoNi, 5 CoNiZr and CoNbTaZr), Fe, Fe alloys (e.g., FeCo, FeCoNi, FeNiMo, FeAlSi, FeAl and FeTaN), Ni or Ni alloys (e.g., NiFe). As the material of the soft magnetic layer, FeCo and FeCoNi are especially preferable.

The substrate of the master information carrier having 10 thereon the irregularity pattern or the pattern of the protruding portions can be formed, for instance, by the use of stamper method or photolithography.

For example, a photo-resist layer is first formed on a smooth glass plate (or a smooth crystal plate), for instance, 15 by spin coating, and a laser beam (or an electron beam) modulated according to the servo signal is projected onto the photo-resist layer while rotating the glass plate so that the photo-resist layer is exposed to the laser beam in a predetermined pattern, e.g., a pattern of servo signals each 20 extending in a radial direction in one track. Thereafter the photo-resist layer is developed and the part exposed to the laser beam is removed with an irregularity pattern of the photo-resist left on the glass plate, thereby obtaining a matrix. Then the surface of the matrix is plated 25 (electroforming), and a Ni substrate having a positive irregularity pattern is formed on the matrix and separated from

the matrix. The Ni substrate as it is may be used as a master information carrier or may be used as a master information carrier after forming a soft magnetic layer and a protective layer along the irregularity pattern as desired.

5 Otherwise, the matrix may be plated to form a second matrix and the second matrix may be plated to form a base sheet having a negative irregularity pattern. Further, a third matrix may be formed by plating the second matrix or pressing a resin syrup against the surface of the second matrix and
10 curing the resin syrup, and a base sheet having a positive irregularity pattern may be formed by plating the third matrix.

 Further, a matrix without photo-resist layer may be first formed by etching the glass plate with an irregularity pattern of the photo-resist to make holes in the glass plate, and a
15 base sheet may be formed by the use of the matrix in the manner described above.

 The substrate may be formed of metal such as Ni or Ni alloy as described above, and as the aforesaid plating for forming the metal substrate, various metal film forming
20 techniques such as electroless plating, electroforming, sputtering, and ion plating can be employed. The height of the protruding portion (the depth of the irregularity pattern) is preferably in the range of 50 to 800nm and more preferably 80 to 600nm. When the irregularity pattern represents sample
25 servo signals, each of the protruding portions is rectangle having longer sides in a radial direction of the substrate and

shorter sides in a circumferential direction of the same. When the irregularity pattern represents sample servo signals, each of the protruding portions is preferably 0.05 to 20 μm in the longer sides and 0.05 to 5 μm in the shorter sides.

5 The soft magnetic layer 3b may be formed on the irregularity pattern by various vacuum film forming techniques or plating method such as vacuum deposition, sputtering, ion plating and the like of magnetic material. The thickness of the soft magnetic layer 3b is preferably 50 to 500nm and more
10 preferably 80 to 300nm.

 It is preferred that a protective film such as of DLC (diamond-like carbon) be provided on the soft magnetic layer on the upper surface of the protruding portion. A lubricant layer may be further provided on the protective film. A
15 reinforcement layer such as a Si layer may be provided between the soft magnetic layer and the protective film to enhance the contact therebetween. The lubricant layer suppresses deterioration in durability of the soft magnetic layer, such as scores due to friction, which occurs in correcting for a
20 shift generated when the soft magnetic layer is brought into contact with the slave medium.

CLAIMS:

1. A master information carrier for magnetic transfer having on the surface thereof a concentric irregularity pattern representing information to be transferred to a disc-like magnetic recording medium, at least the top surface of the protruding portions of the irregularity pattern being formed of magnetic material, wherein the improvement comprises that

the irregularity pattern is formed so that the width L [nm] in a circumferential direction of a protruding portion at a distance R [nm] from the center satisfies the condition

$$L = \alpha(\omega \cdot \Delta T \cdot R), \quad 0.8 \leq \alpha \leq 1.4,$$

wherein ω represents in [rad/sec] the angular velocity of the magnetic recording medium when a signal is read out from the magnetic recording medium after the magnetic transfer and ΔT represents in [sec] a desired signal time width of a reproduction signal waveform in a magnetization transition region corresponding to an interval between the ends of the protruding portion in the circumferential direction.

2. A master information carrier as defined in Claim 1 wherein the cross-sectional shape of the protruding portion taken along a plane extending in a direction parallel to the direction of the track in perpendicular to the surface of the master information carrier is a rectangle or trapezoid and the width in a circumferential direction of a protruding portion, is the width in the direction of the track of the top surface

of the protruding portion.

3. A master information carrier as defined in Claim 1
wherein the cross-sectional shape of the protruding portion
taken along a plane extending in a direction parallel to the
5 direction of the track in perpendicular to the surface of the
master information carrier is a rectangle or trapezoid with
its upper portions cut away at the ends thereof, and the width
in a circumferential direction of a protruding portion is the
distance between the intersections of the extension of the
10 upper side of the rectangle or the trapezoid and the extensions
of the end lines of the rectangle or the trapezoid.