

MASTER DISC AND METHOD OF MANUFACTURING THE SAME

Technical Field of the Invention

The present invention relates to a master disc and a method of manufacturing the same, and more specifically to a master disc in which a servo signal used for positioning of a magnetic head is written by using a magnetic transfer technique, and a method of manufacturing the master disc.

Prior Art

At present, a magnetic disc using a magnetic film as a recording medium has been used in a hard disc drive (hereinafter referred to as HDD) which is mainly used as an external storage device for a computer. In the HDD, the recording/reproducing of a data is performed by a magnetic head. The magnetic head is floated from the surface of a rotating magnetic disc so as to be kept away from the surface of the magnetic disc at a distance of several tens nm by a floating mechanism called as a slider. Bit information on a magnetic disc is stored in data tracks arranged concentrically, and the magnetic head is moved and positioned to a target data track on the recording medium at a high speed to record/reproduce data.

Positioning signals (hereinafter referred to as servo

signal) are concentrically written on the magnetic disc to detect the relative position between the magnetic head and the data tracks. The magnetic head detects the position thereof at a fixed time interval. A servo signal is written on a magnetic disc by using a dedicated device called a servo writer, so that it is not deviated from the center of the magnetic disc or the center of the locus of the magnetic head after the magnetic disc is installed in HDD.

The recording density of the magnetic recording medium such as a magnetic disc or the like at the present developing stage reaches 100Gbis/in², and also the recording capacity thereof is increased every 60% per year. In connection with this, the servo signal for the positioning of the magnetic head has such a tendency that the recording density is increased and the writing time of the servo signal is increased year by year. The increase of the writing time of the servo signal becomes one of critical factors causing reduction in productivity of HDD and increase in cost.

As compared with the system of writing the servo signal by using the magnetic head of the servo writer as described above, the writing time of the servo signal is more rapidly shortened by collectively writing the servo signal through magnetic transfer (see Patent JP-A-2001-283433, for example).

Fig. 1 shows the principle of the conventional magnetic transfer technique, and Fig. 2 shows a magnetic transfer method for a conventional magnetic disc. The magnetic transfer is divided into an initial demagnetization step and a transfer pattern writing step.

Fig. 1(a) shows the initial demagnetization step. A magnetic core 14 having permanent magnet 15 is moved so as to be kept away from the surface of a magnetic disc 11 having a magnetic layer 13 on a substrate 12 at a fixed interval (1mm or less). Initially, the magnetic layer 13 formed on the substrate 12 is not set to such a state that it is magnetized in a fixed direction, however, it is magnetized in the fixed direction by magnetic field leaking from the gap 16 of the magnetic core 14. An arrow indicated in the magnetic layer 13 of the figure represents a magnetization direction.

Fig. 2(a) shows a movement path of the magnetic core 14. The magnetic layer 13 is uniformly magnetized in the circumferential direction. Fig. 2(b) shows a state that a magnetic transfer master disc (hereinafter referred to as master disc) 17 is disposed and positioned on the magnetic disc 11.

Fig. 1(b) shows the transfer pattern writing step. The

master disc 17 is has a structure that a soft magnetic layer 20 is embedded in a magnetic layer 19 on a silicon substrate 18. In the soft magnetic layer 20, a servo signal to be recorded in a magnetic recording medium is embedded as a magnetization pattern. The magnetic core 14 magnetizes the magnetic disc 11 in the opposite direction to the direction of the magnetic field in the initial demagnetization step through the master disc 17. At this time, magnetic field which leaks from the gap 16 and infiltrates into the master disc 17 reaches the magnetic disc 11 in areas having no soft magnetic layer 20 to magnetize the magnetic layer 13. On the other hand, in areas having the soft magnetic layer 20, the magnetic field passes through the soft magnetic layer 20 serving as a magnetic path having small magnetic resistance. New magnetization writing is not carried out in the areas having the soft magnetic layer 20.

Fig. 2(c) shows a movement path of the magnetic core 14. The master disc 17 is brought into close contact with the magnetic disc 11, and the magnetic core 14 is moved along the circumferential direction. The servo signal embedded as a magnetization pattern in the master disc 17 is transferred onto the magnetic disc 11 through magnetic transfer as described above.

Fig. 3 shows the format of the conventional servo signal. The servo signal comprises a servo AGC 31, a servo detection pattern 32, cylinder information 33, sector information 34 and servo burst information 35. The format of the servo signal will be described hereunder in detail.

(1) Servo AGC

A servo AGC (Automatic Gain Control) 31 is associated with an AGC circuit of an amplifier for amplifying a signal read out from a magnetic head. Normally, the AGC circuit of the amplifier operates ordinarily under the state that data are written in portions other than the servo signal. However, under the state that only the servo signal is written and no data are written, or under the state that the servo signal is read out immediately after the data are written, the gain of the amplifier is approximately kept to the maximum value, and thus it is impossible to read out the servo signal normally.

Therefore, a dibit pattern of all "1" bits, that is, a signal having a fixed frequency (hereinafter referred to as servo frequency) is first written in the servo signal. The gain of the amplifier is normally returned by reading out the servo AGC 31. A PLL (Phase Locked Loop) circuit for generating clocks to read out the servo signal is synchronized with the servo frequency. About 100bits are formed as the servo AGC 31.

(2) Servo Detection Pattern

This is a specific pattern to identify the servo signal.

(3) Servo Address Information

The servo address information comprises cylinder information 33 and sector information 34. Cylinder information of servo tracks is written in the cylinder information 33 while subjected to gray coding. HDD carries out the operation of positioning the head to a target track on the basis of the cylinder information 33 and reading out data written there or writing data there. The gray coding will be described later with reference to Fig. 4.

The sector information 34 is information relating to the sectors in the tracks. The sector is an area achieved by dividing a track into several hundreds parts, and it serves as a data recording/reproducing unit in HDD. A sector address is normally represented by binary numbers, and for example when 90 sectors are given on the whole periphery, the sector address has 7-bit length.

(4) Servo Burst Information

The servo burst information 35 is information to position the magnetic head on a target track after the magnetic head is moved to the target track. In general, the

magnetic head is positioned to the center of the target track by comparing the signal amplitude of signals deviated in phase by 180° . The patter shown in Fig. 3 is a burst pattern in which A, B, C and D are deviated in phase in one track width.

Fig. 4 shows the gray coding of the conventional cylinder information. Fig. 4(a) shows a binary gray code conversion rule of 4 bits. Fig. 4(b) shows a gray code conversion rule in the cylinder information of 19 bits. Only variation of one bit is made between neighboring cylinders by the gray coding. Accordingly, even if any one bit is erroneously read out when the cylinder information is read out by the magnetic head, the magnetic head is prevented from accessing a completely different position.

For example, the recording range of a 3.5-inchi type magnetic recording medium is equal to about 29,000 tracks per surface when the radius is set to 17.85 to 47.00 mm and the track width is set to $0.1\mu\text{m}$. When three double-side recordable magnetic recording media are used in HDD, the total number of cylinders is equal to $2 \times 3 \times 29,000 = 174,000$, and it corresponds to 18 bits. When the servo bit length at the radius of 17.85mm is set to $0.1\mu\text{m}$, the total servo bit length is equal to $1.8\mu\text{m}$ and the servo bit length at the radius of 23.5mm is set to $0.13\mu\text{m}$, the total servo bit length is equal

to $2.4\mu\text{m}$. This means that a section in which "0" or "1" continues exists over the length corresponding to the total servo bit length in a specific servo pattern.

A data pattern exists in the magnetic recording medium in addition to the pattern of the servo signal described above. The data pattern is recorded by using an RLL (Run Length Limited) code. The RLL code will be described hereunder. The RLL code is represented by using as parameters the minimum magnetization inverted interval : d , the maximum magnetization inverted interval : k , the bit length of original data : m , and the bit length after modulation : n . Fig. 5 shows a conversion rule of an RLL 1-7 code of $d=1$, $k=7$. The RLL 1-7 code means that the minimum and maximum values of the magnetization inverted interval are equal to 1 and 7 respectively, the data sequence of 2 bits is converted to 3 bits in principle and the data sequence of specific 4 bits is converted to 6 bits.

Fig. 6 shows a conversion example of the data sequence on the basis of the conventional RLL 1-7 code. The RLL 1-7 code is designed so that one "0" at minimum and seven "0" at maximum exists between "1" and "1", and "0" or "1" does not continue over a long section. Since the data bit length is set to $0.1\mu\text{m}$, a section in which "0" or "1" continues is equal to

0.7 μ m.

Problem to be solved by the Invention

In the case where the servo signal is written by magnetic transfer, as described above in the 3.5-inch type magnetic recording medium, the magnetic transit interval of the servo address information, that is, the section where "0" or "1" continues covers a broad range from the data bit length of 0.1 μ m to the total servo bit length of 2.4 μ m, which corresponds to about 24 times.

Fig. 7 shows variation in magnetic flux density of the magnetic layer when the length and period of the soft magnetic layer are varied. As shown in Fig. 7(a), a case where the length W of the soft magnetic layer 20 is equal to 0.7 μ m and the interval P is equal to 1.4 μ m is shown in Fig. 7(b), and a case where the length W is equal to 2.0 μ m and the interval P is equal to 4.0 μ m is shown in Fig. 7(c). As a calculation result, the magnetic flux density at the lower portion of the soft magnetic layer 20 is larger in the case of W=2.0 μ m and P=4.0 μ m. Ideally, the magnetic flux density of the magnetic layer 13 of the magnetic disc 11 at the lower portion of the soft magnetic layer 20 is preferably equal to zero. If the length W of the soft magnetic layer 20 is increased and the interval P of the soft magnetic layer 20 is increased, the magnetic flux

of the recording magnetic field flowing into the soft magnetic layer 20 is increased, and the magnetic flux density of the soft magnetic layer 20 is increased, so that the magnetic flux density exceeds the saturated magnetic flux density of the soft magnetic layer 20, and the magnetic field leaks into the magnetic layer 13 of the magnetic disc 11.

Fig. 8 shows variation in magnetic saturation point at the lower portion of the soft magnetic layer when the length and period of the soft magnetic film are varied. It is apparent that magnetic field leaks due to magnetic saturation. On the other hand, the magnetic flux density in the gap between the two soft magnetic layers 20 is smaller in the case of $W=2.0\mu\text{m}$ and $P=4.0\mu\text{m}$. This is because under the state that the interval between the two soft magnetic layers 20 is large, the magnetic fluxes passing through the soft magnetic layers 20 pass nearer to the magnet side, so that the magnetic flux density in the magnetic layer 13 of the magnetic disc 11 is reduced.

As shown in Fig. 1, the magnetic transfer is carried out in both the initial demagnetization step and the transfer pattern writing step. In order to surely carry out the magnetic transfer on the whole surface of the magnetic disc, it is necessary to reduce the leak magnetic flux density at the lower portion of the soft magnetic layer and increase the magnetic

flux density between the soft magnetic layer and the soft magnetic layer. As shown in Figs. 7, 8, when the length of the soft magnetic layer is increased and the interval is also increased, the leak magnetic flux density at the lower portion of the soft magnetic layer is increased, and the magnetic flux density is reduced between the soft magnetic layers. As a calculation example, the difference corresponds to about three times in the length W of the soft magnetic layer and twice in the interval. However, when the magnetic transit interval of the servo address information covers a broad range of about 24 times, this tendency is further remarkable. That is, there locally appears a place which is not subjected to magnetization inversion, and thus it is difficult to carry out the magnetic transfer stably.

The present invention has been implemented in view of the foregoing problem, and has an object to provide a master disc and a method of manufacturing the master disc which can carry out magnetic transfer with high reliability by shortening the magnetic transit interval.

Means of solving the Problem

In order to attain the above object, according to the invention of claim 1, there is provided a master disc in which a servo signal to be recorded in a magnetic recording medium

is embedded as a magnetization pattern, characterized in that an area for registering information indicating a start position for inverting or non-inverting data of the servo address information is equipped between a servo detection pattern and servo address information in the servo signal, and when a section in which data continue exceeds a predetermined section in the data sequence of the servo address information, data at a subsequent portion to an exceeding position are inverted or non-inverted, and the exceeding position is registered as the start position in the area.

According to the above construction, magnetic transfer can be performed with high reliability by shortening a magnetic transit interval of the servo address information, that is, a section in which data of "0" or "1" continue.

According to the invention of claim 2, there is provided a method of manufacturing a master disc in which a servo signal to be recorded in a magnetic recording medium is embedded as a magnetization pattern and that has an area for registering information indicating a start position for inverting or non-inverting data of the servo address information which is equipped between a servo detection pattern and servo address information in the servo signal, characterized in that when a section in which data continue exceeds a predetermined

section in the data sequence of the servo address information, data at a subsequent portion to an exceeding position are inverted, and the exceeding position is registered as the start position for inversion in the area, and when a data-continuing section exceeds a predetermined section again, the data of a subsequent portion to the exceeding position are non-inverted, and the exceeding position is registered as a start position for non-inversion in the area.

According to the invention of claim 3, there is provided a master disc in which a servo signal to be recorded in a magnetic recording medium is embedded as a magnetization pattern, characterized in that an area for registering information indicating a start position for inverting data of the servo address information and the number of inverted bits is equipped between a servo detection pattern and servo address information in the servo signal, when a data-continuing section exceeds a predetermined section in the data sequence of the servo address information, data at a subsequent portion to the exceeding position are inverted or non-inverted, and the data-inverted exceeding position is registered as a start position for the inversion in the area while the number of bits from the data-inverted exceeding position to the data-non-inverted exceeding position is registered as the inverted bit number in the area.

According to the invention of claim 4, there is provided a method of manufacturing a master disc in which a servo signal to be recorded in a magnetic recording medium is embedded as a magnetization pattern, and that has an area for registering information indicating a start position for inverting data of the servo address information and the number of inverted bits which is equipped between a servo detection pattern and servo address information in the servo signal, characterized in that when a data-continuing section exceeds a predetermined section in the data sequence of the servo address information, data at a subsequent portion to the exceeding position are inverted, and the data-inverted exceeding position is registered as a start position for the inversion in the area, and when a data-continuing section exceeds a predetermined section again, data at a subsequent portion to the exceeding position are non-inverted and the number of bits from the data-inverted exceeding position to the data-non-inverted exceeding position is registered as the inverted bit number in the area.

Brief Description of the Drawings

Fig. 1 is a diagram showing the principle of a conventional magnetic transfer technique, wherein (a) shows an initial demagnetizing step, and (b) shows a transfer pattern writing step.

Fig. 2 is a diagram showing a magnetic transfer method for a conventional magnetic disc.

Fig. 3 is a diagram showing the format of a conventional servo signal.

Fig. 4 is a diagram showing gray coding of conventional cylinder information.

Fig. 5 is a diagram showing a conversion rule of conventional RLL1-7 code.

Fig. 6 is a diagram showing a conversion example of a data sequence based on the conventional RLL1-7 code.

Fig. 7 is a diagram showing variation of magnetic flux density in a magnetic layer when the length and period of a soft magnetic layer are varied.

Fig. 8 is a diagram showing variation of a magnetic saturation point at the lower portion of a soft magnetic layer when the length and period of the soft magnetic film are varied.

Fig. 9 is a diagram showing the format of a servo signal according to an embodiment of this invention.

Fig. 10 is a diagram showing cylinder information according to the embodiment of the present invention.

Fig. 11 is a diagram for explaining data inversion location information according to the first embodiment of this invention.

Fig. 12 is a diagram for explaining data inversion

location information according to a second embodiment of this invention.

Embodiment of the Invention

An embodiment according to the present invention will be described in detail with reference to the drawings. A magnetic recording medium according to this invention is newly equipped with an area for registering information indicating a start position to invert or non-invert the data of servo address information as data inversion location information between a servo detection pattern and the servo address information.

When a section where the data of "0" or "1" continues exceeds a predetermined section in the data sequence of the servo address information, the data at the subsequent portion to the exceeding position are inverted. In addition to the inversion, the exceeding position is registered as a data inversion start position in the data inversion location information. When the section where "0" or "1" continues exceeds a predetermined section again, the data at the subsequent portion to the exceeding position are non-inverted. In addition to the non-inversion, the exceeding position is registered as a data non-inversion start position in the data inversion location information.

Likewise, the data inversion and non-inversion are repeated until the rear end of the servo address information to form a servo signal. In the manner as described above, the section where the data of "0" or "1" continues is prevented from exceeding a predetermined section, that is, a magnetic transit interval is prevented from exceeding a predetermined interval. On the other hand, plan reproduction is carried out by using a magnetic head, the data inversion location information is read out and an indicated portion of the servo address information reproduced is inverted or non-inverted.

Fig. 9 shows the format of the servo signal according to one embodiment of the present invention. The servo signal comprises a servo AGC 91, a servo detection pattern 92, servo address information containing cylinder information 93 and sector information 94 and servo burst information 95. Further, an area for data inversion location information 96 indicating the inversion position of the servo address information is equipped between the servo detection pattern 92 and the cylinder information 93.

Fig. 10 shows cylinder information according to another embodiment of this invention. Fig. 10(a) shows a result achieved by subjecting 18-bit cylinder information to gray coding. In cylinder ID: 0 to 15, the state of "0" exceeds 7 bits. Fig. 10(b)

shows a result achieved by inverting the data sequence of the cylinder information. That is, by inverting the data of the seventh and subsequent bits, the sections in which the state of "0" continues are limited to 7 bits or less (from zero-th bit to sixth bit).

Then, with respect to the cylinder ID: 0 to 7, the bits at the fourteenth bit is subjected to non-inversion so that the sections in which the state of "1" continues are limited to 7 bits or less (from the seventh bit to thirteenth bit). Furthermore, with respect to the cylinder ID: 8 to 15, if the bits at the fourteenth bit is subjected to non-inversion, the state of "1" would exceeds 7 bits, and thus the bits at the fourteenth and subsequent bits are left inverted.

Here, when each of the inversion and non-inversion of data is set as a unit, the data inversion location information is 7 (inversion) and 14 (non-inversion) in the cylinder ID : 0 to 7, and 7 (inversion) and 14 (non-inversion) and 14 (inversion) in the cylinder ID : 8 to 15.

Next, the data inversion location information will be described. Fig. 11 shows data inversion location information according to a first embodiment of this invention. It alternately shows the exceeding position (inversion start

position) at which a data-continuing section exceeds a predetermined section, and an exceeding position (non-inversion start position) at which a data-continuing section exceeds a predetermined section again. When the cylinder information comprises 18 bits and the sector information comprises 7 bits, it is totally equal to 25 bits. Representing a bit position as an address, it corresponds to 5 bits. Since three inversion positions and two non-inversion positions are needed at maximum, totally 25 bits are needed. Furthermore, assuming that a sectioning code of 4 bits of "0110" is inserted every 5 bits in consideration of the 7-bit restriction for sectioning of the data inversion location and magnetic transfer, the area of the data inversion location information has totally 45 bits.

Fig. 12 shows data inversion location information according to a second embodiment of this invention. Start positions of the data inversion and the bit number of inversion sections are shown. An exceeding position (inversion start position) at which a data-continuing section exceeds a predetermined section, and the number of inverted bits achieved by calculating the number of bits from the exceeding position for the inversion to the exceeding position for the non-inversion on the basis of an exceeding position (non-inversion start position) at which a

data-continuing section exceeds a predetermined section again, are registered in the data inversion location information.

As explained with referring to Fig. 7, as the interval of the soft magnetic layer is increased, the magnetic flux density exceeds the saturated magnetic flux density of the soft magnetic layer, and thus the magnetic field leaks into the magnetic layer of the magnetic recording medium. Under this magnetic field, the magnetic field intensity needed for magnetic inversion runs short, so that a servo signal reproduced contains a sub pulse and thus a bit error occurs. According to this embodiment, the section in which "0" or "1" continues is prevented from exceeding 7 bits, so that occurrence of sub pulse due to leakage of magnetic field can be suppressed, and a magnetic pattern of a soft magnetic layer embedded in a master disc can be accurately transferred to a magnetic disc.

Advantageous Effect of the Invention

As described above, according to this invention, the magnetic transit interval of the servo address information, that is, the section in which data of "0" or "1" continues can be shortened, so that magnetic transfer can be performed with high reliability.

CLAIMS

1. A master disc in which a servo signal to be recorded in a magnetic recording medium is embedded as a magnetization pattern, characterized in that an area for registering information indicating a start position for inverting or non-inverting data of the servo address information is equipped between a servo detection pattern and servo address information in the servo signal, and when a section in which data continue exceeds a predetermined section in the data sequence of the servo address information, data at a subsequent portion to an exceeding position are inverted or non-inverted, and the exceeding position is registered as the start position in the area.

2. A method of manufacturing a master disc in which a servo signal to be recorded in a magnetic recording medium is embedded as a magnetization pattern and that has an area for registering information indicating a start position for inverting or non-inverting data of the servo address information which is equipped between a servo detection pattern and servo address information in the servo signal, characterized in that when a section in which data continue exceeds a predetermined section in the data sequence of the servo address information, data at a subsequent portion

to an exceeding position are inverted, and the exceeding position is registered as the inverting start position in the area, and when a data-continuing section exceeds a predetermined section again, the data of a subsequent portion to the exceeding position are non-inverted, and the exceeding position is registered as a start position for non-inversion in the area.

3. A master disc in which a servo signal to be recorded in a magnetic recording medium is embedded as a magnetization pattern, characterized in that an area for registering information indicating a start position for inverting data of the servo address information and the number of inverted bits is equipped between a servo detection pattern and servo address information in the servo signal, when a data-continuing section exceeds a predetermined section in the data sequence of the servo information, data at a subsequent portion to the exceeding position are inverted or non-inverted, and the data-inverted exceeding position is registered as a start position for the inversion in the area while the number of bits from the data-inverted exceeding position to the data-non-inverted exceeding position is registered as the inverted bit number in the area.

4. A method of manufacturing a master disc in which a

servo signal to be recorded in a magnetic recording medium is embedded as a magnetization pattern, and that has an area for registering information indicating a start position for inverting data of the servo address information and the number of inverted bits which is equipped between a servo detection pattern and servo address information in the servo signal, characterized in that when a data-continuing section exceeds a predetermined section in the data sequence of the servo address information, data at a subsequent portion to the exceeding position are inverted, and the data-inverted exceeding position is registered as a start position for the inversion in the area, and when a data-continuing section exceeds a predetermined section again, data at a subsequent portion to the exceeding position are non-inverted and the number of bits from the data-inverted exceeding position to the data-non-inverted exceeding position is registered as the inverted bit number in the area.