

[Designation of Document] Specification

[Title of the Invention]

GLASS SUBSTRATE FOR MAGNETIC RECORDING MEDIUM AND MAGNETIC
RECORDING MEDIUM

5 [Technical Field]

[0001]

The present invention relates to a glass substrate for a magnetic recording medium and a magnetic recording medium.

[Background Art]

10 [0002]

Aluminum alloy substrates have hitherto been used as substrates for magnetic recording media to be used for magnetic recording devices and the like. However, with a demand for high density recording, glass substrates have become mainstream, which are hard as compared with the aluminum alloy substrates and excellent in flatness
15 and smoothness.

[0003]

With recent realization of higher recording density and high speed rotation of the magnetic recording media, a phenomenon has come to occur more frequently than ever before in which magnetic heads lose sight of servo information in which
20 radius/track position information of the magnetic recording media is recorded to generate read/write errors.

[0004]

The generation of such errors has been considered to be caused by a mechanical vibration due to the occurrence of disk fluttering associated with a
25 narrowing of the track width involved in high recording density and associated with high speed rotation.

[0005]

For this reason, in order to suppress the generation of such errors, it has been conducted to suppress the occurrence of fluttering, for example, by using materials having a high specific modulus as materials of the glass substrates for magnetic recording media. The specific modulus means the value obtained by dividing the Young's modulus by the density of the glass, and the value serving as a guideline for representing characteristics of light weight and high strength or light weight and scarce deformability. This is hereinafter also referred to as the specific Young's modulus.

[0006]

Further, Patent Document 1 describes a method for producing a glass substrate for a magnetic disk which decreases errors of servo information recorded in a magnetic recording medium when used as a hard disk by selecting a glass substrate for a magnetic recording medium having symmetry in a thickness direction within a predetermined range.

[Background-Art Documents]

[Patent Documents]

[0007]

Patent Document 1: JP-A-2010-277679

[Summary of the Invention]

[Problems that the Invention is to Solve]

[0008]

As described above, the methods for suppressing the generation of errors of the magnetic recording media have hitherto been studied. However, the generation of errors can not be sufficiently suppressed, and there is still a problem of generating errors when used as the magnetic recording media.

[0009]

In view of the problems of the above-mentioned prior art, it is therefore an object of the present invention to provide a glass substrate for a magnetic recording medium, having a low incidence of errors when used as the magnetic recording medium.

5 [Means for Solving the Problems]

[0010]

In order to solve the above-mentioned problem, the present invention provides a glass substrate for a magnetic recording medium, wherein when an absolute value of a difference between

10 a flatness determined by supporting both diametrically opposing edge portions of the glass substrate for a magnetic recording medium from an underside surface thereof, applying a load on an upper surface of a central portion of the glass substrate for a magnetic recording medium for 48 hours, followed by removing the load, and performing measurement at a time when 5 hours have elapsed since the removal of the
15 load, and

a flatness before applying the load

is defined as an anelasticity deformation amount A, the anelasticity deformation amount A is 4.2 μm or less.

[Advantages of the Invention]

20 [0011]

The invention provides the glass substrate for a magnetic recording medium, which can return to its original form within a predetermined period of time even when deformed by application of a load to the magnetic recording medium. Accordingly, even when the magnetic recording medium is packaged and fixed in a cassette to cause
25 deformation of the glass substrate for a magnetic recording medium in shipping, the glass substrate returns to its original form until the time when servo information is

written therein, and the servo information can be recorded at a suitable position of the magnetic recording medium. It becomes therefore possible to suppress the generation of subsequent errors (read/write errors).

[Brief description of the drawings]

5 [0012]

Fig. 1 is a diagram for illustrating a measuring flow of an anelasticity deformation amount in a first embodiment according to the invention.

Figs. 2(a) and 2(b) show views for illustrating a load application process in measuring an anelasticity deformation amount in a first embodiment according to the
10 invention.

[Modes for Carrying Out the Invention]

[0013]

Embodiments for carrying out the invention will be described below with reference to the drawings. However, the invention should not be construed as being
15 limited to the following embodiments, and various modifications and substitutions can be made thereto without departing from the scope of the invention.

[0014]

[First Embodiment]

In this embodiment, a glass substrate for a magnetic recording medium of the
20 invention will be described.

[0015]

The inventors of the invention have studied causes for the generation of readout errors in the magnetic recording medium even when a material having a high specific modulus is used as a material of the glass substrate for a magnetic recording
25 medium. The specific modulus means the value obtained by dividing the Young's modulus by the density of the glass, and the value serving as a guideline for

representing characteristics of light weight and high strength or light weight and scarce deformability. This is hereinafter also referred to as the specific Young's modulus. As a result, it has been found that one of the causes is that when the magnetic recording medium is deformed in a transportation step, the servo information is written therein
5 before the deformation is sufficiently recovered, thus leading to completion of the invention.

[0016]

In general, the magnetic recording medium obtained by forming a magnetic layer and the like on a surface of the glass substrate for a magnetic recording medium is
10 put in a cassette so as not to contact with another magnetic recording medium, further put in a packaging container under reduced pressure, and shipped and transported to a plant for the manufacture of hard disk drives. When the magnetic recording medium is transported, the magnetic recording medium is further put in the packaging container (packing) under reduced pressure although it is put in the cassette. Accordingly, the
15 magnetic recording medium may be deformed by application of a load.

[0017]

Then, after transportation to the plant for the manufacture of hard disk drives, the magnetic recording medium is taken out of the cassette, and assembled to a hard disk drive. The servo information is written therein, followed by subjecting to a
20 read/write test.

[0018]

When the magnetic recording medium is deformed by applying the load at the time of transportation as described above, the load is removed by taking it out of the cassette. Accordingly, the magnetic recording medium gradually returns to its original
25 form during this step.

[0019]

Usually, the servo information is written in the magnetic recording medium after about 5 to 12 hours after being taken out of the cassette. However, when the magnetic recording medium does not sufficiently return to its original form at this stage, a position in which the servo information has been written is thereafter displaced. For this reason, the position in which the servo information has been written deviates to cause the generation of errors.

[0020]

Further, causes for the generation of readout errors in the magnetic recording medium have been studied. As a result, it has been revealed that the speed at which the magnetic recording medium returns to its original form depends on the anelasticity deformation amount of the glass substrate for a magnetic recording medium, because the magnetic recording medium is obtained by forming the magnetic layer and the like on the surface of the glass substrate for a magnetic recording medium.

[0021]

The invention intends to surely suppress the generation of readout errors in the magnetic recording medium obtained by forming the magnetic layer and the like on the surface of the glass substrate for a magnetic recording medium, by adjusting the anelasticity deformation amount A of the glass substrate for a magnetic recording medium to 4.2 μm or less.

[0022]

Both opposing edge portions of the glass substrate for a magnetic recording medium are supported from an underside surface thereof, and a load is applied on an upper surface of a central portion (central region including the center) of the glass substrate for a magnetic recording medium for 48 hours, followed by removing the load. The anelasticity deformation amount A as used herein is the absolute value of the

difference between the flatness at the time when 5 hours have elapsed since the removal of the load and the flatness before applying the load.

[0023]

Here, when the anelasticity deformation amount A is measured, the load is applied to the glass substrate for a magnetic recording medium for 48 hours. This is based on the time generally taken from packaging and shipping of the magnetic recording medium to opening of the package for assembling of the hard disk drive. Further, in the case where the anelasticity deformation amounts A to C described later are measured, it has been confirmed that changes in flatness are saturated at the time when the load is applied for about 16 hours for all glass substrates. For this reason, the load has been applied for 48 hours from the viewpoint that the changes in flatness are saturated to cause no changes in flatness even by longer application of the load.

[0024]

Further, the flatness after 5 hours after the removal of the load is used for comparison, because the time taken from the opening of the package of the magnetic recording medium to writing of the servo information therein is usually about 5 to 12 hours. In order to suppress errors, the glass substrate for a magnetic recording medium is required to return to its original form during this period of time to such a degree that subsequent displacement does not pose a problem.

[0025]

The value of the anelasticity deformation amount A may be any as long as it is a value allowable even when the glass substrate for a magnetic recording medium is displaced after the servo information has been recorded, and the value of the anelasticity deformation amount A is 4.2 μm or less as described above. The anelasticity deformation amount A is preferably 4.0 μm or less, more preferably 3.5 μm or less, and particularly preferably 3.0 μm or less. Incidentally, the lower limit value of the

anelasticity deformation amount A is 0 μm . The same can be said for the other anelasticity deformation amounts B and C.

[0026]

Further, the both opposing edge portions of the glass substrate for a magnetic recording medium are supported from an underside surface thereof, and a load is applied on an upper surface of a central portion (central region including the center) of the glass substrate for a magnetic recording medium for 48 hours, followed by removing the load. The absolute value of the difference between the flatness at the time when 5 hours have elapsed since the removal of the load and the flatness at the time when 48 hours have elapsed since the removal of the load is defined as the anelasticity deformation amount B. In this case, a magnetic recording medium of 3.0 μm or less in the anelasticity deformation amount B may be preferable.

[0027]

The anelasticity deformation amount B means a deformation amount between the time when 5 hours have elapsed since the removal of the load and the time when 48 hours have elapsed since the removal of the load. For this reason, the lower value thereof means the smaller amount of displacement after the servo information has been written in the magnetic recording medium at the time when 5 hours have elapsed since the removal of the load.

[0028]

Accordingly, the amount of displacement after the servo information has been written in the magnetic recording medium is decreased by allowing the anelasticity deformation amount B to meet the above-mentioned requirement, and it becomes possible to suppress the generation of errors more when used as the magnetic recording medium.

[0029]

The value of the anelasticity deformation amount B may be any as long as it is a value allowable when reading and writing of data are performed after the servo information has been written in the magnetic recording medium, and as described above, it is preferably 3.0 μm or less. The anelasticity deformation amount B is more preferably 2.5 μm or less, and particularly preferably 2.0 μm or less.

[0030]

Furthermore, the both opposing edge portions of the glass substrate for a magnetic recording medium are supported from an underside surface thereof, and a load is applied on an upper surface of a central portion (central region including the center) of the glass substrate for a magnetic recording medium for 48 hours, followed by removing the load. The flatness at the time when 5 hours have elapsed since the removal of the load is defined as an anelasticity deformation amount C, which is preferably 5.5 μm or less.

[0031]

The smaller value of the anelasticity deformation amount C shows the smaller flatness at the time when 5 hours have elapsed since the removal of the load. The glass substrate for a magnetic recording medium satisfying such a parameter shows that the deformation amount is small, despite the application of the load for 48 hours, and/or that the flatness is recovered at the time when 5 hours have elapsed since the removal of the load. Accordingly, even when the servo information is written in the magnetic recording medium at the time when 5 hours have elapsed since the removal of the load, the amount of subsequent deformation of the glass substrate for a magnetic recording medium is small, and it becomes possible to suppress the generation of errors.

[0032]

Methods for measuring the above-mentioned anelasticity deformation amounts A to C will be described with reference to Figs. 1 and 2.

[0033]

Incidentally, in the following description, in Fig. 1, the flatness at each time is expressed as $F(x \text{ h})$. In the formula, x represents the elapsed time from the removal of the load, on the basis of the time (0 h) when the load is removed. Further, the time before the load is removed is expressed by minus. For example, therefore, $F(-48 \text{ h})$ shows the flatness before 48 hours from the removal of the load, that is to say, the flatness of the glass substrate for a magnetic recording medium before the load is applied.

[0034]

10 First, a flow of measurement of the anelasticity deformation amount will be described using Fig. 1.

[0035]

In the measurement, the flatness $F(-48 \text{ h})$ of the glass substrate for a magnetic recording medium is first measured before the load is applied, as shown in Fig. 1 (the point of (1) in Fig. 1). Thereafter, the load is applied to the glass substrate for a magnetic recording medium for 48 hours by a method described later. This is because the time taken from packaging and shipping of the magnetic recording medium to the opening of the package is about 48 hours in a common hard disk drive assembling step. Further, as described above, it has been confirmed that changes in flatness are saturated at the time when the load is applied for about 16 hours for all glass substrates (the glass substrates are completely deformed). For this reason, the load has been applied for 48 hours from the viewpoint that the changes in flatness are saturated to cause no changes in flatness even by the longer application of the load.

[0036]

25 After 48 hours have elapsed, the load is removed (the point of (2) in Fig. 1), and the flatness is measured again (the point of (3) in Fig. 1) at the time when 5 hours

have elapsed since the removal of the load. This has been defined as F(5 h). This is because the time taken from the opening of the package of the magnetic recording medium to the writing of the servo information therein is usually about 5 to 12 hours in the hard disk drive assembling step.

5 [0037]

Further, the flatness at the time when 48 hours have elapsed since the removal of the load is measured (the point of (4) in Fig. 1), and this has been defined as F(48 h). This is because the read/write test is performed at the time when about 48 hours have elapsed since the opening of the package in the common hard disk drive assembling
10 step.

[0038]

Then, as described above, the anelasticity deformation amount A is calculated as the absolute value of the difference between the flatness F(-48 h) before applying the load and the flatness F(5 h) at the time when 5 hours have elapsed since the removal of
15 the load, and represented by the following equation:

$$(\text{Anelasticity deformation amount A}) = |F(5 \text{ h}) - F(-48 \text{ h})|$$

The smaller value of the anelasticity deformation amount A shows that the glass substrate for a magnetic recording medium returns closer to its original form (flatness), from the deformation generated by applying the load thereto.

20 [0039]

Further, as described above, the anelasticity deformation amount B is calculated as the absolute value of the difference between the flatness at the time when 5 hours have elapsed since the removal of the load and the flatness at the time when 48 hours have elapsed since the removal of the load, and represented by the following
25 equation:

$$(\text{Anelasticity deformation amount B}) = |F(5 \text{ h}) - F(48 \text{ h})|$$

The anelasticity deformation amount C indicates the flatness at the time when 5 hours have elapsed since the removal of the load. This is therefore represented by the following equation:

$$(\text{Anelasticity deformation amount } C) = F(5 \text{ h})$$

5 A means to measure the flatness of the glass substrate for a magnetic recording medium is not particularly limited. For example, it can be measured by a phase-measuring interference method (phase shift method).

[0040]

Then, a method for applying the load to the glass substrate for a magnetic
10 recording medium in measuring the anelasticity deformation amount will be described below.

[0041]

When the load is applied to the glass substrate for a magnetic recording medium, the both diametrically opposing edge portions of the glass substrate for a
15 magnetic recording medium are supported from an underside surface thereof, and the load is vertically applied on an upper surface of the central portion including the center of the glass substrate for a magnetic recording medium.

[0042]

A specific example will be described using Figs. 2(a) and 2(b).

20 [0043]

Figs. 2(a) and 2(b) show an example in which a load is applied to a glass substrate for a magnetic recording medium in order to measure the anelasticity deformation amount. Fig. 2(a) shows a transverse side view, and Fig. 2(b) shows a top view.

25 [0044]

As shown in Figs. 2(a) and 2(b), in order to support both edge portions of the glass substrate for a magnetic recording medium, a V-shaped block 11 is used, and the glass substrate 13 for magnetic recording medium and the load (weight) 15 are disposed thereon to apply the load to the glass substrate.

5 [0045]

The V-shaped block 11 has a V-shaped cut portion 12 at a central portion thereof. Then, the glass substrate 13 for magnetic recording medium is disposed so as to cover the V-shaped cut portion 12, thereby being able to support only the both edge portions 14 from an underside surface. Incidentally, a member for supporting the glass
10 substrate for a magnetic recording medium is not limited to the V-shaped block, and may be any as long as the both edge portions 14 of the glass substrate for a magnetic recording medium can be supported. For example, two square pole-shaped blocks may be spaced at a predetermined interval in such a manner that the both edge portions 14 of the glass substrate for a magnetic recording medium can be supported.

15 [0046]

In this case, the both edge portions (supporting portions) 14 which come into contact with the V-shaped block and provided on two places of both diametrically opposing edges for supporting the glass substrate for a magnetic recording medium are each enclosed by a chord 141 (142) and an arc. Then, the chord 141 and the chord 142
20 are edge portions of the cut portions of the V-shaped block, and are parallel to each other. The maximum value of the distance between the chord and the arc, namely, W1 in Figs. 2(a) and 2(b), is preferably the length of 2.3 to 7.7% of the diameter of the glass substrate for a magnetic recording medium, and more preferably the length of 3.0 to 4.6% of the diameter. This is because when the range of the supporting portion is too
25 narrow, there is a possibility that the glass substrate for a magnetic recording medium slips down to cause breakage in the case where the load is applied, whereas when it is

too wide, the distance from a load portion becomes short, and changes in flatness become difficult to occur, resulting in low resolution of measurement.

[0047]

The load is not particularly limited, as long as the load can be applied to the
5 central portion including the center of the glass substrate for a magnetic recording medium, and particularly, the arrangement thereof and the weight of the load are not limited.

[0048]

For example, as shown in Figs. 2(a) and 2(b), this can be performed by
10 disposing a rectangular parallelepiped load (weight) on the central portion of the glass substrate for a magnetic recording medium. In this case, it is preferred that the load is disposed in parallel to the chords 141 and 142 forming the both edge portions for supporting the above-mentioned glass substrate for a magnetic recording medium. Further, it is preferred that the load is disposed so as to cover all the width (range) of the
15 glass substrate for a magnetic recording medium, which has a constant length from a center line parallel to the chords 141 and 142, as shown in Fig. 2(b). For example, as the load (weight), there can be used a rectangular parallelepiped in which the width thereof, namely, the length of W2 in Fig. 2(a) and 2(b), is preferably 35 to 80% and more preferably 55 to 75% of the diameter of the glass substrate for a magnetic
20 recording medium.

[0049]

This is because, for example, when the range to which the load is applied is too narrow, there is a possibility that the glass substrate for a magnetic recording medium is broken by concentration of the load to the narrow range, falling of the destabilized load
25 and the like, and because when the range to which the load is applied is too wide, the

distance from the load portion becomes short, and changes in flatness become difficult to occur, resulting in low resolution of measurement.

[0050]

The longitudinal length of the load (weight) is preferably the same as or longer
5 than the diameter of the glass substrate for a magnetic recording medium, as described above.

[0051]

The weight of the load is not particularly limited, as long as it is within the range in which deformation due to anelasticity sufficiently occurs and the glass
10 substrate for a magnetic recording medium is not broken. It can be selected according to the area, strength or the like of the glass substrate for a magnetic recording medium to be used.

[0052]

For example, it can be selected so as to give a weight of 0.233 gf (2.28 mN) per
15 1 mm² of a main surface of the glass substrate for a magnetic recording medium. That is to say, the weight calculated by (the area of the main surface of the glass substrate for a magnetic recording medium) mm² × 0.233 gf/mm² (2.28 mN/mm²) can be applied. For example, in the case of the glass substrate for a magnetic recording medium (2.5-inch glass substrate for a magnetic recording medium) having an outer diameter of 65
20 mm and an inner diameter (a diameter of a circular hole at a central portion) of 20 mm, the load having a weight of 700 gf (6.86 N) is applied to the upper surface of the central portion of the glass substrate for a magnetic recording medium.

[0053]

The glass substrate for a magnetic recording medium of the invention can be
25 manufactured by a method including the following steps 1 to 4:

(Step 1) A shape-forming step of processing a glass sheet to a disk-shaped glass substrate having a circular hole at a central portion thereof and thereafter chamfering an inner peripheral surface and an outer peripheral surface thereof;

(Step 2) A peripheral surface polishing step of polishing the peripheral surfaces
5 (inner peripheral surface and outer peripheral surface) of the glass substrate;

(Step 3) A main surface polishing step of polishing main surfaces of the glass substrate; and

(Step 4) A cleaning step of cleaning and drying the glass substrate.

[0054]

10 Then, the glass substrate for a magnetic recording medium obtained by the manufacturing method including the above-mentioned respective steps is further subjected to a step of forming a thin film such as a magnetic layer thereon, thereby being able to obtain the magnetic recording medium.

[0055]

15 The shape-forming step of (step 1) used herein is a step of processing the glass sheet formed by a float process, a fusion process, a press molding process, a drawdown process or a redraw process to the disk-shaped glass substrate having the circular hole at the central portion thereof. Incidentally, the glass sheet to be used is not particularly limited, as long as the glass substrate for a magnetic recording medium obtained by
20 processing satisfies the above-mentioned anelasticity deformation amount. For example, the glass sheet may be amorphous glass, crystallized glass or strengthened glass having a compressive stress layer (strengthening layer). It is preferred that the glass substrate has a high specific modulus (specific Young's modulus). For example, the specific modulus is preferably 29 GPa·cm³/g or more, and more preferably 30
25 GPa·cm³/g or more.

[0056]

Then, the peripheral surface polishing step of (step 2) is a step of polishing the peripheral surfaces (side surface portions and chamfered portions) of the glass substrate.

[0057]

The main surface polishing step of (step 3) is a step of polishing the upper and lower main surfaces of the glass substrate at the same time while supplying a polishing slurry to the main surfaces of the glass substrate, using a double-side polishing device. The polishing of the glass substrate of the invention may be only primary polishing, the primary polishing and secondary polishing may be performed, or tertiary polishing may be performed after the second polishing.

10 [0058]

Before the main surface polishing step of (step 3), lapping (for example, loose abrasive lapping or fixed abrasive lapping) of the main surfaces may be performed. Further, between the respective steps, glass substrate cleaning (in-process cleaning) or glass substrate surface etching (in-process etching) may be performed. Incidentally, the term "lapping of the main surfaces" as used herein means polishing of the main surfaces in the broad sense of the term.

[0059]

Further, a strengthening step (for example, chemical strengthening step) of forming a compressive stress layer (strengthening layer) on a surface layer of the glass substrate may be performed before or after the polishing step, or between the polishing steps.

[Second Embodiment]

In this embodiment, the magnetic recording medium using the glass substrate for a magnetic recording medium of the invention will be described.

25 [0060]

The magnetic recording medium (magnetic disk) can be obtained by forming a magnetic layer and the like on the glass substrate for a magnetic recording medium described in the first embodiment.

[0061]

5 Although there are a horizontal magnetic recording system and a perpendicular magnetic recording system in the magnetic recording medium, a procedure will herein be described below, taking the perpendicular magnetic recording system as an example.

[0062]

10 The magnetic recording medium is provided with at least the magnetic layer, a protective layer and a lubricating layer on its surface. Then, in the case of the perpendicular magnetic recording system, there is generally disposed a soft magnetic underlayer composed of a soft magnetic material which plays a role in circulating a recording magnetic field from a magnetic head. Accordingly, for example, the soft magnetic underlayer, a non-magnetic intermediate layer, the magnetic layer for
15 perpendicular recording, the protective layer and the lubricating layer are laminated in this order from the surface of the glass substrate.

[0063]

The respective layers will be described below.

[0064]

20 As the soft magnetic underlayer, there can be used, for example, CoNiFe, FeCoB, CoCuFe, NiFe, FeAlSi, FeTa₂N, FeN, FeTaC, CoFeB or CoZrN.

[0065]

Then, the non-magnetic intermediate layer is composed of Ru or a Ru alloy. The non-magnetic intermediate layer has a function for facilitating epitaxial growth of
25 the magnetic layer for perpendicular recording, and a function of breaking magnetic

exchange coupling between the soft magnetic underlayer and the magnetic layer for perpendicular recording.

[0066]

The magnetic layer for perpendicular recording is a magnetic layer in which an axis of easy magnetization faces in a perpendicular direction to a substrate surface, and contains at least Co and Pt. Then, in order to decrease intergranular exchange coupling which causes high intrinsic medium noise, it is recommended to form a well-separated fine grain structure (granular structure). Specifically, there is preferably used one obtained by adding an oxide (such as SiO₂, SiO, Cr₂O₃, CoO, Ta₂O₃ or TiO₂), or Cr, B, Cu, Ta or Zr to a CoPt-based alloy.

[0067]

The soft magnetic underlayer, the non-magnetic intermediate layer and the magnetic layer for perpendicular recording which have hitherto been described can be continuously manufactured by an inline sputtering process or a DC magnetron sputtering process.

[0068]

Next, the protective layer is provided on the magnetic layer for perpendicular recording in order to prevent corrosion of the magnetic layer for perpendicular recording, and to prevent damage of the surface of the magnetic recording medium even when the magnetic head comes into contact with the magnetic recording medium. As the protective layer, there can be used a material containing C, ZrO₂ or SiO₂.

[0069]

As a method for forming the protective layer, there can be used, for example, an in-line sputtering process, a CVD process and a spin coat process.

[0070]

In order to reduce friction between the magnetic head and the magnetic recording medium (magnetic disk), the lubricating layer is formed on a surface of the protective layer. As the lubricating layer, there can be used, for example, a perfluoropolyether, a fluorinated alcohol or a fluorinated carboxylic acid. The
5 lubricating layer can be formed by a dip process or a spray process.

[0071]

As has been described above, the magnetic recording medium obtained by forming the magnetic layer and the like on the glass substrate for a magnetic recording medium which has been described in the first embodiment has small displacement after
10 the servo information has been written therein, so that it becomes possible suppress the generation of errors.

[Examples]

[0072]

The invention will be further described below with reference to specific
15 examples. However, the invention should not be construed as being limited thereto.

[0073]

First, there will be described a method for evaluating the glass substrate for a magnetic recording medium and a method for evaluating the magnetic recording medium obtained by forming thin films such as the magnetic layer on the surface of the
20 glass substrate, which are used in the following working examples and comparative examples.

(1) Anelasticity Deformation Amounts

For the anelasticity deformation amounts A to C, the flatness $F(-48\text{ h})$ before the load was applied to the glass substrate for a magnetic recording medium was first
25 measured, and the flatness $F(5\text{ h})$ at the time when 5 hours have elapsed since the removal of the load after the load was applied to the glass substrate for 48 hours and the

flatness $F(48\text{ h})$ at the time when 48 hours have elapsed since the removal of the load were each measured.

[0074]

Measurement of the flatness at each time was made by the phase-measuring interference method (phase shift method). Specifically, the flatness was measured at a measuring wavelength of 680 nm using an interference flatness measuring device (manufactured by Zygo Corporation, model: Zygo GI Flat (MESA)).

[0075]

Thereafter, the anelasticity deformation amounts A to C were calculated from the respective measured flatnesses according to the following equations:

$$(\text{Anelasticity deformation amount A}) = |F(5\text{ h}) - F(-48\text{ h})|$$

$$(\text{Anelasticity deformation amount B}) = |F(5\text{ h}) - F(48\text{ h})|$$

$$(\text{Anelasticity deformation amount C}) = F(5\text{ h})$$

Here, conditions in applying the load to the glass substrate for a magnetic recording medium will be described.

[0076]

First, as shown in Figs. 2(a) and 2(b), both edge portions of the glass substrate for a magnetic recording medium were supported with a V-shaped block.

[0077]

Supporting portions 14 were disposed on both diametrically opposing edges, and two places of the both edge portions (supporting portions) were each enclosed by a chord 141 (142) and an arc (a shorter arc cut away by the chord) to form the same form. Then, the both edge portions were disposed in such a manner that the maximum value $W1$ of the distance between the chord 141 (142) and the arc became 3.8% of the diameter of the glass substrate for a magnetic recording medium.

[0078]

Next, a load 15 was disposed on a main surface of the glass substrate for a magnetic recording medium in parallel to the chords 141 and 142 forming the both edge portions supported by the V-shaped block. In this example, there was used the load having a width, namely W2 in Fig. 2(a) and 2(b), of 67% of the diameter of the glass substrate for a magnetic recording medium. In this case, the load was disposed in such a manner that a center line of the load in a width direction passed through the center of the glass substrate for a magnetic recording medium.

[0079]

Further, in a longitudinal direction, the load having a length longer than the diameter of the glass substrate for a magnetic recording medium was used so that the glass substrate for a magnetic recording medium was completely covered with the load over the whole range of the width of the load.

(2) Read/Write Test

After a magnetic layer and the like were formed on the glass substrate for a magnetic recording medium obtained, a read/write test was performed by a procedure described below.

[0080]

Specifically, a magnetic recording medium in which the magnetic layer and the like were formed on the glass substrate for a magnetic recording medium was incorporated in a hard disk drive (HDD), and servo information was written by the following procedure. Thereafter, a magnetic signal was recorded under conditions of a track density of about 254 TPI (track per inch) and a linear recording density of about 1,500 BPI (bit per inch) by a procedure of the following example. The presence or absence of the generation of errors at the time when the signal was read out was confirmed.

[0081]

In this example, several types of glass substrates having high specific Young's modulus (glass substrates for magnetic recording medium of Examples 1 to 9 shown in Table 1) were studied.

[0082]

[Table 1]

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9
Density d (g/cm ³)	2.50	2.40	2.38	2.63	2.51	2.46	2.47	2.47	2.46
Young's Modulus E (GPa)	77	72	73	82	84	83	83.6	84.4	72
Specific Young's Modulus E/d	30.8	30.0	30.7	31.2	33.5	33.7	33.8	34.2	29.3

(Manufacturing of Glass Substrate for Magnetic Recording Medium)

Each glass substrate for a magnetic recording medium was processed into a doughnut form having a diameter of 65 mm, a sheet thickness of 0.6 mm and a 20-mm circular hole at a central portion thereof using glass sheets of Examples 1 to 9 in Table 1
5 by the following procedure.

[0083]

First, the glass sheet was processed into a disk-shaped glass substrate having the circular hole at the central portion thereof.

[0084]

10 An inner peripheral surface and an outer peripheral surface were chamfered so that a glass substrate for a magnetic recording medium having a chamfer angle of 45° was obtained (an inner peripheral chamfering step and an outer peripheral chamfering step).

[0085]

15 After the chamfering, upper and lower main surfaces of the glass substrate were lapped using an aluminum oxide abrasive, and the abrasive was removed by cleaning.

[0086]

20 Then, the outer peripheral surface was polished by polishing an outer peripheral side surface portion and an outer peripheral chamfered portion of the glass substrate for a magnetic recording medium using polishing brushes and a cerium oxide abrasive to remove affected layers by chamfering process (such as scratches, etc.) on the outer peripheral side surface portion and the outer peripheral chamfered portion so as to obtain mirror-finished surfaces (an outer peripheral surface polishing step).

25 [0087]

After the outer peripheral surface polishing, the inner peripheral surface was polished by polishing an inner peripheral side surface portion and an inner peripheral chamfered portion of the glass substrate for a magnetic recording medium using a polishing brush and a polishing slurry containing a cerium oxide abrasive to remove
5 affected layers by chamfering process (such as scratches, etc) on the inner peripheral side surface portion and the inner peripheral chamfered portion so as to obtain mirror-finished surfaces (an inner peripheral surface polishing step). For the glass substrate subjected to the inner peripheral surface polishing, the abrasive was removed by cleaning.

10 [0088]

After the outer and inner peripheral surfaces of the glass substrate were processed, the upper and lower main surfaces of the glass substrate were lapped using a diamond abrasive-containing fixed abrasive tool and a grinding liquid, and cleaned.

[0089]

15 Next, the upper and lower main surfaces were subjected to primary polishing with a 22B type double side polishing machine (manufactured by Speedfam Co., Ltd., product name: DSM22B-6PV-4MH) using a hard urethane polishing pad as a polishing tool and a polishing slurry containing a cerium oxide abrasive, and then cerium oxide was removed by cleaning.

20 [0090]

The upper and lower main surfaces of the glass substrate after the primary polishing were subjected to secondary polishing with the 22B type double side polishing machine using a soft urethane polishing pad as a polishing tool and a polishing slurry containing a cerium oxide abrasive having an average particle size
25 smaller than that of the above-mentioned cerium oxide abrasive, and then cerium oxide was removed by cleaning.

[0091]

The glass substrate after the secondary polishing was subjected to tertiary polishing (finish polishing). The upper and lower main surfaces thereof were polished with the double side polishing machine using a soft urethane polishing pad as a
5 polishing tool for the tertiary polishing and a polishing slurry containing colloidal silica.

[0092]

The glass substrate subjected to the finish polishing (tertiary polishing) was in turn subjected to scrub cleaning, ultrasonic cleaning in a state where the glass substrate was immersed in some detergent solutions and ultrasonic cleaning in a state where the
10 glass substrate was immersed in pure water (precision cleaning), followed by drying with vapor of isopropyl alcohol or the like.

[0093]

For the respective glass substrates for magnetic recording medium obtained, the anelasticity deformation amounts A to C were measured. The results thereof are
15 shown in Table 2.

(Manufacturing of Magnetic Recording Medium)

Then, for 100 pieces of each of the glass substrates for magnetic recording media of Examples 1 to 9 described above, an underlayer, a magnetic layer, a protective layer and a lubricating layer were in turn formed on each glass substrate to manufacture
20 a magnetic recording medium

[0094]

The procedure will be specifically described. A NiFe layer as a soft magnetic underlayer, a Ru layer as a nonmagnetic intermediate layer and a granular structure layer of CoCrPtSiO₂ as a perpendicular magnetic recording layer were in turn stacked
25 on the surface of each of the glass substrates for magnetic recording media of Examples 1 to 9 by an in-line type sputtering device. Then, an amorphous diamond-like carbon

film was formed as a protective layer by a CVD process. Thereafter, a perfluoropolyether-containing lubricating layer was formed by a dip process to prepare each magnetic recording medium.

[0095]

5 Each magnetic recording medium thus obtained was stored in a shipping cassette (manufactured by Entegris, Inc.), vacuum-packed in an Al-laminated bag at a degree of vacuum of 400 mmHg, and allowed to stand for 48 hours.

[0096]

10 After 48 hours, the package was opened, and the magnetic recording medium was taken out and fabricated to a HDD device. Then, servo information was written therein under conditions corresponding to 254 kTPI. The servo information was written after 5 hours after the opening. After 43 hours from the writing of the servo information (after 48 hours after the opening), the read/write test of the HDD was performed.

15 [0097]

The results of the read/write test are shown in Table 2.

[0098]

[Table 2]

	Glass Substrates for Magnetic Recording Medium			Magnetic Recording Medium	
	Anelasticity Deformation Amount A (μm)	Anelasticity Deformation Amount B (μm)	Anelasticity Deformation Amount C (μm)	Implementation Evaluation	
				Error Incidence of HDD (%)	Results of Error Analysis
Example 1	0.1	0.0	1.7	0%	-
Example 2	0.2	0.1	2.2	0%	-
Example 3	0.0	0.0	1.5	0%	-
Example 4	0.1	0.1	2.3	0%	-
Example 5	2.3	1.9	3.0	0%	-
Example 6	2.8	2.4	3.6	1%	Errors were generated around the outer periphery
Example 7	3.8	3.2	5.6	3%	Errors were concentrated around the outer periphery
Example 8	4.3	3.7	5.9	5%	Errors were concentrated around the outer periphery
Example 9	5.0	2.8	6.2	6%	Errors were concentrated around the outer periphery

According to these results, it was confirmed that in Examples 1 to 7 as working examples of the invention in which the anelasticity deformation amount A satisfied a value specified in the invention, the error incidence in the read/write test was at most about 3%, and could be suppressed to about the half compared to that in Examples 8 and 9 as comparative examples.

[0099]

Defects of the magnetic disks having high error incidence in Examples 8 and 9 were analyzed. As a result, it was confirmed that errors were concentrated around outer peripheries. The reason for this is considered to be as follows.

10 [0100]

The magnetic recording medium held in the shipping cassette is deformed by pressure from the atmosphere due to the vacuum packaging, and gradually returns to its original form according to the respective anelasticity properties after the opening. However, the magnetic recording media of Examples 8 and 9 having poor anelasticity properties does not completely return to their original form yet at the time of the writing of the servo information. Thereafter, the magnetic recording media return to their original form. It is therefore considered that the position deviation of the servo information occurred in the subsequent read/write test.

[0101]

20 Changes in form become more significant, nearer to the outer periphery, so that it is presumed that errors were concentrated to the outer peripheral portion.

[0102]

The glass substrate of Example 8 as a comparative example has a high specific modulus compared to the other glass substrates used in the invention, and fluttering is suppressed. Accordingly, the generation of errors is supposed to be suppressed in the implementation evaluation of the magnetic recording medium. However, the

incidence of errors was high as described above. This is considered to be caused by that the glass substrate for a magnetic recording medium of Example 8 has a large anelasticity deformation amount. These results reveal that in order to sufficiently suppress the generation of errors in the magnetic recording medium, only the use of the
5 glass substrate having a high specific modulus as the glass substrates for magnetic recording medium, which has hitherto been found to be useful, is insufficient, and that the use of the glass substrates for magnetic recording medium having a small anelasticity deformation amount is necessary.

[0103]

10 Further, it was also confirmed that in Examples 1 to 6 in which the anelasticity deformation amounts B and C satisfied values specified in the invention, the error incidence was at most about 1%, resulting in being able to suppress the generation of errors.

[0104]

15 The results of Examples described above reveal that the magnetic recording medium in which the generation of errors (read/write errors) is suppressed can be obtained by selecting the glass substrate for a magnetic recording medium having an anelasticity deformation amount within the predetermined range.

[0105]

20 The present application is based on Japanese Patent Application No. 2011-282327 filed on December 22, 2011, and the contents are incorporated herein by reference.

[Description of the Reference Numerals]

[0106]

25 13: Glass substrate for magnetic recording medium
14: Both edge portions

15: Load

Claims

[Claim 1]

A method for manufacturing a glass substrate for a magnetic recording medium, the method comprising a main surface polishing step of polishing a main surface of a glass substrate having a disk shape,

wherein, in the glass substrate for a magnetic recording medium after conducting the main surface polishing step,

when an absolute value of a difference between

a flatness determined by supporting both diametrically edge portions which are provided on opposing two places of the glass substrate for a magnetic recording medium and are each enclosed by a chord and an arc in which a maximum value of a distance between the chord and the arc is a length of 2.3 to 7.7% of a diameter of the glass substrate for a magnetic recording medium, from an underside surface thereof, applying a load calculated by (an area of a main surface of the glass substrate for a magnetic recording medium) $\text{mm}^2 \times 2.28 \text{ mN/mm}^2$ for 48 hours on an upper surface of a central area of the glass substrate for a magnetic recording medium in which a width thereof is a length of 35 to 80% of the diameter of the glass substrate for a magnetic recording medium, and a center line in a direction of the width passes through a center of the glass substrate for a magnetic recording medium and is parallel to the chord, followed by removing the load, and performing measurement at a time when 5 hours have elapsed since the removal of the load, and

a flatness before applying the load

is defined as an anelasticity deformation amount A, the anelasticity deformation amount A is $4.2 \mu\text{m}$ or less.

[Claim 2]

The method for manufacturing a glass substrate for a magnetic recording medium according to claim 1,

wherein, in the glass substrate for a magnetic recording medium after conducting the main surface polishing step,

when an absolute value of a difference between

the flatness determined by supporting the both diametrically edge portions which are provided on the opposing two places of the glass substrate for a magnetic recording medium and are each enclosed by the chord and the arc in which the maximum value of the distance between the chord and the arc is a length of 2.3 to 7.7% of the diameter of the glass substrate for a magnetic recording medium, from the underside surface thereof, applying the load calculated by (an area of a main surface of the glass substrate for a magnetic recording medium) $\text{mm}^2 \times 2.28 \text{ mN/mm}^2$ for 48 hours on the upper surface of the central area of the glass substrate for a magnetic recording medium in which the width thereof is a length of 35 to 80% of the diameter of the glass substrate for a magnetic recording medium, and the center line in the direction of the width passes through the center of the glass substrate for a magnetic recording medium and is parallel to the chord, followed by removing the load, and performing measurement at the time when 5 hours have elapsed since the removal of the load, and

a flatness at a time when 48 hours have elapsed since the removal of the load is defined as an anelasticity deformation amount B, the anelasticity deformation amount B is $3.0 \text{ }\mu\text{m}$ or less.

[Claim 3]

The method for manufacturing a glass substrate for a magnetic recording medium according to claim 1 or 2,

wherein, in the glass substrate for a magnetic recording medium after conducting the main surface polishing step,

when the flatness determined by supporting the both diametrically edge portions which are provided on the opposing two places of the glass substrate for a magnetic recording medium and are each enclosed by the chord and the arc in which the maximum value of the distance between the chord and the arc is a length of 2.3 to 7.7% of the diameter of the glass substrate for a magnetic recording medium, from the underside surface thereof, applying the load calculated by (the area of the main surface of the glass substrate for a magnetic recording medium) $\text{mm}^2 \times 2.28 \text{ mN/mm}^2$ for 48 hours on the upper surface of the central area of the glass substrate for a magnetic recording medium in which the width thereof is a length of 35 to 80% of the diameter of the glass substrate for a magnetic recording medium, and the center line in the direction of the width passes through the center of the glass substrate for a magnetic recording medium and is parallel to the chord, followed by removing the load, and performing measurement at the time when 5 hours have elapsed since the removal of the load is defined as an anelasticity deformation amount C, the anelasticity deformation amount C is $5.5 \mu\text{m}$ or less.

[Claim 4]

A method for manufacturing a magnetic recording medium, using a glass substrate for a magnetic recording medium having an anelasticity deformation amount A of $4.2 \mu\text{m}$ or less, which is defined as an absolute value of a difference between

a flatness determined by supporting both diametrically edge portions which are provided on opposing two places of the glass substrate for a magnetic recording medium and are each enclosed by a chord and an arc in which a maximum value of a distance between the chord and the arc is a length of 2.3 to 7.7% of a diameter of the glass substrate for a magnetic recording medium, from an underside surface thereof,

applying a load calculated by (an area of a main surface of the glass substrate for a magnetic recording medium) $\text{mm}^2 \times 2.28 \text{ mN/mm}^2$ for 48 hours on an upper surface of a central area of the glass substrate for a magnetic recording medium in which a width thereof is a length of 35 to 80% of the diameter of the glass substrate for a magnetic recording medium, and a center line in a direction of the width passes through a center of the glass substrate for a magnetic recording medium and is parallel to the chord, followed by removing the load, and performing measurement at a time when 5 hours have elapsed since the removal of the load, and

a flatness before applying the load

in the glass substrate for a magnetic recording medium.

[Claim 5]

The method for manufacturing a magnetic recording medium according to claim 4, using a glass substrate for a magnetic recording medium having an anelasticity deformation amount B of $3.0 \mu\text{m}$ or less, which is defined as an absolute value of a difference between

the flatness determined by supporting the both diametrically edge portions which are provided on the opposing two places of the glass substrate for a magnetic recording medium and are each enclosed by the chord and the arc in which the maximum value of the distance between the chord and the arc is a length of 2.3 to 7.7% of the diameter of the glass substrate for a magnetic recording medium, from the underside surface thereof, applying the load calculated by (an area of a main surface of the glass substrate for a magnetic recording medium) $\text{mm}^2 \times 2.28 \text{ mN/mm}^2$ for 48 hours on the upper surface of the central area of the glass substrate for a magnetic recording medium in which the width thereof is a length of 35 to 80% of the diameter of the glass substrate for a magnetic recording medium, and the center line in the direction of the width passes through the center of the glass substrate for a magnetic recording medium

and is parallel to the chord, followed by removing the load, and performing measurement at the time when 5 hours have elapsed since the removal of the load, and a flatness at a time when 48 hours have elapsed since the removal of the load in the glass substrate for a magnetic recording medium.

[Claim 6]

The method for manufacturing a magnetic recording medium according to claim 4 or 5, using a glass substrate for a magnetic recording medium having an anelasticity deformation amount C of 5.5 μm or less, which is the flatness determined by supporting the both diametrically edge portions which are provided on the opposing two places of the glass substrate for a magnetic recording medium and are each enclosed by the chord and the arc in which the maximum value of the distance between the chord and the arc is a length of 2.3 to 7.7% of the diameter of the glass substrate for a magnetic recording medium, from the underside surface thereof, applying the load calculated by (the area of the main surface of the glass substrate for a magnetic recording medium) $\text{mm}^2 \times 2.28 \text{ mN/mm}^2$ for 48 hours on the upper surface of the central area of the glass substrate for a magnetic recording medium in which the width thereof is a length of 35 to 80% of the diameter of the glass substrate for a magnetic recording medium, and the center line in the direction of the width passes through the center of the glass substrate for a magnetic recording medium and is parallel to the chord, followed by removing the load, and performing measurement at the time when 5 hours have elapsed since the removal of the load, in the glass substrate for a magnetic recording medium.