TITLE OF THE INVENTION

METHOD OF MANUFACTURING MAGNETIC RECORDING MEDIUM AND MAGNETIC RECORDING MEDIUM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority of the Japanese Patent Applications No. 2013-130269 filed on June 21, 2013, and No. 2014-108921 filed on May 27, 2014, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of manufacturing a magnetic recording medium, and the magnetic recording medium.

2. Description of the Related Art

A substrate for a magnetic recording medium that is used in a magnetic storage apparatus (or magnetic recording and/or reproducing apparatus) or the like is conventionally formed by an aluminum alloy substrate. However, due to demands to further increase the recording density, a glass substrate that is hard compared to the aluminum alloy substrate and has superior flatness and smoothness is becoming more popular.

Recently, the recording density and the rotational speed of the magnetic recording medium, which are already high, have increased further. As a result, a read or write error (hereinafter also simply referred to as an "error") is generated more frequently because a magnetic head may be unable to read servo information from the magnetic recording medium. The servo information includes radial or track position information that

indicates a radial or track position on the magnetic recording medium.

It is conventionally regarded that the error described above is caused by a mechanical vibration generated due to narrow tracks and high-speed rotation of the magnetic recording medium that are employed to achieve the high recording density.

For this reason, in order to suppress the error, the fluttering is suppressed by using, for example, a material having a high specific modulus for the glass substrate of the magnetic recording medium. The specific modulus is also referred to as a specific Young's modulus, and is a quantity that is obtained by dividing the Young's modulus of glass by the density of glass. Thus, the specific modulus is an index representing a property that is both light and strong and light and uneasily deformable.

For example, Japanese Laid-Open Patent Publication No. 2010-277679 proposes a method of manufacturing the glass substrate for a magnetic disk, which selects a glass substrate having a symmetry within a predetermined range along a direction of the thickness, in order to reduce the error of the servo information written on the magnetic disk which forms a hard disk.

Although the proposed method described above suppresses the error of the magnetic recording medium by selecting the glass substrate, the generation of the error may not be suppressed to a sufficient extent.

SUMMARY OF THE INVENTION

The present invention is conceived in view of the above problem, and one object of the present invention is to provide a method of manufacturing a magnetic recording medium, and the magnetic recording, which can

reduce the generation of the error.

According to one aspect of the present invention, a method of manufacturing a magnetic recording medium that includes a glass substrate, includes generating at least one of a buckling deformation and a bending deformation in the glass substrate, wherein a glass forming the glass substrate includes an Al_2O_3-content of 5 mol% or more, and wherein the glass forming the glass substrate further includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less.

Other objects and further features of the present invention may be apparent from the following detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGs. 1A and 1B are diagrams for explaining a buckling deformation and a bending deformation;

FIG. 2 is a diagram for explaining an example of a configuration of a holding tool used during a magnetic layer deposition process;

FIG. 3 is a flow diagram for explaining measurement of a pseudoelastic deformation quantity;

FIGs. 4A and 4B are diagrams for explaining a load applying method at the time of measuring the pseudoelastic deformation quantity;

FIG. 5 is a diagram illustrating a dependency of a flatness immediately after removing load with respect to a load applying time before removing the load in one embodiment of the present invention;

FIG. 6 is a diagram illustrating the dependency of the flatness immediately after removing the load with respect to the load applying time before removing the load in one embodiment of the present invention;

FIG. 7 is a diagram illustrating a dependence of the flatness after removing the load with respect to an elapsed time after removing the load, after applying the load for 24 hours in one embodiment of the present invention; and

FIG. 8 is a diagram illustrating the dependence of the flatness after removing the load with respect to the elapsed time after removing the load, after applying the load for 24 hours in one embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A detailed description will hereinafter be given of embodiments of the present invention with reference to the drawings. The present invention is described below in detail with reference to specific embodiments, however, it may be apparent to those skilled in the art that various variations, modifications, and substitutions may be made without departing from the spirit and scope of the present invention.

[First Embodiment]

A description will be given of a method of manufacturing a magnetic recording medium in this embodiment.

The method of manufacturing the magnetic recording medium in this embodiment manufactures a magnetic recording medium that includes a glass substrate in which at least one of a buckling deformation and a bending deformation occurs.

The glass forming the glass substrate may include an Al_2O_3-content of 5 mol% or more.

In addition, the glass forming the glass substrate may include a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less.

The present inventors studied the causes for the error generated in the magnetic recording medium even in a case in which a material having a high specific modulus is used for the substrate material of the glass substrate for the magnetic recording medium. The specific modulus is also referred to as the specific Young's modulus, and is a quantity that is obtained by dividing the Young's modulus of glass by the density of glass. Thus, the specific modulus is an index representing a property that is both light and strong and light and uneasily deformable.

As a result of the studies conducted by the present inventors, in a case in which a force (or load) is applied to the glass substrate during the manufacturing process of the magnetic recording medium and a buckling deformation or a bending deformation occurs, the glass substrate returns to its original shape when the force (or load) is removed after the deformation, however, it was found that a behavior after removing the force (or load) differs depending on a glass composition of the glass substrate. In other words, even when the shape of the glass substrates are the same, the glass substrate may return to its original shape within a short time after removing the force (or load), or the glass substrate may gradually return to its original shape over a long time after removing the force (or load), depending on the glass

composition of the glass substrate. The latter deformation that takes a long time to return to the original shape after removing the force (or load) may sometimes be referred to as a delayed restore deformation. In the following description, "a deformation" may also refer to "a deformation accompanying delayed restore deformation".

In the case of the magnetic recording medium including the glass substrate that takes a long time to return to its original shape from the deformed shape after removing the force (or load), the servo information may be written while the restoration of the glass substrate (or magnetic recording medium) takes place, depending on a write timing of the servo information. For this reason, the present inventors found that positions where the servo information is written may change after the servo information is written due to the restoration, and the present inventors found that this change in the written positions of the servo information is one cause of the error generated in the magnetic recording medium.

In the method of manufacturing the magnetic recording medium in this embodiment, at least one of the buckling deformation and the bending deformation occurs in the glass substrate during the manufacturing process, as described above.

Next, a description will be given of the buckling deformation and the bending deformation, by referring to FIGs. 1A and 1B.

A description will be given of the buckling deformation, by referring to FIG. 1A. FIG. 1A illustrates a glass substrate 10 viewed from a side thereof. The buckling deformation refers to a deformation that occurs in a direction perpendicular to principal planes 11 and 12

of the glass substrate 10, as illustrated by dotted lines in FIG. 1A, when two opposing forces indicated by arrows X1 and X2 and parallel to the principal planes 11 and 12 of the glass substrate 10 are applied with respect to side surface parts of the glass substrate 10. FIG. 1A illustrates an example in which the glass substrate 10 is curved downwardly by the deformation, however, the deformation is not limited to such, and the glass substrate 10 may curve upwardly by the deformation.

A description will be given of the bending deformation, by referring to FIG. 1B. FIG. 1B illustrates the glass substrate 10 viewed from the side thereof. The bending deformation refers to a deformation that occurs in a direction perpendicular to the principal planes 11 and 12 of the glass substrate 10, as illustrated by dotted lines in FIG. 1B, when two opposing forces indicated by arrows Y1 and Y2 and perpendicular to the principal planes 11 and 12 of the glass substrate 10 are applied with respect to the principal planes 11 and 12 of the glass substrate 10, respectively.

The case in which at least one of the buckling deformation and the bending deformation occurs in the glass substrate refers to a case in which the forces described above are applied to the glass substrate itself or to the magnetic recording medium, and the glass substrate itself and a magnetic layer or the like deposited on the surface of the glass substrate become deformed. In the case in which the force (or load) is applied to the magnetic recording medium, the magnetic layer or the like are deformed in accordance with the deformation of the glass substrate, and thus, the magnetic recording medium also exhibits a behavior similar to that of the glass substrate included in the magnetic recording

medium. In addition, even in a case in which the deformation of the glass substrate is the delayed restore deformation, the magnetic layer or the like are also deformed in accordance with the deformation of the glass substrate, and thus, the magnetic recording medium also exhibits a behavior similar to that of the glass substrate included in the magnetic recording medium.

Examples of the case in which the force (or load) is applied to the glass substrate include a case in which the glass substrate is held by a holding tool and transported, and a case in which the glass substrate is accommodated within a cassette or the like and transported, and it may be regarded that the deformation mainly occurs when the glass substrate is transported in a state making contact with the tool or the like.

As will be described later, the method of manufacturing the magnetic recording medium in this embodiment preferably includes at least one of processes selected from a magnetic layer deposition process to deposit the magnetic layer on the glass substrate, and a magnetic recording medium holding process to hold the magnetic recording medium within the cassette.

During the magnetic layer deposition process, the glass substrate is held by the holding tool and is transported to a position where the magnetic layer deposition takes place, as will be described later, and the glass substrate is easily deformed due to a force of the holding tool applied to the glass substrate. Hence, during the magnetic layer deposition process, the glass substrate is preferably held at end surfaces (or side surfaces) thereof before deposition of the magnetic layer, during the deposition of the magnetic layer because the magnetic layer is deposited on both surfaces of the glass

substrate, and after the deposition of the magnetic layer because the magnetic layer is preferably protected. However, as illustrated in FIG. 6 which will be described later, the delayed restore deformation may occur depending on the material used for the glass substrate, even in a case in which the load (or force) is continuously applied to the glass substrate only for approximately 30 seconds. For this reason, when the end surface parts of the glass substrate are held during the magnetic layer deposition process, the delayed restore deformation is easily generated by the buckling deformation. Particularly in the case of the magnetic recording medium employing a heat-assisted (or thermally assisted) magnetic recording system to which much attention is recently drawn, a heat treatment at a high temperature is required during the magnetic layer deposition process. In the case of the heat treatment at the high temperature, the glass substrate needs to be held for a long time in order to raise and lower the temperature (or heat and cool) or the like, and it may be regarded that the deformation of the glass substrate particularly during the magnetic layer deposition process may introduce problems in the future.

In addition, a magnetic recording medium holding process holds the glass substrate within the cassette. Because the glass substrate is accommodated, forwarded or shipped, and transported within a decompressed packaging container, a load is applied to the glass substrate and deformation of the glass substrate easily occurs. For this reason, in at least one process selected from the magnetic layer deposition process and the magnetic recording medium holding process, for example, at least one of the buckling deformation and the bending deformation can be generated in the glass substrate.

Although the magnetic layer deposition process and the magnetic recording medium holding process are described above, the process in which the force (or load) is applied to the glass substrate is not limited to these processes. For example, the glass substrate is mechanically transported between two processes of the manufacturing process of the magnetic recording medium, and the force (or load) may be applied to the glass substrate when the glass substrate is held by the holding tool and transported during a process other than the magnetic layer deposition process and the magnetic recording medium holding process. For this reason, the buckling deformation or the bending deformation may occur in the glass substrate when the glass substrate is transported between two processes of the manufacturing process of the magnetic recording medium.

In the method of manufacturing the magnetic recording medium in this embodiment, the glass forming the glass substrate may include an Al_2O_3-content of 5 mol% or more. In addition, the glass forming the glass substrate may preferably include a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less. The alkali metal oxide may be any kind of alkali metal oxide, and is not limited to a particular kind of alkali metal oxide. For example, the alkali metal oxide may typically include LiO_2, Na_2O, and K_2O.

According to the studies conducted by the present inventors, the Young's modulus of the glass substrate can be made sufficiently high by making the Al_2O_3-content of the glass forming the glass substrate 5

mol% or more.

Further, in the case in which the glass forming the glass substrate includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less, even when the force (or load) is applied to the glass substrate, the time it takes for the glass substrate to return to its original shape after removing the force (or load) can be reduced. In other words, after the force (or load) applied to the glass substrate is removed, the time (or duration) for which the glass substrate is deformed can be reduced.

In the method of manufacturing the magnetic recording medium in this embodiment, the glass forming the glass substrate of the magnetic recording medium preferably includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less. This is because, even when a force (or load) is applied to the glass substrate and deformation of the glass substrate occurs, the time it takes for the glass substrate to return to its original shape after the force (or load) is removed can further be reduced.

Particularly in the case in which the glass forming the glass substrate of the magnetic recording medium includes B_2O_3, a lower limit of the B_2O_3-content is preferably 0.2 mol% or more, and more preferably 0.5 mol% or more. In addition, an upper limit of the B_2O_3-content is preferably 12 mol% or less, more preferably 10 mol% or less, even more preferably 5 mol% or less, and particularly more preferably less than 2 mol%. In a case in which the B_2O_3-content is less than 2 mol%, even when a force (or load) is applied to the glass substrate and

deformation of the glass substrate occurs, the time it takes for the glass substrate to return to its original shape after the force (or load) is removed can be reduced, and furthermore, the specific modulus of the glass substrate can be made high. For this reason, even in a case in which the magnetic recording medium is rotated at a high speed, the generation of fluttering can be suppressed, and it is possible to particularly suppress the generation of a read or write error associated with the magnetic recording medium.

In the case in which the glass forming the glass substrate of the magnetic recording medium includes one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, the content of the alkali metal oxide is preferably 22 mol% or less, and more preferably 10 mol% or less. One or less kind of alkali metal oxide included in the glass refers to a case in which one kind of alkali metal oxide selected from alkali metal oxides such as Na_2O, K_2O, Li_2O, or the like is included in the glass, or a case in which no alkali metal oxide is included in the glass.

In the case in which the glass forming the glass substrate of the magnetic recording medium includes two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less, the content of the alkali metal oxide is preferably 17 mol% or less, and more preferably 10 mol% or less.

Two or more kinds of alkali metal oxide included in the glass refers to a case in which two or more kinds of alkali metal oxides selected from alkali metal oxides such as Na_2O, K_2O, Li_2O, or the like are included in the glass. In this case, the content of each alkali metal oxide is not limited to a particular amount, and may be

set to an arbitrary amount. For example, contents (or mol%) of each of the alkali metal oxides may be equal or balanced.

By using glass including a predetermined composition for the glass substrate of the magnetic recording medium in this embodiment, even when a force (or load) is applied to the glass substrate and deformation of the glass substrate occurs, a displacement in the glass substrate due to its restoration force after the force (or load) applied to the glass substrate is removed ends or essentially ends by the time the servo information is written on the magnetic recording medium. For this reason, the glass substrate (or magnetic recording medium) after being written with the servo information undergoes no displacement or only a displacement to a negligible extent. Consequently, it is possible to prevent the positions where the servo information are written from changing, and the error generation rate can be suppressed.

In addition, the glass forming the glass substrate of the magnetic recording medium in this embodiment preferably includes an Al_2O_3-content of 5 mol% or more and 20 mol% or less. A lower limit of the Al_2O_3-content is preferably 8 mol% or more, more preferably 10 mol% or more, and particularly more preferably 11.5 mol% or more. An upper limit of the Al_2O_3-content is preferably 17.5 mol% or less, and more preferably 15 mol% or less.

In the method of manufacturing the magnetic recording medium in this embodiment, the glass forming the glass substrate of the magnetic recording medium preferably includes a SiO_2-content of 55 mol% or more and 75 mol% or less, and an alkali earth metal oxide with a content of 0 mol% or more and 30 mol% or less. The SiO_2-content is more preferably 66 mol% or more and 75 mol% or

less, and even more preferably 66 mol% or more and 70 mol% or less. The content of the alkali earth metal oxide is more preferably 5 mol% or more and 30 mol% or less, and even more preferably 16 mol% or more and 30 mol% or less.

In the case in which the glass forming the glass substrate of the magnetic recording medium includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, the content of the alkali metal oxide is preferably 0 mol% or more and 25 mol% or less. The content of the alkali metal oxide in this case is more preferably 0 mol% or more and 15 mol% or less, and even more preferably 0 mol% or more and 2.5 mol% or less.

The specific modulus (or specific Young's modulus) of the glass substrate is preferably high, and is preferably 32 MNm/kg or higher, and more preferably 33 MNm/kg or higher. When the specific modulus is high, the generation of the fluttering can be suppressed even when the magnetic recording medium is rotated at a high speed, and it is possible to particularly suppress the generation of a read or write error associated with the magnetic recording medium.

Furthermore, the glass substrate preferably has a flatness that uneasily changes even when the load is applied to the glass substrate. For example, in a case in which the load is applied for 24 hours in a similar manner as when measuring a pseudoelastic deformation quantity to be described later, that is, in the case in which both end parts of the glass substrate along diametrically opposite directions are supported from a lower surface side of the glass substrate and the load is applied to a central upper surface of the glass substrate for 24 hours, a rate of change of the flatness before and after applying the load is preferably 200% or less. The rate of change of the

flatness before and after applying the load is more preferably 100% or less.

The rate of change of the flatness before and after applying the load can be represented by the following formula, where F(24h) denotes the flatness immediately after removing the load after applying the load to the glass substrate for 24 hours, F(-24h) denotes the flatness before the load is applied to the glass substrate, and R_f denotes the rate of change of the flatness before and after applying the load.

$$R_f = |F(24h) - F(-24h)|/F(-24h) \times 100$$

Next, a description will be given of examples of the processes of the method of manufacturing the magnetic recording medium in this embodiment.

The method of manufacturing the magnetic recording medium in this embodiment preferably includes at least one of the processes selected from the magnetic layer deposition process to deposit the magnetic layer on the glass substrate, and the magnetic recording medium holding process to hold the magnetic recording medium within the cassette. The method is not limited to including these processes, and may arbitrarily or additionally include one or more other processes.

More particularly, the method may include the following processes, for example.

(a) A glass substrate preparation process to prepare the glass substrate;

(b) The magnetic layer deposition process to deposit the magnetic layer on the glass substrate; and

(c) The magnetic recording medium holding process to hold the magnetic recording medium, obtained by the magnetic layer deposition process (b), within the cassette.

A description will now be given of each of the

processes (a) through (c).

[Glass Substrate Preparation Process (a)]

The glass substrate preparation process (a) prepares a glass substrate satisfying specifications required by the magnetic recording medium. Details of the glass substrate preparation process (a) are not limited in particular.

The glass substrate preparation process (a) may further include the following processes (s1) through (s4), for example.

(s1) A shaping process to cut a glass substrate base into a disk-shaped glass substrate having a circular center hole, and to thereafter chamfer an inner peripheral end surface and an outer peripheral end surface of the disk-shaped glass substrate;

(s2) An end surface polishing process to polish the end surfaces (inner peripheral end surface and outer peripheral end surface) of the glass substrate;

(s3) A principal plane polishing process to polish the principal planes of the glass substrate; and

(s4) A cleaning process to clean the glass substrate.

The shaping process (s1) cuts the glass substrate base that is formed by float glass method, fusion method, press-molding method, downdraw method, or redraw forming method, into the disk-shaped glass substrate having the circular center hole.

The glass substrate base is not limited to a particular type, but is preferably made of a composition similar to that of the glass substrate included in the magnetic recording medium described above.

More particularly, the glass substrate base is made of glass including an Al_2O_3-content of 5 mol% or more. In addition, the glass forming the glass substrate base

may include a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less.

In a case in which the glass forming the glass substrate base includes B_2O_3, a lower limit of the B_2O_3-content is preferably 0.2 mol% or more, and more preferably 0.5 mol% or more. In addition, an upper limit of the B_2O_3-content is preferably 12 mol% or less, more preferably 10 mol% or less, even more preferably 5 mol% or less, and particularly more preferably less than 2 mol%.

In a case in which the glass forming the glass substrate base includes one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, the content of the alkali metal oxide is preferably 22 mol% or less, and more preferably 10 mol% or less. The glass forming the glass substrate base may include no alkali metal oxide.

In a case in which the glass forming the glass substrate base includes two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less, the content of the alkali metal oxide is preferably 17 mol% or less, and more preferably 10 mol% or less.

In addition, the glass forming the glass substrate base preferably includes an Al_2O_3-content of 5 mol% or more and 20 mol% or less. A lower limit of the Al_2O_3-content is preferably 8 mol% or more, more preferably 10 mol% or more, and particularly more preferably 11.5 mol% or more. An upper limit of the Al_2O_3-content is preferably 17.5 mol% or less, and more preferably 15 mol% or less.

The glass forming the glass substrate base

preferably includes a SiO_2-content of 55 mol% or more and 75 mol% or less, and an alkali earth metal oxide with a content of 0 mol% or more and 30 mol% or less. The SiO_2-content is more preferably 66 mol% or more and 75 mol% or less, and even more preferably 66 mol% or more and 70 mol% or less. The content of the alkali earth metal oxide is more preferably 5 mol% or more and 30 mol% or less, and even more preferably 16 mol% or more and 30 mol% or less.

In the case in which the glass forming the glass substrate base includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, the content of the alkali metal oxide is preferably 0 mol% or more and 25 mol% or less. The content of the alkali metal oxide in this case is more preferably 0 mol% or more and 15 mol% or less, and even more preferably 0 mol% or more and 2.5 mol% or less.

The specific modulus (or specific Young's modulus) of the glass substrate base is preferably high, and is preferably 32 MNm/kg or higher, and more preferably 33 MNm/kg or higher.

The end surface polishing process (s2) polishes the end surface (side surface part and chamfered part) of the glass substrate.

The principal plane polishing process (s3) uses a double side polisher to simultaneously polish the upper and lower principal planes of the glass substrate, while supplying a polishing fluid to the principal planes of the glass substrate. The glass substrate may be polished solely by a primary polishing. Further, the glass substrate may be polished by the primary polishing and a secondary polishing, or may be polished by performing a third polishing after the secondary polishing.

Lapping (for example, loose abrasive lapping, fixed abrasive lapping, or the like) of the principal

planes of the glass substrate may be carried out before the principal plane polishing process (s3). In addition, glass substrate cleaning (inter-process cleaning) or glass substrate etching (inter-process etching) may be carried out between processes. The lapping of the principal planes may broadly be interpreted as being included in the polishing of the principal planes.

[Magnetic Layer Deposition Process (b)]

The magnetic layer deposition process (b) deposits the magnetic layer (or magnetic film) on the glass substrate. A configuration of the magnetic layer that is deposited is not limited to a particular configuration, and may be arbitrarily selected according to a performance or the like required by the magnetic recording medium.

In addition, layers other than the magnetic layer may be formed between the glass substrate and the magnetic layer, or on the surface of the magnetic layer. Examples of these other layers include an underlayer formed between the glass substrate and the magnetic layer, and a protection layer, a lubricant layer, or the like provided on the surface of the magnetic layer.

Recording systems of the magnetic recording medium may include a longitudinal magnetic recording system, a perpendicular magnetic recording system, a heat-assisted magnetic recording system, or the like. The method of manufacturing the magnetic recording medium in this embodiment may be applied to the magnetic recording medium employing any of such recording systems. As an example, a description will be given of processes of forming various layers of the magnetic recording medium employing the perpendicular magnetic recording system, including the magnetic layer, on the surface of the glass

substrate.

The magnetic recording medium may have a configuration including the magnetic layer, the protection layer, and the lubricant layer. In the case in which the perpendicular magnetic recording system is employed, a soft magnetic underlayer that is made of a soft magnetic material is generally provided, in order to circular a recording magnetic field from a magnetic head. In this case, for example, the soft magnetic underlayer, a nonmagnetic intermediate layer, the magnetic layer for the perpendicular recording, the protection layer, and the lubricant layer may be successively stacked on the surface of the glass substrate.

A description will be given of the layers forming the magnetic recording medium employing the perpendicular magnetic recording system.

The soft magnetic underlayer may be formed by CoNiFe, FeCoB, CoCuFe, NiFe, FeAlSi, FeTaN, FeN, FeTaC, CoFeB, CoZrN, or the like, for example.

The nonmagnetic intermediate layer may be formed by Ru, Ru alloys, or the like, for example. The nonmagnetic intermediate layer includes a function to facilitate epitaxial growth of the magnetic layer for the perpendicular recording, and a function to block magnetic exchange coupling between the soft magnetic underlayer and the magnetic layer for the perpendicular recording.

The magnetic layer for the perpendicular recording has its axis of easy magnetization oriented in a direction perpendicular to the substrate surface, and includes at least Co and Pt. In order to reduce intergranular exchange coupling that causes high characteristic medium noise, the magnetic layer for the perpendicular recording preferably has a satisfactorily

isolated micrograin structure (or granular structure). More particularly, the magnetic layer for the perpendicular recording preferably includes an CoPt alloy or the like that is added with an oxide (SiO_2, SiO, Cr_2O_3, CoO, Ta_2O_3, TiO_2, or the like), Cr, B, Cu, Ta, Zr, or the like.

The soft magnetic underlayer, the nonmagnetic intermediate layer, and the magnetic layer for the perpendicular recording described above may be deposited continuously by inline sputtering, DC (Direct Current) magnetron sputtering, or the like.

The protection layer is provided on the magnetic layer for the perpendicular recording, in order to prevent corrosion of the magnetic layer for the perpendicular recording and prevent damage to a medium surface even when the magnetic head makes contact with the magnetic recording medium. The protection layer may be formed by a material including C, ZrO_2, SiO_2, or the like, for example. The protection layer may be deposited by inline sputtering, CVD (Chemical Vapor Deposition), spin-coating, or the like.

The lubricant layer is provided on the surface of the protection layer in order to reduce friction between the magnetic head and the magnetic recording medium (for example, magnetic disk). The lubricant layer may be formed by perfluoropolyether, fluorinated alcohol, fluorinated carboxylic acid, or the like, for example. The lubricant layer may be deposited by dipping, spraying, or the like.

The magnetic recording medium described above employs the perpendicular magnetic recording system, however, the magnetic recording medium according to the present invention is not limited to such, and the magnetic recording medium may employ other magnetic recording

systems including the heat-assisted magnetic recording system. For example, in the case of the magnetic recording medium employing the heat-assisted magnetic recording system, the magnetic layer preferably includes FePt, $SmCo_5$, or the like. In addition, the configuration of layers other than the magnetic layer may be selected arbitrarily according to the recording system that is employed by the magnetic recording medium.

The method of manufacturing the magnetic recording medium in this embodiment may include the magnetic layer deposition process (b). In the magnetic layer deposition process (b), a glass substrate, for example, is held by the holding tool such as a chuck or the like, and the magnetic layer may be deposited on the surface of the glass substrate while subjecting the glass substrate to heating or the like. The holding tool used in the magnetic layer deposition process (b) is not limited to a particular tool. For example, as illustrated in FIG. 2, an outer end surface part (or side surface part) of a glass substrate 20 my be held at a plurality of points by holding parts 211, 212, and 213 of the holding tool. The holding parts 211, 212, and 213 hold the glass substrate 20 by applying forces in directions towards the center of the glass substrate 20, as indicated by arrows A, B, and C. The holding parts 211, 212, and 213 apply forces in the directions parallel to the principal planes of the glass substrate 20, however, depending on the magnitude of the forces, the glass substrate 20 may undergo buckling deformation in a direction perpendicular to the principal planes thereof. The glass substrate 20 at parts in the vicinities of the holding parts 211, 212, and 213 undergoes local deformation in many cases, and a delayed restore deformation may occur. When the delayed

restore deformation occurs, the read error of the servo information is likely generated.

FIG. 2 illustrates an example in which the holding tool holds the glass substrate 20 at 3 points. However, the glass substrate 20 may be held at 2 points, or at 4 or more points. Further, the glass substrate 20 may be held by the holding parts of two or more holding tools.

In the example described above, the glass substrate is held by the holding parts that apply the forces from the outer end surface part towards the center of the glass substrate, however, the configuration used to hold the glass substrate is not limited to such a configuration. For example, two or more holding members may be arranged within the center hole of the glass substrate, and the holding members may apply forces to an inner end surface part defining the center hole of the glass substrate towards an outer periphery of the glass substrate, in order to hold the glass substrate.

In addition, a plurality of holding members may be arranged within the center hole of the glass substrate and also at the outer end surface part of the glass substrate. In this case, the holding members arranged within the center hole of the glass substrate apply forces to the inner end surface part of the glass substrate towards an outer periphery of the glass substrate, while the holding members arranged at the outer end surface part of the glass substrate apply forces to the outer end surface part towards the center of the substrate, in order to hold the glass substrate.

The holding tool is not limited to holding the glass substrate 20 by applying forces to the end surface part of the glass substrate 20 at a plurality of points,

and the magnetic layer may be deposited on the glass substrate 20 that is held by one or more holding tools having other holding configurations.

The holding tool described above may be used when depositing the magnetic layer on the glass substrate. However, a holding tool similar to that described above may be used when depositing the underlayer, the protection layer, the lubricant layer, or the like on the glass substrate. In other words, a holding tool similar to that described above used during the magnetic layer deposition process (b) may be used during an underlayer deposition process, a protection layer deposition process, a lubricant layer deposition process, or the like, and the buckling deformation may similarly occur during such processes.

[Magnetic Recording Medium Holding Process (c)]

The magnetic recording medium holding process (c) holds the magnetic recording medium obtained by the magnetic layer deposition process (b) within the cassette.

Generally, the magnetic recording medium that is obtained by depositing the magnetic layer or the like on the glass substrate is forwarded or shipped and transported to a factory that manufactures a HDD (Hard Disk Drive). For this reason, the magnetic recording medium manufacturing process may end when the magnetic recording medium is accommodated within the cassette. It may be sufficient to accommodate the magnetic recording medium within the cassette, however, it may be preferable to further accommodate the cassette that accommodates the magnetic recording medium within a decompressed packaging container.

A load is applied to the magnetic recording medium (or glass substrate) in the state held within the

cassette, or in the state further accommodated within the decompressed packaging container, and the buckling deformation or the bending deformation may occur in the magnetic recording medium, that is, in the glass substrate included in the magnetic recording medium. For this reason, inside the packaging container of the cassette that accommodates the magnetic recording medium during the magnetic recording medium holding process (c), a force is applied to the magnetic recording medium, and the force is removed when the packaging container is opened and the magnetic recording medium (or glass substrate) undergoes a displacement to return to its original shape.

For example, in a case in which the manufacturing process of the HDD is carried out after the magnetic recording layer deposition process (b) without changing the location of the process, the magnetic recording medium holding process (c) may be omitted.

The magnetic recording medium that is obtained by the method of manufacturing the magnetic recording medium described above may further be subjected to a hard disk assembling process to assemble the magnetic recording medium into the HDD, and a servo information write process to write servo information on the magnetic recording medium assembled within the HDD, in order to manufacture the HDD.

In the method of manufacturing the magnetic recording medium in this embodiment, the glass of the glass substrate included in the magnetic recording medium may include an Al_2O_3-content of 5 mol% or more. In addition, the glass forming the glass substrate included in the magnetic recording medium in this embodiment may include a predetermined amount of B_2O_3 or an amount of alkali metal oxide within a predetermined range. For this

reason, even in a case in which at least one of the buckling deformation and the bending deformation occurs in the glass substrate when performing the method of manufacturing the magnetic recording medium in this embodiment, the time it takes for the glass substrate to return to its original shape after the force (or load) is removed can be reduced. Consequently, even when the force (or load) is applied to the glass substrate (or magnetic recording medium) and the glass substrate (or magnetic recording medium) undergoes a deformation, a displacement in the glass substrate (or magnetic recording medium) due to its restoration force after the force (or load) applied thereto is removed ends or essentially ends by the time the servo information is written on the magnetic recording medium. Accordingly, the glass substrate (or magnetic recording medium) after being written with the servo information undergoes no displacement or only a displacement to a negligible extent, and it is possible to prevent the positions where the servo information are written from changing, and the error generation rate can be suppressed.

Next, a description will be given of the magnetic recording medium in this embodiment.

The magnetic recording medium in this embodiment may include the magnetic layer deposited on the glass substrate, and it is possible to obtain the magnetic recording medium to which the servo information is to be written on the magnetic layer that is deposited on the glass substrate. In the magnetic recording medium, the underlayer, the protection layer, the lubricant layer, or the like may be arbitrarily provided on the glass substrate, in addition to the magnetic layer. In the magnetic recording medium in this embodiment, the glass

forming the substrate may include an Al_2O_3-content of 5 mol% or more. In addition, the glass forming the glass substrate may preferably include a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less. The alkali metal oxide may be any kind of alkali metal oxide, and is not limited to a particular kind of alkali metal oxide. For example, the alkali metal oxide may typically include LiO_2, Na_2O, and K_2O.

According to the studies conducted by the present inventors, the Young's modulus of the glass substrate can be made sufficiently high by making the Al_2O_3-content of the glass forming the glass substrate 5 mol% or more.

Further, in the case in which the glass forming the glass substrate includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less, even when the force (or load) is applied to the glass substrate, the time it takes for the glass substrate to return to its original shape after removing the force (or load) can be reduced. In other words, after the force (or load) applied to the glass substrate is removed, the time (or duration) for which the glass substrate is deformed can be reduced.

In the magnetic recording medium in this embodiment, the glass forming the glass substrate of the magnetic recording medium preferably includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less. This is

because, even when a force (or load) is applied to the glass substrate and deformation of the glass substrate occurs, the time it takes for the glass substrate to return to its original shape after the force (or load) is removed can further be reduced.

Particularly in the case in which the glass forming the glass substrate of the magnetic recording medium includes B_2O_3, a lower limit of the B_2O_3-content is preferably 0.2 mol% or more, and more preferably 0.5 mol% or more. In addition, an upper limit of the B_2O_3-content is preferably 12 mol% or less, more preferably 10 mol% or less, even more preferably 5 mol% or less, and particularly more preferably less than 2 mol%. In a case in which the B_2O_3-content is less than 2 mol%, even when a force (or load) is applied to the glass substrate and deformation of the glass substrate occurs, the time it takes for the glass substrate to return to its original shape after the force (or load) is removed can be reduced, and furthermore, the specific modulus of the glass substrate can be made high. For this reason, even in a case in which the magnetic recording medium is rotated at a high speed, the generation of fluttering can be suppressed, and it is possible to particularly suppress the generation of a read or write error associated with the magnetic recording medium.

In the case in which the glass forming the glass substrate of the magnetic recording medium includes one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, the content of the alkali metal oxide is preferably 22 mol% or less, and more preferably 10 mol% or less. One or less kind of alkali metal oxide included in the glass refers to a case in which one kind of alkali metal oxide selected from alkali

metal oxides such as Na_2O, K_2O, Li_2O, or the like is included in the glass, or a case in which no alkali metal oxide is included in the glass.

In the case in which the glass forming the glass substrate of the magnetic recording medium includes two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less, the content of the alkali metal oxide is preferably 17 mol% or less, and more preferably 10 mol% or less.

Two or more kinds of alkali metal oxide included in the glass refers to a case in which two or more kinds of alkali metal oxides selected from alkali metal oxides such as Na_2O, K_2O, Li_2O, or the like are included in the glass. In this case, the content of each alkali metal oxide is not limited to a particular amount, and may be set to an arbitrary amount. For example, contents (or mol%) of each of the alkali metal oxides may be equal or balanced.

By using glass including a predetermined composition for the glass substrate of the magnetic recording medium in this embodiment, even when a force (or load) is applied to the glass substrate and deformation of the glass substrate occurs, a displacement in the glass substrate due to its restoration force after the force (or load) applied to the glass substrate is removed ends or essentially ends by the time the servo information is written on the magnetic recording medium. For this reason, the glass substrate (or magnetic recording medium) after being written with the servo information undergoes no displacement or only a displacement to a negligible extent. Consequently, it is possible to prevent the positions where the servo information are written from changing, and the error generation rate can be suppressed.

In addition, the glass forming the glass substrate of the magnetic recording medium in this embodiment preferably includes an Al_2O_3-content of 5 mol% or more and 20 mol% or less. A lower limit of the Al_2O_3-content is preferably 8 mol% or more, more preferably 10 mol% or more, and particularly more preferably 11.5 mol% or more. An upper limit of the Al_2O_3-content is preferably 17.5 mol% or less, and more preferably 15 mol% or less.

In the magnetic recording medium in this embodiment, the glass forming the glass substrate of the magnetic recording medium preferably includes a SiO_2-content of 55 mol% or more and 75 mol% or less, and an alkali earth metal oxide with a content of 0 mol% or more and 30 mol% or less. The SiO_2-content is more preferably 66 mol% or more and 75 mol% or less, and even more preferably 66 mol% or more and 70 mol% or less. The content of the alkali earth metal oxide is more preferably 5 mol% or more and 30 mol% or less, and even more preferably 16 mol% or more and 30 mol% or less.

In the case in which the glass forming the glass substrate of the magnetic recording medium includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, the content of the alkali metal oxide is preferably 0 mol% or more and 25 mol% or less. The content of the alkali metal oxide in this case is more preferably 0 mol% or more and 15 mol% or less, and even more preferably 0 mol% or more and 2.5 mol% or less.

The specific modulus (or specific Young's modulus) of the glass substrate is preferably high, and is preferably 32 MNm/kg or higher, and more preferably 33 MNm/kg or higher. When the specific modulus is high, the generation of the fluttering can be suppressed even when the magnetic recording medium is rotated at a high speed,

and it is possible to particularly suppress the generation of a read or write error associated with the magnetic recording medium.

A pseudoelastic deformation quantity A of the glass substrate included in the magnetic recording medium in this embodiment is preferably 2.0 μm or less. A lower limit of the pseudoelastic deformation quantity A is 0 μm. A lower limit of each of pseudoelastic deformation quantities B and C is also 0 μm, as will be described later.

In the case in which both end parts of the glass substrate along diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central upper surface of the glass substrate for 48 hours, the pseudoelastic deformation quantity A refers to an absolute value of a difference between the flatness after 5 hours elapses from the time when the applied load is removed and the flatness before the load is applied to the glass substrate.

For example, the pseudoelastic deformation quantity A may be calculated in the following manner. First, the two end parts of the glass substrate along diametrically opposite directions, surrounded by a chord and an arc located at each of the two opposing ends on the glass substrate, are supported from the lower surface side of the glass substrate, where a maximum value of a distance between the chord and the arc is 2.3% to 7.7% of the diameter of the glass substrate. A centerline along the direction of a width amounting to 35% to 80% of the diameter of the glass substrate, passes through the center of the glass substrate. A load calculated from PP_a mm^2 x 2.28 mN/mm^2 is applied on the central upper surface of the

glass substrate parallel to the chord for 48 hours, where PP_a denotes an area of the principal plane of the glass substrate. Thereafter, the load is removed, and the pseudoelastic deformation quantity A is obtained from the absolute value of the difference between the flatness after 5 hours elapses from the time when the applied load is removed and the flatness before the load is applied.

Accordingly, the smaller the value of the pseudoelastic deformation quantity A, the shorter the time it takes for the glass substrate and the magnetic recording medium to return to their original shapes after the load (or force) that deformed the glass substrate and the magnetic recording medium is removed.

When measuring the pseudoelastic deformation quantity A, the load is applied to the glass substrate for 48 hours because the studies conducted by the present inventors confirmed that a change in the flatness saturates after the load is applied to the glass substrate for approximately 16 hours, regardless of the composition of the glass substrate. For this reason, the time of 48 hours is set from the standpoint of a length of time by which the change in the flatness saturates and no further change occurs in the flatness even when the load is applied to the glass substrate for a longer time.

The flatness before applying the load to the glass substrate is compared with the flatness after 5 hours elapses from the time when the load is removed, because after the magnetic recording medium is manufactured by carrying out the magnetic layer deposition process, the magnetic recording medium holding process, or the like, the hard disk assembling process to assemble the magnetic recording medium in the HDD or the like is carried out before the servo information is written on the

magnetic recording medium. Normally, after the magnetic recording medium is manufactured, that is, after the magnetic layer deposition process or after the packaging container formed by the magnetic recording medium holding process is opened, it takes at least approximately 5 hours to approximately 12 hours before the servo information is written on the magnetic recording medium.

When the pseudoelastic deformation quantity A of the glass substrate included in the magnetic recording medium in this embodiment is within the range described above, the glass substrate and the magnetic recording medium return to their original shapes within a short time, even when the buckling deformation, the bending deformation, or the like occurs in the glass substrate (or the magnetic recording medium). In addition, even in a case in which the glass substrate (or magnetic recording medium) undergoes a further displacement with further lapse of time, the displacement becomes less than the pseudoelastic deformation quantity A, and an amount of change in the flatness becomes small. For this reason, when the pseudoelastic deformation quantity A of the glass substrate included in the magnetic recording medium is within the range described above, the displacement after the servo information is written on the magnetic recording medium becomes small, to thereby suppress the generation of the error.

In the case of the glass substrate of the magnetic recording medium, the pseudoelastic deformation quantity A is preferably 1.5 μm or less, and more preferably 1.0 μm or less, and even more preferably 0.4 μm or less.

Further, in a case in which both end parts of the glass substrate along diametrically opposite

directions are supported from the lower surface side of the glass substrate and the load is applied to the central (or center region including the center of) upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity B refers to an absolute value of a difference between the flatness after 5 hours elapses from the time when the applied load is removed and a flatness after 48 hours elapses from the time when the applied load is removed. The pseudoelastic deformation quantity B of the glass substrate is preferably 1. 5 μm or less.

For example, the pseudoelastic deformation quantity B may be calculated in the following manner. First, the two end parts of the glass substrate along diametrically opposite directions, surrounded by a chord and an arc located at each of the two opposing ends on the glass substrate, are supported from the lower surface side of the glass substrate, where the maximum value of the distance between the chord and the arc is 2.3% to 7.7% of the diameter of the glass substrate. The centerline along the direction of a width amounting to 35% to 80% of the diameter of the glass substrate, passes through the center of the glass substrate. The load calculated from PP_a mm^2 x 2.28 mN/mm^2 is applied on the central upper surface of the glass substrate parallel to the chord for 48 hours, where PP_a denotes the area of the principal plane of the glass substrate. Thereafter, the load is removed, and the pseudoelastic deformation quantity B is obtained from the absolute value of the difference between the flatness after 5 hours elapses from the time when the applied load is removed and the flatness after 48 hours elapses from the time when the applied load is removed.

The pseudoelastic deformation quantity B corresponds to an amount of change in the flatness at a

time after 5 hours elapses from the time when the load applied to the glass substrate is removed to the flatness at a time after 48 hours elapses from the time when the load is removed. For this reason, the smaller the value of the pseudoelastic deformation quantity B, the smaller the amount of change in the flatness from the time after 5 hours elapses from the time when the load is removed.

When the pseudoelastic deformation quantity B of the glass substrate included in the magnetic recording medium in this embodiment is within the range described above and the servo information is written on the magnetic recording medium after 5 hours elapses from the time when the load applied to the glass substrate is removed, the change in the flatness after the writing of the servo information, that is, the displacement in the glass substrate (or magnetic recording medium), is small. For this reason, when the pseudoelastic deformation quantity B of the glass substrate included in the magnetic recording medium is within the range described above, the displacement after the servo information is written on the magnetic recording medium can be prevented, to thereby further suppress the generation of the error.

The pseudoelastic deformation quantity B is not limited to a particular value, as long as the displacement of the servo information after being written on the magnetic recording medium is within a tolerable range such that the read and write of data can be performed without error. For example, the the pseudoelastic quantity B is preferably 1.5 μm or less, as described above. Further, the pseudoelastic quantity B is more preferably 1.0 μm or less, even more preferably 0.5 μm or less, and particularly more preferably 0.4 μm or less.

Further, in a case in which both end parts of

the glass substrate along diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central (or center region including the center of) upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity C refers to the flatness after 5 hours elapses from the time when the applied load is removed. The pseudoelastic deformation quantity C of the glass substrate is preferably 2. 5 μm or less, more preferably 2.0 μm or less, even more preferably 1. 5 μm or less, and particularly more preferably 1.0 μm or less.

For example, the pseudoelastic deformation quantity C may be calculated in the following manner. First, the two end parts of the glass substrate along diametrically opposite directions, surrounded by a chord and an arc located at each of the two opposing ends on the glass substrate, are supported from the lower surface side of the glass substrate, where the maximum value of the distance between the chord and the arc is 2.3% to 7.7% of the diameter of the glass substrate. The centerline along the direction of a width amounting to 35% to 80% of the diameter of the glass substrate, passes through the center of the glass substrate. The load calculated from PP_a mm^2 x 2.28 mN/mm^2 is applied on the central upper surface of the glass substrate parallel to the chord for 48 hours, where PP_a denotes the area of the principal plane of the glass substrate. Thereafter, the load is removed, and the pseudoelastic deformation quantity C is obtained from the flatness after 5 hours elapses from the time when the applied load is removed.

The smaller the value of the pseudoelastic deformation quantity C, the smaller the flatness at a time after 5 hours elapses from the time when the load applied

to the glass substrate is removed. In other words, even when the load is applied to the glass substrate for 48 hours, the displacement in the glass substrate satisfying the parameters described above is small and/or the flatness recovers in 5 hours after the load applied to the glass substrate is removed. For this reason, even when the servo information is written on the magnetic recording medium after 5 hours elapses from the time when the load applied to the glass substrate is removed, the deformation of the glass substrate that occurs thereafter is small, and it is possible to further suppress the generation of the error.

Next, a description will be given of a method of measuring the pseudoelastic deformation quantities A through C described above, by referring to FIGs. 3, 4A, and 4B.

In the following description, the flatness at each point in time is represented as F(xh) in FIG. 3, where "x" denotes an elapsed time from a point in time when the load is removed, using a reference (0h) as the point in time when the load is removed. In addition, a point in time before the load is removed is represented with a minus sign "-", and for example, F(-48h) indicates the flatness of the glass substrate at a point in time 48 hours before the load is removed, that is, at the point in time before the load is applied to the glass substrate.

First, a description will be given of a flow diagram for explaining measurement of the pseudoelastic deformation quantity, by referring to FIG. 3.

As illustrated in FIG. 3, before applying the load to the glass substrate, a flatness F(-48h) of the glass substrate is measured at a point (1) in time in FIG. 3. Thereafter, the load is applied to the glass substrate

for 48 hours by a method which will be described later. The load is applied to the glass substrate for 48 hours because the studies conducted by the present inventors confirmed that the change in the flatness saturates after the load is applied to the glass substrate for approximately 16 hours, regardless of the composition of the glass substrate. For this reason, the time of 48 hours is set from the standpoint of the length of time by which the change in the flatness saturates and no further change occurs in the flatness even when the load is applied to the glass substrate for a longer time.

The load is removed at a point (2) in time after the load is applied to the glass substrate for 48 hours, and the flatness at this point (2) in time is denoted by F(0h). Thereafter, at a point (3) in time when 5 hours elapses from the point (2) in time when the load is removed, the flatness is measured again, and the flatness measured at the point (3) in time is denoted by F(5h). This is because, in general, after the magnetic layer deposition process or after the packaging container formed by the magnetic recording medium holding process is opened, it takes at least approximately 5 hours to approximately 12 hours before the servo information is written on the magnetic recording medium.

At a point (4) in time after 48 hours elapses from the time when the load is removed, the flatness is measured, and the flatness measured at the point (4) in time is denoted by F(48h). This is because, in a general HDD assembling process, a read and write test is performed after approximately 48 hours elapses from a time when the packaging container formed by the magnetic layer deposition process and the magnetic recording medium holding process is opened.

As described above, the pseudoelastic deformation quantity A can be calculated from the absolute value of the difference between the flatness F(-48h) at the point (1) in time before the load is applied to the glass substrate and the flatness F(5h) at the point (3) in time after 5 hours elapses from the time when the load applied to the glass substrate is removed, as represented by the following formula.

$$A = |F(5h) - F(-48h)|$$

The formula above indicates that the smaller the value of the pseudoelastic deformation quantity A, the more the glass substrate returns to its original shape (or flatness) from the deformed state caused by the applied load.

In addition, the pseudoelastic deformation quantity B can be calculated from the absolute value of the difference between the flatness F(5h) at the point (3) in time after 5 hours elapses from the time when the load applied to the glass substrate is removed and the flatness F(48h) at the point (4) in time after 48 hours elapses from the time when the load applied to the glass substrate is removed, as represented by the following formula.

$$B = |F(5h) - F(48h)|$$

The pseudoelastic deformation quantity C can be calculated from the flatness F(5h) at the point (3) in time after 5 hours elapses from the time when the load applied to the glass substrate is removed, as represented by the following formula.

$$C = F(5h)$$

A means or method of measuring the flatness of the glass substrate is not limited to a particular means or method. For example, the flatness of the glass substrate may be measured using the phase shift

interference method (or phase shift method).

Next, a description will be given of a method of applying the load to the glass substrate when measuring the pseudoelastic deformation quantity.

When applying the load to the glass substrate, both end parts of the glass substrate along the diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central upper surface of the glass substrate in a downward direction perpendicular to the upper surface of the glass substrate.

A description will be given of an example of the load applying method, by referring to FIGs. 4A and 4B. FIGs. 4A and 4B are diagrams for explaining the load applying method at the time of measuring the pseudoelastic deformation quantity.

FIGs. 4A and 4B illustrate an example in which a load 45 is applied to a glass substrate 43 in order to measure the pseudoelastic deformation quantity. FIG. 4A illustrates a lateral side view, and FIG. 4B illustrates a top view.

As illustrated in FIGs. 4A and 4B, a V-shaped block 41 is used to support the two end parts of the glass substrate 43. The load (or weight) 45 is arranged on the glass substrate 43 that is arranged on the V-shaped block 41, in order to apply the load 45 on the glass substrate 43.

The V-shaped block 41 includes a V-shaped cutout part 42 at a central part thereof. The glass substrate 43 is arranged on the V-shaped block 41 so as to cover the V-shaped cutout part 42, in order to to support only two end parts 44 of the glass substrate 43 from the lower surface side of the glass substrate 43. A member that supports

the glass substrate 43 is not limited to the V-shaped block 41, and any suitable member may be used as long as the member is capable of supporting the two end parts 44 of the glass substrate 43. For example, two rectangular column-shaped blocks may be arranged with a gap therebetween, to support the two end parts 44 of the glass substrate 43.

The two end parts (or supported parts) 44 of the glass substrate 43 along the diametrically opposite directions are surrounded by arcs and chords 441 and 442, respectively. The chords 441 and 442 are formed by end parts of the V-shaped cutout part 42 of the V-shaped block 41, and are parallel to each other. A maximum distance between the chord 441 (or 442) and the arc, that is, a distance W1 in FIG. 4A, is preferably 2.3% to 7.7% of the diameter of the glass substrate 43, and more preferably 4.0% to 6.0% of the diameter of the glass substrate 43, for example. This is because, if the range of the glass substrate 43 that is supported is to narrow, the glass substrate 43 may slip and fall and become damaged when the load is applied to the glass substrate 43. On the other hand, if the range of the glass substrate 43 that is supported is too wide, a distance between the part of the glass substrate 43 applied with the load and the part of the glass substrate 43 that is supported becomes short, thus making it difficult to detect a change in the flatness and deteriorating the resolution of the flatness measurement.

The load is preferably applied to the central part, including the center, of the glass substrate 43. However, the exact location where the load is applied and the magnitude of the load are not limited to a particular location and a particular magnitude, respectively.

For example, as illustrated in FIG. 4B, a load (or weight) 45 having a rectangular parallelepiped shape may be arranged on the central upper surface of the glass substrate 43. In this case, the load 45 is preferably arranged on the surface of the glass substrate 43 to be parallel to the chords 441 and 442 that surround the two end parts 44 of the glass substrate 43 together with the corresponding arcs. In addition, as illustrated in FIG. 4B, the load 45 is preferably arranged to completely cover the glass substrate 43 by a predetermined width (or range) from a centerline that is parallel to the chords 441 and 442. A width W2 of the load (or weight) 45 in FIGs. 4A and 4B is preferably 35% to 80% of the diameter of the glass substrate 43, and more preferably 35% to 50% of the diameter of the glass substrate 43.

If the range in which the load 45 is applied is too narrow, for example, the load 45 may become unstable and fall, and damage the glass substrate 43. On the other hand, if the range in which the load 45 is applied is too wide, the distance between the part where the load 45 is applied and the two end parts 44 that are supported becomes narrow, thus making it difficult to detect a change in the flatness and deteriorating the resolution of the flatness measurement.

The length of the load (or weight) 45 along the vertical direction in FIG. 4B is preferably the same as or longer than the diameter of the glass substrate 43.

The weight of the load 45 is not limited to a particular weight, as long as the weight causes pseudoelastic deformation of the glass substrate 43 to such an extent that the glass substrate 43 does not break. The weight of the load 45 may be selected according to the area, the strength, or the like of the glass substrate 43.

For example, the weight of the load 45 may be selected so that the load 45 applied for an area of 1 mm^2 of the principal plane of the glass substrate 43 is 0.233 gf (or 2.28 mN). In other words, the weight of the load 45 may be selected so that load 45 calculated from PP_a mm^2 x 0.233 gf/mm^2 (or 2.28 mN/mm^2) is applied to the glass substrate 43, where PP_a denotes the area of the principal plane of the glass substrate 43. For example, in the case of a glass substrate (2.5-inch glass substrate) having an outer diameter of 65 mm and an inner diameter (diameter of the circular center hole) of the glass substrate, a load of 700 gf (6.86 N) is applied on the central upper surface of the glass substrate.

Even when the force (or load) applied to the glass substrate is the same, stress caused by the buckling deformation or the bending deformation becomes larger as the the glass substrate becomes thinner, and local deformation is more likely to occur. The magnetic recording medium in this embodiment more effectively functions in such a case. For example, when two ends of a simple beam having a rectangular column shape and a rectangular cross section are supported and a constant load is applied to a center of the simple beam, a bending amount d at a central part of the simple beam may be represented by the following formula, where P denotes a center load, L denotes a length of the simple beam, E denotes a Young's modulus of a material forming the simple beam, I denotes a second moment of inertia represented by $(bh^3)/12$, b denotes a width of the simple beam, and h denotes a thickness of the glass substrate.

$$d = (PL^3)/(48EI)$$

For this reason, the delayed restore deformation is inversely proportional to the thickness of the glass

substrate to the third power, and the thinner the glass substrate, the more notably the relayed restore deformation increases. However, according to the magnetic recording medium in this embodiment, even in a case in which the glass substrate is thin, the displacement of the glass substrate ends or essentially ends by the time the servo information is written on the magnetic recording medium.

In the magnetic recording medium of this embodiment described above, even when the force (or load) is applied to the glass substrate included in the magnetic recording medium and the glass substrate (or magnetic recording medium) is deformed, the displacement in the glass substrate due to its restoration force after the force (or load) applied to the glass substrate is removed ends or essentially ends by the time the servo information is written on the magnetic recording medium. For this reason, the glass substrate (or magnetic recording medium) after being written with the servo information undergoes no displacement or only a displacement to a negligible extent. Consequently, it is possible to prevent the positions where the servo information are written from changing, and the error generation rate can be suppressed.

[Second Embodiment]

Next, a description will be given of the configuration of the magnetic recording medium in a second embodiment of the present invention.

The magnetic recording medium in this embodiment includes a magnetic layer that is deposited on a glass substrate, and is to be written with the servo information. The pseudoelastic deformation quantity A of the glass substrate included in the magnetic recording medium is preferably 2.0 μm or less. The lower limit of the

pseudoelastic deformation quantity A is 0 μm, and the same holds true for the lower limits of the pseudoelastic deformation quantities B and C.

In the case in which both end parts of the glass substrate along diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central upper surface of the glass substrate for 48 hours, the pseudoelastic deformation quantity A refers to an absolute value of a difference between the flatness after 5 hours elapses from the time when the applied load is removed and the flatness before the load is applied to the glass substrate.

For example, the pseudoelastic deformation quantity A may be calculated in the following manner. First, the two end parts of the glass substrate along diametrically opposite directions, surrounded by a chord and an arc located at each of the two opposing ends on the glass substrate, are supported from the lower surface side of the glass substrate, where a maximum value of a distance between the chord and the arc is 2.3% to 7.7% of the diameter of the glass substrate. A centerline along the direction of a width amounting to 35% to 80% of the diameter of the glass substrate, passes through the center of the glass substrate. A load calculated from PP_a mm^2 x 2.28 mN/mm^2 is applied on the central upper surface of the glass substrate parallel to the chord for 48 hours, where PP_a denotes an area of the principal plane of the glass substrate. Thereafter, the load is removed, and the pseudoelastic deformation quantity A is obtained from the absolute value of the difference between the flatness after 5 hours elapses from the time when the applied load is removed and the flatness before the load is applied.

Accordingly, the smaller the value of the pseudoelastic deformation quantity A, the shorter the time it takes for the glass substrate and the magnetic recording medium to return to their original shapes after the load (or force) that deformed the glass substrate and the magnetic recording medium is removed.

When measuring the pseudoelastic deformation quantity A, the load is applied to the glass substrate for 48 hours because the studies conducted by the present inventors confirmed that a change in the flatness saturates after the load is applied to the glass substrate for approximately 16 hours, regardless of the composition of the glass substrate. For this reason, the time of 48 hours is set from the standpoint of a length of time by which the change in the flatness saturates and no further change occurs in the flatness even when the load is applied to the glass substrate for a longer time.

The flatness before applying the load to the glass substrate is compared with the flatness after 5 hours elapses from the time when the load is removed, because after the magnetic recording medium is manufactured by carrying out the magnetic layer deposition process, the magnetic recording medium holding process, or the like, the hard disk assembling process to assemble the magnetic recording medium in the HDD or the like is carried out before the servo information is written on the magnetic recording medium. Normally, after the magnetic recording medium is manufactured, that is, after the magnetic layer deposition process or after the packaging container formed by the magnetic recording medium holding process is opened, it takes at least approximately 5 hours to approximately 12 hours before the servo information is written on the magnetic recording medium.

When the pseudoelastic deformation quantity A of the glass substrate included in the magnetic recording medium in this embodiment is within the range described above, the glass substrate and the magnetic recording medium return to their original shapes within a short time, even when the buckling deformation, the bending deformation, or the like occurs in the glass substrate (or the magnetic recording medium). In addition, even in a case in which the glass substrate (or magnetic recording medium) undergoes a further displacement with further lapse of time, the displacement becomes less than the pseudoelastic deformation quantity A, and an amount of change in the flatness becomes small. For this reason, when the pseudoelastic deformation quantity A of the glass substrate included in the magnetic recording medium is within the range described above, the displacement after the servo information is written on the magnetic recording medium becomes small, to thereby suppress the generation of the error.

In the case of the glass substrate of the magnetic recording medium, the pseudoelastic deformation quantity A is preferably 1.5 μm or less, and more preferably 1.0 μm or less, and even more preferably 0.4 μm or less.

Further, in a case in which both end parts of the glass substrate along diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central (or center region including the center of) upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity B refers to an absolute value of a difference between the flatness after 5 hours elapses from the time when the applied load is removed and a flatness

after 48 hours elapses from the time when the load is removed. The pseudoelastic deformation quantity B of the glass substrate is preferably 1. 5 μm or less.

For example, the pseudoelastic deformation quantity B may be calculated in the following manner. First, the two end parts of the glass substrate along diametrically opposite directions, surrounded by a chord and an arc located at each of the two opposing ends on the glass substrate, are supported from the lower surface side of the glass substrate, where the maximum value of the distance between the chord and the arc is 2.3% to 7.7% of the diameter of the glass substrate. The centerline along the direction of a width amounting to 35% to 80% of the diameter of the glass substrate, passes through the center of the glass substrate. The load calculated from PP_a mm^2 x 2.28 mN/mm^2 is applied on the central upper surface of the glass substrate parallel to the chord for 48 hours, where PP_a denotes the area of the principal plane of the glass substrate. Thereafter, the load is removed, and the pseudoelastic deformation quantity B is obtained from the absolute value of the difference between the flatness after 5 hours elapses from the time when the applied load is removed and the flatness after 48 hours elapses from the time when the load is removed.

The pseudoelastic deformation quantity B corresponds to an amount of change in the flatness at a time after 5 hours elapses from the time when the load applied to the glass substrate is removed to the flatness at a time after 48 hours elapses from the time when the load is removed. For this reason, the smaller the value of the pseudoelastic deformation quantity B, the smaller the amount of change in the flatness from the time after 5 hours elapses from the time when the load is removed.

When the pseudoelastic deformation quantity B of the glass substrate included in the magnetic recording medium in this embodiment is within the range described above and the servo information is written on the magnetic recording medium after 5 hours elapses from the time when the load applied to the glass substrate is removed, the change in the flatness after the writing of the servo information, that is, the displacement in the glass substrate (or magnetic recording medium), is small. For this reason, when the pseudoelastic deformation quantity B of the glass substrate included in the magnetic recording medium is within the range described above, the displacement after the servo information is written on the magnetic recording medium can be prevented, to thereby further suppress the generation of the error.

The pseudoelastic deformation quantity B is not limited to a particular value, as long as the displacement of the servo information after being written on the magnetic recording medium is within a tolerable range such that the read and write of data can be performed without error. For example, the the pseudoelastic quantity B is preferably 1.5 μm or less, as described above. Further, the pseudoelastic quantity B is more preferably 1.0 μm or less, even more preferably 0.5 μm or less, and particularly more preferably 0.4 μm or less.

Further, in a case in which both end parts of the glass substrate along diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central (or center region including the center of) upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity C refers to the flatness after 5 hours elapses from the time when the applied load is

removed. The pseudoelastic deformation quantity C of the glass substrate is preferably 2. 5 μm or less, more preferably 2.0 μm or less, even more preferably 1. 5 μm or less, and particularly more preferably 1.0 μm or less.

For example, the pseudoelastic deformation quantity C may be calculated in the following manner. First, the two end parts of the glass substrate along diametrically opposite directions, surrounded by a chord and an arc located at each of the two opposing ends on the glass substrate, are supported from the lower surface side of the glass substrate, where the maximum value of the distance between the chord and the arc is 2.3% to 7.7% of the diameter of the glass substrate. The centerline along the direction of a width amounting to 35% to 80% of the diameter of the glass substrate, passes through the center of the glass substrate. The load calculated from PP_a mm^2 x 2.28 mN/mm^2 is applied on the central upper surface of the glass substrate parallel to the chord for 48 hours, where PP_a denotes the area of the principal plane of the glass substrate. Thereafter, the load is removed, and the pseudoelastic deformation quantity C is obtained from the flatness after 5 hours elapses from the time when the applied load is removed.

The smaller the value of the pseudoelastic deformation quantity C, the smaller the flatness at a time after 5 hours elapses from the time when the load applied to the glass substrate is removed. In other words, even when the load is applied to the glass substrate for 48 hours, the displacement in the glass substrate satisfying the parameters described above is small and/or the flatness recovers in 5 hours after the load applied to the glass substrate is removed. For this reason, even when the servo information is written on the magnetic recording

medium after 5 hours elapses from the time when the load applied to the glass substrate is removed, the deformation of the glass substrate that occurs thereafter is small, and it is possible to further suppress the generation of the error.

The measurements of the pseudoelastic deformation quantities A through C described above in this embodiment may be performed similarly to the measurements of the pseudoelastic deformation quantities A through C in the first embodiment described above, and a description thereof will be omitted.

In the magnetic recording medium of this embodiment described above, even when the force (or load) is applied to the magnetic recording medium and the magnetic recording medium is deformed, the displacement in the magnetic recording medium due to its restoration force after the force (or load) applied to the magnetic recording medium is removed ends or essentially ends by the time the servo information is written on the magnetic recording medium. For this reason, the magnetic recording medium after being written with the servo information undergoes no displacement or only a displacement to a negligible extent. Consequently, it is possible to prevent the positions where the servo information are written from changing, and the error generation rate can be suppressed.

[Practical Examples]

Next, a description will be given of practical examples, however, the present invention is not limited to these practical examples.

[Practical Example 1]

First, a description will be given of an evaluation method for the glass substrate used in the

magnetic recording media of the following practical examples and comparison examples, and an evaluation method for the magnetic recording media deposited with thin films such as the magnetic layer on the glass substrate surface.

(1) Evaluation of Dependency of Flatness Immediately After Removing Load on Load Applying Time Before Removing Load:

The load applying time before removing the load is changed, and a change in the flatness immediately after removing the load (or force) is evaluated.

A description will be given of the method of applying the load (or force) to the glass substrate.

First, the two end parts 44 of the glass substrate 43 to be used for the magnetic recording medium are supported on the V-shaped block 41, as illustrated in FIGs. 4A and 4B.

The two end parts (or supported parts) 44 of the glass substrate 43 along the diametrically opposite directions are surrounded by the chords 441 and 442 and the arcs (or shorter arcs cut out by the chords 441 and 442), respectively. The maximum distance W1 between the chord 441 (or 442) and the arc is set to be 5.4% (3.5 mm) of the diameter of the glass substrate 43.

Next, the load 45 is arranged on the principal plane of the glass substrate 43 to be parallel to the chords 441 and 442 that surround the two end parts 44 of the glass substrate 43 together with the corresponding arcs. In this example, the load 45 has a size such that its horizontal width, that is, the width W2, is 38.5% (25 mm) of the diameter of the glass substrate 43, and the load applied by the load 45 is 700 gf (6.86 N). In this case, the load 45 is arranged so that its centerline along the direction of the width of the load 45 passes through

the center of the glass substrate 43.

In addition, the length of the load 45 along the vertical direction in FIG. 4B is longer than the diameter of the glass substrate 43, in order to completely cover the glass substrate 43 by the horizontal width (or range).

The change in the flatness depending on the load applying time is evaluated by changing the time for which the load (or force) is applied to the glass substrate, in order to evaluate the flatness of the glass substrate depending on the load applying time. For each sample, the load 45 is arranged on the glass substrate 43 for the load applying times illustrated in Table 2 which will be described later, and the flatness is measured immediately after removing the load 45.

The load is applied for a predetermined time with respect to each glass substrate, and the flatness is measured immediately after removing the load applied for the predetermined time. The flatness is measured using the phase shift interference method (or phase shift method). More particularly, an interference flatness measuring apparatus (product name Zygo GI Flat (MESA) manufactured by Zygo Corporation) is used to measure the flatness using a measuring wavelength of 680 nm.

(2) Evaluation of Dependency of Flatness Immediately After Removing Load on Elapsed Time After Removing Load:

The method of applying the load to the glass substrate is the same as when performing the evaluation (1) of the dependency of the flatness immediately after removing the load on the load applying time before removing the load. The load is applied to the glass substrate for 24 hours.

Then, after removing the load, the flatness is measured for every predetermined time indicated by the

elapsed time after removing the load illustrated in Table 3 which will be described later. The flatness is measured using the phase shift interference method (or phase shift method), similarly to that when performing the evaluation (1) of the dependency of the flatness immediately after removing the load on the load applying time before removing the load.

(3) Evaluation of Pseudoelastic Deformation Quantities A, B, and C:

In order to evaluate the pseudoelastic deformation quantities A, B, and C, the flatness F(-48h) before applying the load to the glass substrate, the flatness F(5h) after 5 hours elapses from the time when the load is removed after being applied for 48 hours, and the flatness F(48h) after 48 hours elapses from the time when the load is removed after being applied for 48 hours are measured, as described above in conjunction with the first embodiment.

The flatness at each point in time is measured using the phase shift interference method (or phase shift method). More particularly, the interference flatness measuring apparatus (product name Zygo GI Flat (MESA) manufactured by Zygo Corporation) is used to measure the flatness using the measuring wavelength of 680 nm.

Thereafter, the pseudoelastic deformation quantities A, B, and C are calculated from the measured flatnesses based on the following formulas.

$$A = |F(5h) - F(-48h)|$$

$$B = |F(5h) - F(48h)|$$

$$C = F(5h)$$

The method of applying the load to the glass substrate is the same as when performing the evaluation (1) of the dependency of the flatness immediately after

removing the load on the load applying time before removing the load. The load is applied to the glass substrate for 48 hours.

(4) Read and Write Test:

A read and write test is performed according to the following procedure, with respect to the magnetic recording media that are obtained.

More particularly, each magnetic recording medium having the magnetic layer or the like formed on the glass substrate is assembled within the HDD, and the servo information is written on the magnetic recording medium according to the following procedure. Thereafter, magnetic signals are recorded under the condition including a track density of approximately 254 kTPI (Tracks Per Inch) and a linear recording density of approximately 1500 BPI (Bits Per Inch), according to the procedures of each practical example, and the recorded signals are read in order to confirm the generation of error.

In this practical example 1, the magnetic recording media in accordance with examples Ex-1 through Ex-10 are manufactured and evaluated. The magnetic recording media in accordance with examples Ex-1 through Ex-10 include glass substrates having different glass compositions, as illustrated in Table 1. The examples Ex-1 through Ex-7 correspond to practical examples, and the examples Ex-8 through Ex-10 correspond to comparison examples.

Table 1

		Ex-1	Ex-2	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8	Ex-9	Ex-10
GLASS COMPOSITION (mol%)	SiO_2	65.8	63.9	62.1	60.4	67.0	66.9	67.0	64.5	65.8	67.7
	Al_2O_3	11.1	10.7	10.4	10.1	13.0	12.7	13.5	12.0	8.8	4.9
	B_2O_3	7.6	7.4	7.1	6.9	1.0	1.9	—	—	—	—
	MgO	5.7	5.5	5.4	5.3	9.0	8.5	10.0	—	—	10.9
	CaO	4.9	4.8	4.7	4.5	5.5	5.5	5.0	—	—	—
	SrO	4.9	4.8	4.6	4.5	4.5	4.5	4.5	—	—	—
	BaO	—	—	—	—	—	—	—	—	—	—
	TiO_2	—	—	—	—	—	—	—	—	—	4.0
	ZrO_2	—	—	—	—	—	—	—	1.8	2.8	—
	Li_2O	—	—	—	—	—	—	—	12.8	11.7	—
	Na_2O	—	2.9	5.7	8.3	—	—	—	5.5	10.6	4.9
	K_2O	—	—	—	—	—	—	—	3.4	0.3	7.6
	RO	15.5	15.1	14.7	14.3	19.0	18.5	19.5	0.0	0.0	10.9
	R_2O	0.0	2.9	5.7	8.3	0.0	0.0	0.0	21.7	22.6	12.5

[Manufacturing Glass Substrate]

The glass substrates are formed according to the following procedures using glass substrate bases having the glass compositions of the examples Ex-1 through Ex-10 in Table 1, by cutting the glass substrate bases into a donut shape or a disk shape having an outer diameter of 65 mm, a thickness of 0.635 mm, and a circular center hole having a diameter of 20 mm. In Table 1, RO indicates a content of an alkali earth metal oxide included in the glass composition of the glass substrate base, and R_2O indicates a content of an alkali metal oxide included in the glass composition of the glass substrate base. In addition, in Table 1, "-" indicates that no corresponding component is included, that is, a content of the corresponding component included in the glass composition is 0.

First, the glass substrate base is formed into the disk-shaped glass substrate having the circular center hole.

A chamfering process (inner peripheral chamfering and outer peripheral chamfering) is performed on the inner peripheral end surface and the outer peripheral end surface of the disk-shaped glass substrate, in order to obtain a glass substrate having a chamfering angle of 45°.

After the chamfering process, a lapping process is performed on the upper and lower principal planes of the glass substrate using alumina abrasive grains, and the abrasive grains are removed by cleaning.

Next, the outer peripheral side surface and the outer peripheral chamfered part of the glass substrate are polished using a polishing brush and a polishing fluid including cerium oxide abrasive grains, in order to remove an affected or damaged layer (scratches or the like) on the outer peripheral side surface and the outer peripheral chamfered part of the glass substrate, and further, the outer peripheral end surface of the glass substrate is polished into a mirror surface (outer peripheral end surface polishing process).

After polishing the outer peripheral end surface of the glass substrate, the inner peripheral side surface and the inner peripheral chamfered part of the glass substrate are polished using a polishing brush and a polishing fluid including cerium oxide abrasive grains, in order to remove an affected or damaged layer (scratches or the like) on the inner peripheral side surface and the inner peripheral chamfered part of the glass substrate, and further, the inner peripheral end surface of the glass substrate is polished into a mirror surface (inner

peripheral end surface polishing process). The glass substrate after the inner peripheral end surface thereof is polished is cleaned in order to remove the abrasive grains.

After the end surface of the glass substrate is processed, a lapping process is performed on the upper and lower principal planes of the glass substrate, using a fixed diamond abrasive grain tool and a grinding fluid, and the glass substrate is then cleaned.

Next, the upper and lower principal planes of the glass substrate is subjected to a primary polishing by a 22B type double side polisher (product name DSM22B-6PV-4MH manufactured by Speedfam Co., Ltd.) using a polishing pad made of a rigid urethane as the polishing tool and a polishing fluid including cerium oxide abrasive grains, and the glass substrate is then cleaned to remove the cerium oxide.

The upper and lower principal planes of the glass substrate that is subjected to the primary polishing is further subjected to a secondary polishing by a 22B type double side polisher using a polishing pad made of a soft urethane as the polishing tool and a polishing fluid including cerium oxide abrasive grains smaller than those used by the primary polishing, and the glass substrate is then cleaned to remove the cerium oxide.

The upper and lower principal planes of the glass substrate that is subjected to the secondary polishing is further subjected to a third polishing (or finishing) by a double side polisher using a polishing pad made of a soft urethane as the polishing tool and a polishing fluid including colloidal silica.

The glass substrate subjected to the finishing (or third polishing) are successively subjected to a scrub

cleaning, an ultrasonic cleaning in a state submerged within a cleaning solution, and an ultrasonic cleaning in a state submerged within pure water (precision cleaning). The glass substrate that is cleaned in this manner is dried under isopropyl alcohol steam.

Each glass substrate that is obtained is subjected to the evaluation (1) of the dependency of the flatness immediately after removing the load on the load applying time before removing the load, the evaluation (2) of the dependency of the flatness immediately after removing the load on the elapsed time after removing the load, and the evaluation (3) of the pseudoelastic deformation quantities A, B, and C.

Table 2 illustrates results of the evaluation (1) of the dependency of the flatness immediately after removing the load on the load applying time before removing the load for the glass substrates used in the magnetic recording media of the examples Ex-1, Ex-8, and Ex-9. In addition, the results of Table 2 are illustrated in FIGs. 5 and 6 in the form of a graph. In FIG. 6, the abscissa indicates the load applying time on a logarithmic axis.

Table 2

Ex-1		Ex-8		Ex-9	
LOAD APPLYING TIME (h)	FLATNESS (μm)	LOAD APPLYING TIME (h)	FLATNESS (μm)	LOAD APPLYING TIME (h)	FLATNESS (μm)
0.002	1.6	0.002	1.8	0.002	0.7
0.02	1.9	0.08	5.5	0.05	9.4
0.05	2.0	0.17	4.5	0.08	10.2
0.08	1.6	0.33	5.5	0.17	12.4
0.50	1.7	0.75	6.8	0.50	16.8
4.5	1.5	16.5	15.1	1.0	18.2
7.5	2.1	26.0	14.3	2.0	20.5
46.0	1.5	42.5	15.7	17.5	23.7
51.0	1.8			24.0	24.0

As may be seen from the results illustrated in Table 2 and FIGs. 5 and 6, it is confirmed that the flatness of the glass substrates used in the magnetic recording media of the examples Ex-8 and Ex-9 becomes large by applying the load, and that the change in the flatness saturates when approximately 10 hours (h) is exceeded. In this case, the rate of change of the flatness in 24 hours from the time when the applying of the load to the glass substrate starts is 870% for the glass substrate of the example Ex-8 and 330% for the glass substrate of the example Ex-9.

On the other hand, the flatness of the glass substrate used in the magnetic recording medium of the example Ex-1, which is the practical example, virtually does not change, and it is confirmed that the rate of change of the flatness in 24 hours from the time when the applying of the load to the glass substrate starts is 20%.

From these results, it is confirmed that the

change in the flatness with respect to the applied load differs depending on the glass composition of the glass substrate. It is also confirmed that particularly the glass substrate of the example Ex-1 including a B_2O_3-content of 7.6 mol% has a small change in the flatness.

Next, Table 3 illustrates results of the evaluation (2) of the dependency of the flatness immediately after removing the load on the elapsed time after removing the load for the glass substrates used in the magnetic recording media of the examples Ex-1 through Ex-10. In addition, the results of Table 3 are illustrated in FIGs. 7 and 8 in the form of a graph. FIG. 8 illustrates a region in which the flatness is small in FIG. 7 on an enlarged scale.

The evaluation (2) of the dependency of the flatness immediately after removing the load on the elapsed time after removing the load is performed as described above by applying the load on the glass substrate for 24 hours, thereafter removing the load, and evaluating the change in the flatness after removing the load.

Table 3

Ex-1		Ex-2		Ex-3	
ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)	ELAPSE TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)	ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)
0.01	0.8	0.01	0.7	0.01	1.0
0.08	0.6	0.12	0.6	0.17	0.8
0.20	0.5	0.30	0.9	0.40	1.1
1.2	0.9	1.0	0.9	1.0	0.7
4.1	1.0	3.1	0.8	3.8	0.8
8.1	0.9	7.2	0.7	8.3	0.7

Ex-4		Ex-5		Ex-6	
ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)	ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)	ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)
0.01	0.5	0.01	0.8	0.01	0.6
0.08	0.7	0.07	0.8	0.08	0.8
0.35	0.5	0.23	1.0	0.38	0.7
1.2	0.8	0.80	0.8	0.90	0.7
2.9	1.2	4.3	0.7	5.2	0.6
7.7	0.9				

Ex-7		Ex-8		Ex-9		Ex-10	
ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)	ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)	ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)	ELAPSED TIME AFTER REMOVING LOAD (h)	FLAT-NESS (μm)
0.01	2.9	0.01	15.7	0.002	24.0	0.002	21.1
0.12	2.1	0.05	12.9	0.02	18.9	0.05	14.3
0.23	1.6	0.08	12.2	0.05	14.4	0.08	12.7
0.47	1.6	0.17	11.0	0.20	11.9	0.17	11.6
0.88	1.4	0.50	8.9	0.37	9.5	0.50	8.9
5.4	0.9	1.0	7.9	0.50	8.4	1.0	7.3
		2.3	6.5	0.67	7.5	2.3	6.5
		7.5	4.4	1.0	6.4	7.5	3.8
		23.0	3.3	2.0	4.6	23.0	2.3
				16.0	1.6		

From the results illustrated in Table 3, it is confirmed that the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-7 has a small flatness immediately after the load is applied to the glass substrate for 24 hours, and after the load is removed, there is virtually no change in the flatness

regardless of the elapsed time.

On the other hand, it is confirmed that the glass substrate used in each of the magnetic recording media of the examples Ex-8 through Ex-10 has a large flatness immediately after the load is applied to the glass substrate for 24 hours, and the flatness gradually becomes small with the lapse of time after the load is removed.

From these results, it is confirmed that the change in the flatness when the load is applied to the glass substrate differs depending on the glass composition of the glass substrate. In addition, it is confirmed that the displacement of the glass substrate by the restoration force thereof after the load is removed differs depending on the glass composition of the glass substrate.

Particularly in the case of the glass substrate used in each of the magnetic recording media of the examples Ex-8 through Ex-10, it is confirmed that the change in the flatness when the load is applied to the glass substrate is large. For this reason, when such a glass substrate is used in the magnetic recording medium and the servo information is written after 5 hours elapses after the load is removed, for example, it may be seen that the positions of the servo information greatly change thereafter to cause the generation of the error.

Table 4 illustrates results of the evaluation (3) of the pseudoelastic deformation quantities A, B, and C for the glass substrates of the examples Ex-1 through Ex-10, and calculation results of the specific modulus.

Table 4

	Ex-1	Ex-2	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8	Ex-9	Ex-10
SPECIFIC MODULUS (MNm/kg)	31	31	30	29	34	34	34	34	34	29
PSEUDO-ELASTIC DEFORMATION QUANTITY A (μm)	0.1	0.0	0.0	0.1	0.0	0.1	0.6	3.8	2.4	3.9
PSEUDO-ELASTIC DEFORMATION QUANTITY B (μm)	0.1	0.0	0.0	0.0	0.1	0.0	0.5	3.1	1.9	3.0
PSEUDO-ELASTIC DEFORMATION QUANTITY C (μm)	0.9	0.8	0.7	0.9	0.7	0.6	1.2	5.1	3.2	4.9

From Table 4, it is confirmed that the specific modulus of the glass substrate used in each of the magnetic recording media of examples Ex-1 through Ex-7 is high, that is, 29 MNm/kg or higher. It is confirmed that the specific modulus is 34 MNm/kg and particularly high for the glass substrate used in each of the magnetic recording media of examples Ex-5 and Ex-6, including a B_2O_3-content of less than 2.0 mol%. In addition, it is also confirmed that the specific modulus is 34 MNm/kg and particularly high for the glass substrate used in the magnetic recording medium of the example Ex-7, including no B_2O_3-content and in which the content of the alkali metal oxide is 0 mol%. When the specific modulus of the glass substrate is high, the generation of fluttering can be suppressed even when the magnetic recording medium including such a glass substrate is rotated at a high speed, and it is possible to particularly suppress the generation of the read or write error associated with the magnetic recording medium.

It is confirmed that the pseudoelastic deformation quantity A, indicating the absolute value of

the difference between the flatness after 5 hours elapses from the time when the applied load is removed and the flatness before the load is applied to the glass substrate, is 2.0 μm or less for the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-7, and small compared to that for the glass substrate used in each of the magnetic recording media of the examples Ex-8 through Ex-10. It is also confirmed that the pseudoelastic deformation quantity A is 0.1 μm or less and smaller for the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-6.

In addition, it is confirmed that the pseudoelastic deformation quantity B, indicating the absolute value of the difference between the flatness after 5 hours elapses from the time when the applied load is removed and the flatness after 48 hours elapses from the time when the applied load is removed, is 1.5 μm or less for the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-7, and extremely small compared to that for the glass substrate used in each of the magnetic recording media of the examples Ex-8 through Ex-10. It is also confirmed that the pseudoelastic deformation quantity B is 0.1 μm or less and particularly small for the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-6.

It is confirmed that the pseudoelastic deformation quantity C, indicating the flatness after 5 hours elapses from the time when the applied load is removed, is 2.5 μm or less for the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-7, and small compared to that for the glass substrate used in each of the magnetic recording media of

the examples Ex-8 through Ex-10. It is also confirmed that the pseudoelastic deformation quantity C is 1.0 μm or less and particularly small for the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-6.

Although the load applying times are different, the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-7 has a small flatness even immediately after the applied load is removed, and the change in the flatness after the applied load is removed is small, as described above in conjunction with the evaluation (2) of the dependency of the flatness immediately after removing the load on the elapsed time after removing the load. It may be regarded that, for these reasons, the pseudoelastic deformation quantities A, B, and C are small for the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-7 as described above.

[Manufacturing Magnetic Recording Medium]

Next, 100 magnetic recording media were manufactured for each of the examples Ex-1 through Ex-10, by successively providing the underlayer, the magnetic layer, the protection layer, and the lubricant layer on the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-10.

More particularly, an inline sputtering apparatus is used to successively stack an NiFe layer forming the soft magnetic underlayer, a Ru layer forming the nonmagnetic intermediate layer, and a $CoCrPtSiO_2$ granular layer forming the perpendicular magnetic recording layer on the surface of the glass substrate used in each of the magnetic recording media of the examples Ex-1 through Ex-10. Then, a DLC (Diamond-Like Carbon)

layer forming the protection layer is formed by CVD. Thereafter, a perfluoropolyether layer forming the lubricant layer is formed by dipping, to form the magnetic recording medium.

Each magnetic recording medium that is formed is accommodated within a shipping cassette (manufactured by Entegris, Inc.), vacuum packed in an Al laminated pouch forming the packaging container at a vacuum of 400 mmHg, and left to stand or shelved for 48 hours.

After 48 hours, the Al laminated pouch is opened to remove the shipping cassette, and the magnetic recording medium removed from the shipping cassette and assembled into the HDD. The servo information is written on the magnetic recording medium within the HDD under conditions corresponding to 254 kTPI. The writing of the servo information is performed 5 hours after opening the Al laminated pouch. After 43 hours elapses from the writing of the servo information (or after 48 elapses from the opening of the Al laminated pouch), data are written to and read from the magnetic recording medium in order to perform a read and write test.

As a result of the read and write test, no error was generated in the 100 magnetic recording media manufactured for each of the examples Ex-1 through Ex-7. On the other hand, an error of approximately 1% was generated in the 100 magnetic recording media manufactured for each of the examples Ex-8 through Ex-10.

It may be regarded that the error generation rate is higher for the magnetic recording media manufactured for each of the examples Ex-8 through Ex-10 for the reasons described below.

That is, the magnetic recording medium that is held within the shipping cassette is deformed by the

pressure from the atmosphere because the Al laminated pouch is vacuum packed, and after the vacuum-packed Al laminated pouch is opened, the magnetic recording medium gradually returns to its original shape according to the properties of the glass substrate included in the magnetic recording medium. However, as is evident from the evaluation of the glass substrate described above for each of the examples Ex-8 through Ex-10, the shape of the glass substrate gradually changes when the load is applied to the glass substrate and the load is thereafter removed. For this reason, when the servo information is written on the magnetic recording medium, the glass substrate is still undergoing a change in its shape, and the shape of the glass substrate further changes after the servo information is written on the magnetic recording medium. Accordingly, it may be regarded that the positions of the servo information after being written on the magnetic recording medium changed by the time the read and write test was performed.

Because the change in shape of the glass substrate becomes more conspicuous towards the outer periphery of the glass substrate, it may be assumed that the error is concentrated at the outer peripheral part of the glass substrate, depending on the glass substrate.

The glass substrates used in the magnetic recording media of the examples Ex-8 and Ex-9 have specific moduli higher than those of the glass substrates used in the magnetic recording media of the examples Ex-1 through Ex-4, and the fluttering is suppressed by the glass substrates used in the magnetic recording media of the examples Ex-8 and Ex-9. Hence, according to the conventional understanding of the magnetic recording medium, the error generation rate should be suppressed

when the magnetic recording media of the examples Ex-8 and Ex-9 are evaluated. However, as described above, the error generation rate is actually higher for the magnetic recording media manufactured for each of the examples Ex-8 and Ex-9.

It may be regarded that, even though the buckling deformation or the bending deformation occurs in the glass substrates used in the magnetic recording media manufactured for each of the examples Ex-8 and Ex-9, the servo information is written while the glass substrates are still undergoing changes to return to their original shapes after being deformed, due to inappropriate selection of the glass compositions for the glass substrates.

From these results, it is confirmed that, in order to sufficiently suppress the generation of the error in the magnetic recording medium, it is insufficient to simply use a glass substrate having a high specific modulus even though the conventional understanding of the magnetic recording medium considered it sufficient, and that the glass substrate needs to be selected to include a B_2O_3-content within a predetermined range, or to include an alkali metal oxide with a content within a predetermined amount.

[Practical Example 2]

In this practical example 2, magnetic recording media in accordance with examples Ex-11 through Ex-24 are manufactured and evaluated. The magnetic recording media in accordance with the examples Ex-11 through Ex-24 include glass substrates having different glass compositions, as illustrated in Table 5. The examples Ex-11 through Ex-21 correspond to practical examples, and the examples Ex-22 through Ex-24 correspond to comparison

examples.

[Manufacturing Glass Substrate]

The glass substrates are formed according to the following procedures using glass substrate bases having the glass compositions of the examples Ex-11 through Ex-24 in Table 5, by cutting the glass substrate bases into a donut shape or a disk shape having an outer diameter of 65 mm, a thickness of 0.635 mm, and a circular center hole having a diameter of 20 mm. The procedure used to manufacture the glass substrate in this practical example 2 is the same as that used in the practical example 1 described above, and thus, a description thereof will be omitted.

In Table 5, RO indicates a content of an alkali earth metal oxide included in the glass composition of the glass substrate base, and R_2O indicates a content of an alkali metal oxide included in the glass composition of the glass substrate base. In addition, in Table 5, "-" indicates that no corresponding component is included, that is, a content of the corresponding component included in the glass composition is 0.

The pseudoelastic deformation quantity A is evaluated in a manner similar to that of the practical example 1 described above, for each of the glass substrates of the examples Ex-11 through Ex-24. Results of the evaluation are illustrated in Table 5.

Table 5

		Ex-11	Ex-12	Ex-13	Ex-14	Ex-15	Ex-16	Ex-17
GLASS COMPOSITION (mol%)	SiO_2	65.0	65.0	65.0	65.0	65.0	65.0	65.0
	Al_2O_3	13.0	13.0	13.0	13.0	13.0	13.0	13.0
	B_2O_3	—	—	—	—	—	—	—
	MgO	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	CaO	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	SrO	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	BaO	—	—	—	—	—	—	—
	TiO_2	—	—	—	—	—	—	—
	ZrO_2	—	—	—	—	—	—	—
	Li_2O	—	—	8.0	—	4.0	4.0	2.7
	Na_2O	8.0	4.0	—	—	—	4.0	2.7
	K_2O	—	4.0	—	8.0	4.0	—	2.7
	RO	14.0	14.0	14.0	14.0	14.0	14.0	14.0
	R_2O	8.0	8.0	8.0	8.0	8.0	8.0	8.0
PSEUDO-ELASTIC DEFORMATION QUANTITY A (μm)		<0.6	1.3	<0.6	<0.6	1.7	1.8	<0.6

		Ex-18	Ex-19	Ex-20	Ex-21	Ex-22	Ex-23	Ex-24
GLASS COMPOSITION (mol%)	SiO_2	64.5	64.5	64.4	68.0	64.5	64.5	64.5
	Al_2O_3	12.0	12.0	8.0	10.0	12.0	12.0	12.0
	B_2O_3	—	—	—	—	—	—	—
	MgO	—	—	10.5	8.0	—	—	—
	CaO	—	—	0.1	—	—	—	—
	SrO	—	—	0.1	—	—	—	—
	BaO	—	—	0.1	—	—	—	—
	TiO_2	—	—	—	—	—	—	—
	ZrO_2	1.8	1.8	0.5	—	1.8	1.8	1.8
	Li_2O	—	21.7	—	—	—	10.9	10.9
	Na_2O	21.7	—	12.5	14.0	10.9	—	10.9
	K_2O	—	—	4.0	—	10.9	10.9	—
	RO	—	—	10.8	8.0	—	—	—
	R_2O	21.7	21.7	16.5	14.0	21.7	21.7	21.7
PSEUDO-ELASTIC DEFORMATION QUANTITY A (μm)		<0.6	<0.6	0.96	<0.6	6.1	4.0	5.1

From the results illustrated in Table 5, it is

confirmed that the pseudoelastic deformation quantity A is less than 0.6 μm for the examples Ex-11, Ex-13, Ex-14, Ex-18, Ex-19, and Ex-21 in which the glass substrates include one kind of alkali metal oxide and the content of the alkali metal oxide is 0 mol% or more and 25 mol% or less.

In addition, it is confirmed that the pseudoelastic deformation quantity A is less than 2.0 μm for the examples Ex-12, Ex-15, Ex-16, Ex-17, and Ex-20 in which the glass substrates include two kinds of alkali metal oxide and a sum of the contents of the alkali metal oxides is 0 mol% or more and 20 mol% or less. On the other hand, it is confirmed that the pseudoelastic deformation quantity A is extremely large for the examples Ex-22, Ex-23, and Ex-23 that are comparison examples in which the glass substrates include two kinds of alkali metal oxide and a sum of the contents of the alkali metal oxides exceeds 20 mol%, when compared to the pseudoelastic deformation quantity A for the examples Ex-11 through Ex-24 described above.

[Manufacturing Magnetic Recording Medium]

Next, 100 magnetic recording media were manufactured for each of the examples Ex-11 through Ex-24, by successively providing the underlayer, the magnetic layer, the protection layer, and the lubricant layer on the glass substrate used in each of the magnetic recording media of the examples Ex-11 through Ex-24.

The procedure used to manufacture the magnetic recording media in this practical example 2 is the same as that used in the practical example 1 described above, and thus, a description thereof will be omitted.

Each magnetic recording medium that is formed is accommodated within a shipping cassette (manufactured by Entegris, Inc.), vacuum packed in an Al laminated pouch

forming the packaging container at a vacuum of 400 mmHg, and left to stand or shelved for 48 hours, in a manner similar to that for the practical example 1 described above. After 48 hours, the Al laminated pouch is opened to remove the shipping cassette, and the magnetic recording medium removed from the shipping cassette and assembled into the HDD. The servo information is written on the magnetic recording medium within the HDD under conditions corresponding to 254 kTPI. The writing of the servo information is performed 5 hours after opening the Al laminated pouch. After 43 hours elapses from the writing of the servo information (or after 48 elapses from the opening of the Al laminated pouch), data are written to and read from the magnetic recording medium in order to perform a read and write test.

As a result of the read and write test, no error was generated in the 100 magnetic recording media manufactured for each of the examples Ex-11 through Ex-21. On the other hand, an error of approximately 1% was generated in the 100 magnetic recording media manufactured for each of the examples Ex-22 through Ex-24.

It may be regarded that the error generation rate is higher for the magnetic recording media manufactured for each of the examples Ex-22 through Ex-24 for the reasons described below.

That is, the magnetic recording medium that is held within the shipping cassette is deformed by at least one of the buckling deformation and the bending deformation due to the pressure from the atmosphere because the Al laminated pouch is vacuum packed, and after the vacuum-packed Al laminated pouch is opened, the magnetic recording medium gradually returns to its original shape according to the properties of the glass

substrate included in the magnetic recording medium. However, as is evident from the evaluation of the glass substrate described above for each of the examples Ex-22 through Ex-24, the shape of the glass substrate gradually changes when the load is applied to the glass substrate and the load is thereafter removed. For this reason, when the servo information is written on the magnetic recording medium, the glass substrate is still undergoing a change in its shape, and the shape of the glass substrate further changes after the servo information is written on the magnetic recording medium. Accordingly, it may be regarded that the positions of the servo information after being written on the magnetic recording medium changed by the time the read and write test was performed.

Because the change in shape of the glass substrate becomes more conspicuous towards the outer periphery of the glass substrate, it may be assumed that the error is concentrated at the outer peripheral part of the glass substrate, depending on the glass substrate.

According to the embodiments and practical examples described above, it is to provide a method of manufacturing a magnetic recording medium, and the magnetic recording, which can reduce the generation of the error.

Although the embodiments and practical examples thereof are numbered with, for example, "first," or "second," the ordinal numbers do not imply priorities of the embodiments or practical examples thereof.

WHAT IS CLAIMED IS

1. A method of manufacturing a magnetic recording medium that includes a magnetic layer deposited on a glass substrate, and to which servo information is to be written, comprising:

generating at least one of a buckling deformation and a bending deformation in the glass substrate,

in a case in which both end parts of the glass substrate along diametrically opposite directions are supported from a lower surface side of the glass substrate and a load is applied to a central upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity A indicated by an absolute value of a difference between a flatness after 5 hours elapses from a time when the applied load is removed and a flatness before the load is applied to the glass substrate, is 2.0 μm or less,

wherein glass forming the glass substrate includes an Al_2O_3-content of 5 mol% or more, and

wherein the glass forming the glass substrate further includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of alkali metal oxides with a content of more than 0 mol% and 20 mol% or less.

2. The method of manufacturing the magnetic recording medium as claimed in claim 1, wherein

in the case in which both the end parts of the glass substrate along the diametrically opposite directions are supported from the lower surface side of the glass substrate

and the load is applied to the central upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity B indicated by an absolute value of a difference between the flatness after 5 hours elapses from the time when the applied load is removed and a flatness after 48 hours elapses from the time when the applied load is removed, is 1.5 μm or less.

3. The method of manufacturing the magnetic recording medium as claimed in claim 1 or 2, wherein

in the case in which both the end parts of the glass substrate along the diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity C indicated by the flatness after 5 hours elapses from the time when the applied load is removed, is 2.5 μm or less.

4. The method of manufacturing the magnetic recording medium as claimed in any of claims 1 to 3, further comprising:

at least one of a magnetic layer deposition process to deposit the magnetic layer on the glass substrate, and a magnetic recording medium holding process to hold the magnetic recording medium within a cassette,

wherein at least one of the buckling deformation and the bending deformation is generated in the glass substrate during the at least one of the magnetic layer deposition process and the magnetic recording medium holding process.

5. The method of manufacturing the magnetic recording medium as claimed in any of claims 1 to 4, wherein the glass forming the glass substrate includes an Al_2O_3-content of 5 mol% or more and 20 mol% or less.

6. The method of manufacturing the magnetic recording medium as claimed in any of claims 1 to 5, wherein the glass forming the glass substrate includes a SiO_2-content of 55 mol% or more and 75 mol% or less, and an alkali earth metal oxide with a content of 0 mol% or more and 30 mol% or less.

7. A magnetic recording medium comprising:

a glass substrate; and

a magnetic layer arranged above the glass substrate and to which servo information is to be written,

in a case in which both end parts of the glass substrate along diametrically opposite directions are supported from a lower surface side of the glass substrate and a load is applied to a central upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity A indicated by an absolute value of a difference between a flatness after 5 hours elapses from a time when the applied load is removed and a flatness before the load is applied to the glass substrate, is 2.0 μm or less,

wherein glass forming the glass substrate includes an Al_2O_3-content of 5 mol% or more, and

wherein the glass forming the glass substrate further includes a B_2O_3-content of 0.1 mol% or more and 15 mol% or less, or one or less kind of alkali metal oxide with a content of 0 mol% or more and 25 mol% or less, or two or more kinds of

alkali metal oxides with a content of more than 0 mol% and 20 mol% or less.

8. The magnetic recording medium as claimed in claim 7, wherein

in the case in which both the end parts of the glass substrate along the diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity B indicated by an absolute value of a difference between the flatness after 5 hours elapses from the time when the applied load is removed and a flatness after 48 hours elapses from the time when the applied load is removed, is 1.5 μm or less.

9. The magnetic recording medium as claimed in claim 7 or 8, wherein

in the case in which both the end parts of the glass substrate along the diametrically opposite directions are supported from the lower surface side of the glass substrate and the load is applied to the central upper surface of the glass substrate for 48 hours, a pseudoelastic deformation quantity C indicated by the flatness after 5 hours elapses from the time when the applied load is removed, is 2.5 μm or less.

10. The magnetic recording medium as claimed in any of claims 7 to 9, wherein the glass forming the glass substrate includes an Al_2O_3-content of 5 mol% or more and 20 mol% or less.

11. The magnetic recording medium as claimed in any of claims 7 to 10, wherein the glass forming the glass substrate includes a SiO_2-content of 55 mol% or more and 75 mol% or less, and an alkali earth metal oxide with a content of 0 mol% or more and 30 mol% or less.