

Description

METHOD OF MANUFACTURING A GLASS SUBSTRATE FOR HARD DISK DRIVE

Technical Field

[0001] The present invention relates to a method of manufacturing a glass substrate for hard disk drive (HDD).

Background Art

[0002] Magnetic data recording devices record data on a data recording medium by using magnetism, light or photomagnetism and the like. A typical example thereof is a hard disk drive (HDD). Hard disk drive is devices that use a magnetic head to magnetically record data onto a data recording medium in the form of a magnetic disk obtained by forming a recording layer on a substrate. A glass substrate is preferably used as the base material, or substrate, of such data recording media.

[0003] In addition, HDD record data onto a magnetic disk while rotating at a high speed and suspended only several nanometers above the magnetic disk without allowing the magnetic head to contact the magnetic disk. Moreover, accompanying dramatic increases in the recording capacity of HDDs in recent years, it is essential to reduce the recording area of the medium allocated to a single bit. Since the size of magnetic particles becomes increasingly fine in proportion thereto, problems such as read/write errors and disk crashing have become increasingly severe as a result of improvements in the read/write functions of microregions and further reductions in the distance between the magnetic head and recording medium.

[0004] Moreover, accompanying the need for portability and the growing number of applications in notebook PCs and portable HDDs, recent HDDs are required to ensure a

higher level of impact resistance than in the past with respect to the glass substrate used therein. Chemically reinforced glass substrate has been developed as means for ensuring adequate impact resistance. This chemical reinforcing treatment consists of forming a compression stress layer near the surface of the glass substrate by immersing the glass substrate in potassium or sodium nitrate melted by heating to a high temperature of about 350°C to 500°C, and replacing alkaline ions contained near the surface of the glass substrate with alkaline ions having a large ionic radius.

[0005] On the other hand, known examples of methods used to produce the glass blank used for the raw material of the glass substrate used in the HDD include a float method, consisting of pouring a melt obtained by melting a glass raw material onto molten tin to form a glass plate by allowing to solidify while in that state, and a direct press method, consisting of feeding a molten glass gob between a lower mold and upper mold followed by forming a glass plate by pressing. In either of these methods, the resulting glass plate is cut into the shape of a glass disk that approximates the shape of a glass substrate to prepare a glass blank, and the glass blank further undergoes grinding and polishing to obtain a glass substrate for use in an HDD. Among these methods, the float method is used preferably since the surface roughness of the resulting glass blank is comparatively low resulting in less of a burden in the grinding step.

[0006] However, in this float method, when molten glass is poured onto the molten tin, a tin layer diffuses into the surface of the glass plate on the side in contact with the tin layer (lower surface), thereby resulting in a phenomenon in which the glass composition differs between the lower surface of the glass plate having the tin layer diffused therein and the upper surface of the glass plate. Although glass used for glass substrate is manufactured so as to possess desired properties in accordance with a rigorous material design, the formation of this tin layer results in the appearance of different material properties, thereby potentially resulting in

the occurrence of unforeseen problems when used to manufacture a magnetic recording medium.

[0007] In response to such problems, Patent Documents 1 and 2, for example, describe glass substrate in which the lower surface of a glass plate in which tin is diffused is not used for magnetic recording, while the other surface is used for magnetic recording since a glass substrate produced using the float method demonstrates differences in the composition of the glass between the upper and lower surfaces thereof. However, accompanying the reduced size of HDD in recent years, there has been a strong desire for increases in the recording capacity of magnetic recording media, and since magnetic recording on both sides of a glass substrate is an essential condition for this, it has become necessary to make improvements.

[0008] In the case of manufacturing glass substrate for magnetic disks using glass blanks produced by the float method, such problems are thought to be able to be solved by removing at least the portion where the tin layer has been formed in a grinding step. Consequently, the tin layer has been removed by adequately grinding the glass substrate.

[0009] However, in the case of having removed the tin layer by a grinding step, there was the problem of being unable to obtain adequate impact strength even in the case of having subsequently carried out a chemical reinforcing step on the glass substrate.

[0010] Patent Document 1: Japanese Patent Application Laid-open No. 2010-257563

Patent Document 2: Japanese Patent Application Laid-open No. 2010-238271

Summary of the Invention

[0011] With the foregoing in view, an object of the present invention is to provide a method of manufacturing a glass substrate for HDD that demonstrate superior impact resistance in the case of mounting a glass substrate in a hard disk drive having high recording density.

[0012] One aspect of the present invention is a method of manufacturing a glass substrate

for HDD, the method including: a step of obtaining a glass plate by a float method, a step of forming a glass blank by cutting the glass plate into the shape of a disk, a surface processing step of grinding and/or polishing the glass blank, and a chemical reinforcing step of carrying out ion exchange on the surface of the glass blank by immersing the surface-processed glass blank in a chemical reinforcing treatment liquid, wherein in the glass blank immediately prior to the chemical reinforcing step, in a case where the amount of retardation from a cross-section is measured when the glass blank has been cut into the shape of a strip in a direction perpendicular to the main surface thereof, a difference between a first maximum value of the amount of retardation per unit optical path length in a range from one main surface to 10 μm , and a second maximum value of the amount of retardation per unit optical path length in a range from the other main surface to 10 μm , is 10 nm/mm or less.

[0013] The object, characteristics, aspects and advantages of the present invention will become clear from the following detailed description and appended drawings.

Brief Description of the Drawings

[0014] [Fig. 1] Fig. 1 is an overhead view showing a glass substrate for a magnetic data recording medium manufactured by a method of manufacturing glass substrate for magnetic data recording media according to the present embodiment.

[Fig. 2] Fig. 2 depicts schematic cross-sectional views of a glass blank cutting step in a method for manufacturing glass substrate for magnetic data recording media according to the present embodiment.

[Fig. 3] Fig. 3 is a schematic cross-sectional view showing an example of a grinding device used in a grinding step in a method of manufacturing glass substrate for magnetic data recording media according to the present embodiment.

[Fig. 4] Fig. 4 is a schematic diagram of a glass blank following a coring step.

[Fig. 5] Fig. 5 is a partial cross-sectional perspective view showing a magnetic disk as an example of a magnetic recording medium that uses a glass substrate for HDD manufactured by the method of manufacturing a glass substrate for HDD according to the present embodiment.

Best Mode for Carrying Out the Invention

[0015] As a result of study and experiment by the inventors of the present invention, it was determined that, in the case of having removed a tin layer by a grinding step, even in the case of having subsequently carried out a chemical reinforcing step on a glass substrate, since the state of the compression reinforced layer introduced by chemical reinforcing varies, the balance of compression strength between the upper and lower surfaces of the glass substrate becomes poor, thereby resulting in the possibility of being unable to obtain adequate impact strength. Therefore, upon a more detailed examination of the cause thereof, it was determined that, in the case of having manufactured a glass blank using the float method, since an annealing step is carried out in the state of having a tin layer, different degrees of stress are generated by the annealing step between the side having the tin layer and the side not having the tin layer, thereby resulting in a difference in residual stress between the upper surface and lower surface. Since this residual stress is generated deeper than the tin layer, the difference in stress between the upper and lower surfaces remains even if the tin layer is removed by grinding. In the case of subsequently chemically reinforcing a glass substrate having a difference in residual stress between the upper and lower surfaces thereof, it was determined that the difference in stress is further amplified in the chemical reinforcing step, which not only prevents the obtaining of adequate strengthening effects attributable to the chemical reinforcing, but also causes a decrease in impact resistance.

[0016] With the foregoing in view, an object of the present invention is to provide a method

of manufacturing a glass substrate for HDD that demonstrate superior impact resistance in the case of mounting a glass substrate in a hard disk drive having high recording density.

[0017] As a result of conducting extensive studies to solve the problems described above, the inventors of the present invention found that a glass substrate for HDD having superior impact resistance are obtained by employing the constitution described below, thereby leading to completion of the present invention.

[0018] Although the following provides an explanation of embodiments according to the present invention, the present invention is not limited thereto.

[0019] <Glass Substrate for HDD>

In the method of manufacturing a glass substrate for HDD according to the present embodiment, in a glass blank immediately prior to a chemical reinforcing step, when the amount of retardation from a cross-section is measured when the glass blank has been cut into the shape of a strip in a direction perpendicular to the main surface thereof, the difference between a maximum value of the amount of retardation per unit optical path length over a range up to 10 μm from one main surface (first maximum value), and a maximum value of the amount of retardation per unit optical path length over a range up to 10 μm from the other main surface (second maximum value), is 10 nm/mm or less.

[0020] As was previously described, if the difference between the first maximum value and the second maximum value, namely the difference in maximum values of the amounts of retardation between the upper surface and lower surface, in a glass blank immediately prior to a chemical reinforcing step is 10 nm/mm or less, the difference in residual stress between the upper and lower surfaces of the glass blank becomes small, and since stress can then be said to be distributed uniformly between the upper and lower surfaces, even in the case of having manufactured a glass substrate by subjecting a glass blank to a chemical reinforcing step, there is no exacerbation of the balance of compression strength between the upper and lower

surfaces, and impact resistance is superior in the case of incorporating as a glass substrate for an HDD. In addition, the difference in the maximum values of the amounts of retardation between the upper and lower surfaces as described above is preferably 3 nm/mm or less. If the difference in maximum values of the amounts of retardation between the upper and lower surfaces in a glass blank immediately prior to a chemical reinforcing step is 10 nm/or less, there is no exacerbation of the balance of compression strength between the upper and lower surfaces even in the case of having undergone a chemical reinforcing step, thereby making it possible to reduce the risk of cracking even in the case of having mistakenly dropped the HDD or subjected to an impact when carrying. In addition, as the difference in the maximum values of the amounts of retardation between the upper and lower surfaces as described above approaches 0 nm/mm, the difference in residual strength of the glass blank decreases and the distribution thereof can be said to be uniform.

[0021] (Measurement of Amount of Retardation)

In the present embodiment, amount of retardation refers to an indicator representing residual stress in the vicinity of each surface of a glass blank, and in a glass blank following a chemical reinforcing step, is an indicator representing the magnitude of compression stress imparted by the chemical reinforcing step. An example of a method of measuring the amount of retardation consists of cutting a glass blank or glass substrate into the shape of a strip, transmitting linearly polarized light from a cross-sectional direction using a polarimeter (Shinko Seiki Co., Ltd.), and observing the change in the status of the polarized light after passing through the glass blank or glass substrate. The amount of retardation is then measured at multiple points at a depth of 10 μm from the side of each recording surface (one main surface and other main surface) of the glass substrate cut into the shape of a strip, the maximum values thereof are determined, the maximum values in the vicinity of each surface are compared, and the maximum value of that difference is identified.

[0022] In addition, a layer (tin layer) is formed on the side of the lower surface of a glass substrate produced by the float method as previously described in which a tin component is diffused and remains therein. As a result of carrying out annealing treatment in the presence of this tin layer, large residual stress is generated on the side of the lower surface of the glass substrate, and a difference in residual stress remains between the upper and lower surfaces of the glass substrate even after the tin layer has been removed.

[0023] In that case, residual stress in the vicinity of each surface cannot be made uniform simply by removing the tin layer. If the portion where residual stress is not uniform is attempted to be reduced by grinding, the amount of material ground off by processing increases, thereby causing thickness to be reduced beyond a desired thickness while also resulting in the problem of increased processing costs. Therefore, it is desirable to make the distribution of stress in a glass blank uniform without having to carry out excessive grinding on the lower surface of a glass substrate.

[0024] Accordingly, if the difference in maximum values of the amount of retardation between the side of the upper surface and the side of the lower surface (one surface and other surface) of a glass blank is within a prescribed range immediately prior to the chemical reinforcing step, the distribution of compression strength in a glass substrate following the chemical reinforcing step can be made to be uniform, thereby allowing the obtaining of a glass substrate having superior impact resistance.

[0025] (Glass Substrate Composition)

Aluminosilicate glass is preferably used for the material that composes the glass substrate for HDD according to the present embodiment. The composition of the aluminosilicate glass contains SiO_2 , Al_2O_3 and B_2O_3 as main components of the glass blank. In addition, alkaline components of the glass blank consist of Li_2O , Na_2O and K_2O . Alkaline earth components of the glass blank consist of MgO , CaO , BaO , SrO and ZnO .

[0026] The total amount w(FMO) of the SiO_2 , Al_2O_3 and B_2O_3 is preferably 70% by mass to 85% by mass. This is to stabilize the structure of the glass. If this total amount is excessively low, the glass structure tends to become unstable. In addition, if this total amount is excessively high, viscosity properties during melting become poor and productivity tends to decrease.

[0027] As mentioned above, the amounts of the alkaline components of a glass blank used in the present invention are 1% by mass to 8% by mass for LiO_2 , 2% by mass to 13% by mass for Na_2O and 0.2% by mass to 2% by mass for K_2O , and the total amount thereof, namely the total amount of Li_2O , Na_2O and K_2O , is preferably 3.2% by mass to 23% by mass.

[0028] In addition, components other than those indicated above may be contained in the glass blank. More specifically, ZrO_2 or cerium oxide may be contained. The content of ZrO_2 is preferably 0% by mass to 5% by mass. In addition, the content of cerium oxide is preferably 0% by mass to 2% by mass. Furthermore, cerium oxide has the effect of inhibiting the formation of fine surface irregularities when polishing the glass blank using an abrasive containing cerium oxide.

[0029] <Method of Manufacturing Glass Substrate for HDD>

The method of manufacturing a glass substrate for HDD according to the present embodiment is provided with a step of obtaining a glass plate by the float method, a step of forming a glass blank by cutting the glass plate into the shape of a disk, a surface processing step of carrying out grinding and/or polishing on the glass blank, and a chemical reinforcing step of carrying out ion exchange on the surface of the glass blank by immersing the surface-processed glass blank in a chemical reinforcing treatment liquid. In this manufacturing method, in the glass blank immediately prior to the chemical reinforcing step, when the amount of retardation from a cross-section is measured when the glass blank has been cut into the shape of a strip in a direction perpendicular to the main surface thereof, the

difference between the maximum value of the amount of retardation per unit optical path length in a range from one main surface to 10 μm , and the maximum value of the amount of retardation per unit optical path length in a range from the other main surface to 10 μm , is 10 nm/mm or less.

[0030] Furthermore, the polishing step may be carried out once or a plurality of times. The polishing step comprises a rough polishing step of removing scratches and strain remaining from the grinding step, and a precision polishing step of finishing the main surface of the glass substrate to a smooth mirrored surface.

[0031] In addition, in the method of manufacturing glass substrate according to the present embodiment, other steps may be provided in addition to the grinding step and the polishing step.

[0032] In addition, a cleaning step of removing abrasive adhered by the polishing step, or an end face polishing step of chamfering the outer peripheral end face and inner peripheral end face of a glass substrate precursor, for example, may be provided. Moreover, an equalization step is preferably provided for equalizing the distribution of stress between one main surface and the other main surface (distribution of stress between the surface on the upper side and the surface on the lower side) of a glass blank immediately prior to the chemical reinforcing step. As a result of providing such steps, exacerbation of the balance of compression strength in the subsequent chemical reinforcing step is inhibited by reducing the difference in residual stress between the upper and lower surfaces of the glass blank, thereby allowing the obtaining of a glass substrate for HDD having superior impact resistance.

[0033] As a result of forming a magnetic film on the glass substrate for HDD obtained by the production method as previously described, magnetic recording media can be obtained and mounted on HDD.

[0034] The following provides a detailed description of the method of manufacturing a glass

substrate for HDD according to the present embodiment.

[0035] <Disk Forming Step>

The disk forming step is a step of forming a glass substrate formed into the shape of a plate from a glass raw material of a prescribed composition into a glass blank 10 in the shape of a disk having a through hole 10d formed in the central portion thereof so that the inner circumference and outer circumference are concentric as shown in Fig. 1. The glass substrate for HDD according to the present embodiment is processed using the float method.

[0036] The following provides an explanation of the float method.

[0037] (Float Method)

The float method is a method consisting of pouring a melt obtained by melting a glass raw material over molten tin and then allowing to solidify while in that state. More specifically, a glass plate is obtained by pouring molten glass into a float bath filled with molten tin to form a molten glass layer followed by cooling the molten glass layer to solidify the glass and form into the shape of a plate.

[0038] The molten glass layer is formed by pouring molten glass formulated to the composition of a glass product into a float bath filled with molten tin. Since the molten glass has a lower specific gravity than the molten tin, a bilayer structure forms in the float bath in which the molten glass layer constitutes the upper layer while the molten tin layer constitutes the lower layer. A flat, smooth surface is formed on the upper surface of the lower layer in the form of the molten tin layer due to surface tension. On the other hand, a flat, smooth surface conforming to the upper surface of the molten tin layer is similarly formed on the surface on the lower side of the molten glass layer that forms an interface in contact with the surface on the upper side of the molten tin layer. On the other hand, a flat, smooth surface is formed on the upper surface of the molten glass layer due to the surface tension of the molten glass per se. In other words, the molten glass layer has a smooth surface on both the upper

surface and lower surface thereof, and is in a state in which it rises to the upper layer in the float bath.

[0039] Next, the molten glass layer is cooled. Since the melting temperature of glass is lower than the melting point of tin, the molten glass layer begins to solidify first if the molten glass layer and molten tin layer in the float bath are both cooled gradually. The molten glass layer is completely solidified to form glass in the form of a plate by holding at a temperature equal to or lower than the melting temperature of glass and equal to or higher than the melting point of tin. In other words, since external force does not act on the upper surface and lower surface of the molten glass layer when the molten glass solidifies, the glass solidifies and adopts the form of a plate while maintaining its flat state. Consequently, the pair of upper and lower main surfaces of the resulting plate-shaped glass are both mirrored.

[0040] Next, the plate-shaped glass held floating on the molten tin is separated from the molten tin layer. Next, float glass can be obtained by cooling the plate-shaped glass to room temperature and removing the tin component adhered to the plate-shaped glass by a cleaning step and the like.

[0041] As a result of using the float method as described above, a glass blank can be obtained in which the pair of main surfaces of the plate-shaped glass are both mirrored. In addition, the manufactured float glass can be formed to an arbitrary thickness by adjusting the amount of molten glass poured onto the molten tin. The glass substrate for HDD according to the present embodiment is not dependent on glass composition or plate thickness provided they are manufactured from glass plates using the previously described float method.

[0042] Here, in a glass plate manufactured using the float method, one main surface contacts molten tin while the other main surface does not contact molten tin as was previously described. Consequently, a tin component remains on the lower surface of a glass blank manufactured using the float method. The tin layer of plate-shaped glass manufactured

using the float method can be reduced by a grinding step. In addition, sodium ions and potassium ions are distributed in the composition of glass, and tin ions diffuse inside from the surface of the glass as a result of ion exchange between a portion of these ions and tin ions.

In the float method in particular, since high-temperature molten glass contacts high-temperature molten tin, a tin component diffuses into the glass surface to an even greater degree.

[0043] The thickness of the tin layer in which the tin component remains is typically about 10 μm to 50 μm .

[0044] (Annealing Step)

The annealing step is a heat treatment step carried out on a glass blank obtained by the previously described float method. Residual stress (residual strain) present in the glass blank can typically be removed by carrying out this annealing step. However, since the compositions of the upper and lower surfaces differ in glass blanks obtained by the float method due to the presence of a tin layer as previously described, different levels of residual stress easily occur in the vicinity of the glass surface. In the case of having carried out a typical annealing step, although stress and strain within the glass can be reduced to a certain extent, the magnitude of residual stress in the vicinity of the surface easily becomes non-uniform.

[0045] The temperature of the annealing step of removing internal residual stress is typically considered to be preferably -50°C to $+50^{\circ}\text{C}$ from the glass transition temperature (T_g). If the temperature is below the aforementioned range, there are cases in which the decrease in internal residual stress (residual strain) is inadequate. In addition, if the temperature is higher than the aforementioned range, it may approach the softening point, causing the glass and apparatus used to carry out annealing treatment to adhere or resulting in poor flatness.

[0046] In addition, the time during which the temperature is held at the maximum

temperature of the aforementioned annealing temperature is normally 1 hour to 10 hours. In addition, although gradual cooling is carried out at a rate of 3°C/min, since other warping occurs if gradual cooling is carried out rapidly (rapid cooling), a slow gradual cooling rate is preferable.

[0047] (Cutting Step)

Next, an explanation is provided of the cutting step of cutting the glass blank that has undergone the aforementioned annealing into the shape of a disk.

[0048] In the cutting step, a cutting line is made in one side of the glass blank formed in the shape of a plate on molten metal followed by cutting along this cutting line. The cutting step refers to cutting the glass blank into the shape of a disk by forming a cutting line in the surface of the glass blank in contact with the molten metal of the glass blank, followed by advancing the cutting line in the direction of thickness of the glass blank.

[0049] Fig. 2 depicts cross-sectional views of the previously described cutting step, and Fig. 2A is a cross-sectional view of a plate-shaped glass blank 1.

[0050] The glass blank is manufactured by the previously described float method, and a glass blank in the shape of a plate that has undergone annealing treatment is used. The thickness of the glass blank is, for example, 0.95 mm. Furthermore, surface roughness Ra, for example, of a glass blank or glass substrate can be measured using an ordinary surface roughness measuring instrument.

[0051] As was previously described, the glass blank has a surface that contacts the molten tin and another surface. In the case of a glass blank 1 shown in Fig. 2A, the surface on the upper side is a contact surface 1A while the surface on the lower side is a free surface 1B.

[0052] A cutting line describing a curve that forms the approximate periphery of a region serving as a glass substrate for a magnetic disk is formed on the contact surface 1A of the glass blank (glass raw material) 1. In the present embodiment, as shown in Fig. 2B, circular

cutting lines 2 and 3 respectively describing the outer peripheral side and inner peripheral side of a disk shape are formed with a glass cutter 4 in the contact surface 1A of the glass raw material 1.

[0053] The cutting lines 2 and 3 on the outer peripheral side and inner peripheral side in this case are formed diagonally with respect to the direction of thickness of the glass plate. In addition, in the present embodiment, the cutting lines 2 and 3 are formed diagonally to the outside from the contact surface 1A towards the free surface 1B of the glass raw material 1, and when viewed in the cross-sectional view of Fig. 2B, the left and right cutting lines 2 and cutting lines 3 are formed to respectively form a truncated V shape. In addition, in the present embodiment, although the cutting lines 2 and 3 are formed diagonally to the outside from the contact surface 1A towards the free surface 1B of the glass raw material 1, the cutting lines 2 and 3 are not limited thereto, but rather the cutting lines 2 and 3 may be formed diagonally to the inside from the contact surface 1A towards the free surface 1B of the glass raw material 1, and when viewed in Fig. 2B, the left and right cutting lines 2 and cutting lines 3 are formed to respectively form an inverted truncated V shape, and these cutting lines are advanced so as to take out the inside portion surrounded by the cutting lines in the upward direction.

[0054] Next, as shown in Fig. 2C, the cutting lines 2 and 3 formed in the contact surface 1A of the glass raw material 1 are advanced towards the side of the free surface 1B. As a result, a region 10a to the inside surrounded by the cutting line 2 can be separated from the glass raw material 1. In addition, an inside portion 10b surrounded by the cutting line 3 can be separated from the region 10a surrounded by the cutting line 2.

[0055] An example of means for advancing the cutting lines 2 and 3 formed in the contact surface 1A of the glass raw material 1 towards the side of the free surface 1B consists of creating a difference in thermal expansion in the glass raw material 1, and a preferable

example thereof is a method consisting of heating one side of the glass raw material 1. As a result of heating the glass raw material 1, a difference in thermal expansion is created in the direction of plate thickness of the glass raw material 1, thereby enabling the glass raw material to be easily cut to the target disk shape.

[0056] Continuing, as shown in Fig. 2D, by pushing the inside regions 10a and 10b surrounded by the cutting line 2 downward and further pushing the region 10b surrounded by the cutting line 3, the disk-shaped glass blank 10 is obtained provided with a circular hole in the central portion thereof.

[0057] In addition, the surface roughness Ra of the glass blank after the cutting step is preferably 5 nm to 50 nm, and the maximum height roughness Rz is preferably 20 nm to 100 nm. Damage caused by grinding becomes large if the surface roughness Ra and maximum height roughness Rz of the glass blank after the cutting step are excessively high, while the grinding step can no longer be carried out if they are excessively low.

[0058] In the disk forming step according to that described above, the glass raw material is formed to a disk-shaped glass blank having a thickness obtained by adding about 0.3 mm to the thickness of the ultimately manufactured glass substrate for an outer diameter r1 of 2.5 inches (approx. 64 mm), 1.8 inches (approx. 46 mm), 1 inch (approx. 25 mm) or 0.8 inches (approx. 20 mm) and the like. If this thickness is exceeded, the amount of material ground off by processing increases, thereby resulting in poor production efficiency. Since the thickness of the ultimately manufactured glass substrate is fixed, the thickness resulting from forming in the disk forming step is determined by calculating backward therefrom.

[0059] A glass substrate for HDD can be manufactured by carrying out a grinding step and a polishing step to be subsequently described on the glass blank manufactured by the disk forming step described above.

[0060] Fig. 3 depicts drawings showing an example of a glass substrate for an HDD

manufactured by the method of manufacturing a glass substrate for HDD according to the present embodiment. Fig. 3A is a perspective view while Fig. 3B is a cross-sectional view. A glass substrate 30 for an HDD is a disk-shaped glass substrate having a center hole 33 formed therein, and has a main surface 31, an outer peripheral end face 34 and an inner peripheral end face 35. Chamfers 36 and 37 are respectively formed in the outer peripheral end face 34 and the inner peripheral end face 35.

[0061] <Grinding Step>

The grinding step is a step of processing the glass blank to a prescribed plate thickness. A specific example thereof is a step of grinding (lapping) both sides of the glass blank. As a result of processing in this manner, in addition to being able to adjust the parallelism, flatness and thickness of the glass blank, the tin layer formed on the surface in the float method can be removed.

[0062] There are no particular limitations on the grinding device used in the grinding step provided it is a grinding device used in the manufacturing of glass substrate. A specific example thereof is a grinding device 5 shown in Fig. 4. Furthermore, Fig. 4 is a schematic cross-sectional view showing an example of a grinding device used in a grinding step in the method of manufacturing glass substrate for magnetic data recording media according to an embodiment of the present invention.

[0063] The grinding device 5 as shown in Fig. 4 is a device capable of simultaneously grinding both sides. In addition, this grinding device 5 is provided with a device main unit 5a, and a coolant supply unit 5b that supplies cooling liquid in the form of a coolant to the device main unit 5a.

[0064] The device main unit 5a is provided with a disk-shaped upper surface plate 6 and a disk-shaped lower surface plate 7, and they are arranged at a distance from each other in the vertical direction so as to be mutually parallel. The disk-shaped upper surface plate 6 and

the disk-shaped lower surface plate 7 rotate in mutually opposite directions.

[0065] A fixed abrasive grain 8 containing diamond particles is respectively provided on the opposing surfaces of the disk-shaped upper surface plate 6 and the disk-shaped lower surface plate 7 in order to grind both the top and bottom surfaces of the glass blank 10. The fixed abrasive grain 8 containing diamond particles used in this grinding step may be in the form of pellets obtained by bonding a plurality of diamond particles with a resin, or may be in the form of a sheet obtained by two-dimensionally adhering diamond particles to the upper surface plate 6 and the lower surface plate 7 by adhesion using a resin or by electrodeposition.

[0066] A carrier may be interposed between the fixed abrasive grain 8 and the surface plates 6 and 7. This carrier revolves in the same direction as the lower surface plate 7 about the center of rotation of the surface plates 6 and 7 while rotating in a state that holds a plurality of the glass blanks 10. Furthermore, the disk-shaped upper surface plate 6 and the disk-shaped lower surface plate 7 can be operated by driving separately. In the grinding device 5 operating in this manner, grinding treatment can be carried out on the glass blank 10 by respectively supplying a coolant 11 between the fixed abrasive grain 8 and the glass blank 10 and between the fixed abrasive grain 8 and the glass blank 10.

[0067] The coolant supply unit 5b is provided with a container containing the coolant 11 and a pump 9. Namely, the coolant 11 in the container is circulated by being supplied inside the surface plates 6 and 7 by the pump 9. Cuttings ground by the grinding surfaces of the upper and lower surface plates 6 and 7 generated during circulation are removed from each of the grinding surfaces. More specifically, during circulation of the coolant 11, cuttings are filtered by a filter provided within the lower surface plate 7 causing cuttings to be retained in that filter.

[0068] In addition, the amount of material ground from the glass blank in the grinding step is preferably 10 μm to 250 μm . If this amount is less than 10 μm , the tin layer on the lower

surface may not be able to be adequately removed, while if the ground amount exceeds 250 μm , processing time becomes excessively long thereby resulting in poor efficiency of the manufacturing method.

[0069] In addition, this grinding step may be carried out one time or two or more times. For example, in the case of carrying out the grinding step twice and carrying out an equalization step of equalizing the distribution of residual stress as will be subsequently described, the upper and lower surfaces of the glass blank can be ground the first time the grinding step is carried out (first grinding step), and only the lower surface of the glass blank can be ground the second time the grinding step is carried out (second grinding step).

[0070] <Equalization Step>

The method of manufacturing a glass substrate for HDD according to the present embodiment is preferably provided with an equalization step of equalizing the distribution of stress between the surface on the upper side and the surface on the lower side (one main surface and other main surface) of a glass substrate for an HDD prior to the chemical reinforcing step. This equalization step is a step of further reducing the difference in residual stress between the upper and lower surfaces of the glass blank.

[0071] A tin component diffuses over a broad range on the lower surface of a glass blank obtained by the float method, and as a result of carrying out annealing in the presence of this tin component in order to release internal residual strain, residual stress in the vicinity of the surface becomes non-uniform. Although this tin component can be removed by the aforementioned grinding step, a large difference in residual stress remains on the upper and lower surfaces of the glass blank. In addition, if chemical reinforcing step is carried out with a difference in residual stress remaining in the glass blank, the distribution of compression strength in the resulting glass substrate becomes poor, thereby preventing the obtaining of adequate impact resistance.

[0072] In consideration of the aforementioned problems, examples of methods used to make the distribution of stress (retardation value) between the upper and lower surfaces of a glass blank prior to the chemical reinforcing step uniform include: (1) a method consisting of carrying out an annealing step on a glass blank formed by the float method, followed by carrying out a re-annealing step after making the composition of the upper and lower surfaces of the glass blank more homogeneous by grinding off the tin layer (lower surface), (2) a method consisting of asymmetrically heat-treating the upper and lower surfaces of a glass blank when carrying out an annealing step on a glass blank formed by the float method, and (3) a method consisting of reducing the difference in residual stress near the surface by providing a longer duration than normal for the duration of an annealing step carried out in order to reduce internal residual strain on a glass blank formed by the float method.

[0073] With respect to (1) above, as was previously described, it is difficult to make the distribution of residual stress (retardation value) between the upper and lower surfaces of a glass blank more uniform by only grinding the lower surface of the glass blank in which a tin component has diffused. Thus, by carrying out a re-annealing step after having removed the tin layer by the grinding step, residual stress in the upper and lower surfaces of the glass can be released equally.

[0074] Here, the temperature during the re-annealing step is preferably -50°C to $+50^{\circ}\text{C}$ from the glass transition temperature (T_g). If the temperature is lower than the aforementioned range, glass viscosity becomes excessively high and the effect of alleviating stress is not adequately obtained. In addition, if the temperature exceeds the aforementioned range, there is risk of the shape becoming poor due to softening of the glass.

[0075] In addition, the compositional distribution differs between the surface layer on the lower side and the surface layer on the upper side of a glass blank obtained by the float method as previously described. Thus, with respect to (2) above, by carrying out heat

treatment at a higher temperature on the lower surface of a glass blank on which a diffused tin layer has formed in the annealing step and carrying out heat treatment on the upper surface at a lower temperature than the lower surface, the distribution of residual stress on the surface can be made to be uniform.

[0076] For example, the temperature at which the lower surface of a glass blank is held during heat treatment is preferably +5°C to +15°C from the temperature during heat treatment of the upper surface. A uniform stress distribution can be formed on the upper and lower surfaces of the glass blank by adjusting the temperature at which the upper and lower surfaces of the glass blank are held according to the difference in the glass transition temperature T_g between the surface layers thereof.

[0077] In this manner, the distribution of residual stress prior to the chemical reinforcing step can be made to be uniform similarly to (1) above by respectively carrying out heat treatment asymmetrically on the upper and lower surfaces of the glass blank.

[0078] In addition, there are many cases in which residual stress of a glass blank is generated when the glass blank is cooled. Accordingly, with respect to (3) above, annealing treatment is carried out for a long period of time on the glass blank in order to inhibit the generation of residual stress attributable to this rapid cooling, thereby enabling the generation of residual stress on the surface of the glass blank to be evenly reduced. A specific example thereof is a method in which the duration of the annealing step is set to one to two months.

[0079] <Rough Polishing Step>

The rough polishing step (primary polishing step) is carried out using the polishing step indicated below for the purpose of removing scratches and strain remaining from the grinding step by polishing the main surfaces of a glass blank with a polishing slurry containing cerium oxide.

[0080] There are no particular limitations on the polishing device used in the rough

polishing step provided it is a polishing device used to manufacture glass substrate.

[0081] The surface polished in the rough polishing step is a main surface and/or end face.

A main surface refers to a surface parallel to the planar direction of the glass blank. An end face refers to a surface composed of an inner peripheral end face and an outer peripheral end face. In addition, an inner peripheral end face refers to a surface perpendicular to the planar direction of the glass blank of the inner peripheral side, and a surface having an inclination with respect to the planar direction of the glass blank. In addition, an outer peripheral end face refers to a surface perpendicular to the planar direction of the glass blank and a surface having an inclination with respect to the planar direction of the glass blank.

[0082] Next, the abrasive used in the polishing step of the present embodiment contains cerium oxide as a main component thereof. The content of cerium oxide is preferably 3% by mass to 15% by mass based on the total amount of abrasive. As a result of making the content to be within this range, a glass substrate for a magnetic data recording medium can be manufactured that has higher surface smoothness.

[0083] In addition, a polishing slurry refers to a liquid in the state of having the aforementioned abrasive and a dispersant and the like dispersed in water, namely a slurry. When the abrasive is dispersed in water, even if the water contains an alkaline earth metal, since the alkaline earth metal is dissolved, it is difficult for it to adhere to the surface of the glass blank, while an alkaline earth metal contained in the abrasive easily adheres to the surface of the glass blank. For reasons such as this, by using an abrasive having a low alkaline earth metal content for the abrasive, the adhesion of alkaline earth metals to the glass blank after polishing can be adequately inhibited.

[0084] <Precision Polishing Step (Secondary Polishing Step)>

The precision polishing step consists of mirror polishing treatment for finishing to a smooth, mirrored surface having a surface roughness (R_{max}) of the main surface of about 6

nm or less while maintaining the flat, smooth main surface obtained in the previously described rough polishing step. This precision polishing step is carried out by changing the polishing pad from a hard polishing pad to a soft polishing pad using a polishing device similar to that used in the rough polishing step. Furthermore, the surface polished in the precision polishing step is a main surface in the same manner as the surface polished in the rough polishing step.

[0085] In addition, an abrasive that is less abrasive and reduces the formation of scratches to a greater extent than the abrasive used in the rough polishing step is used for the abrasive used in the precision polishing step. A specific example thereof is an abrasive containing a silica abrasive grain (colloidal silica) having a smaller particle diameter than the abrasive used in the rough polishing step. The mean particle diameter of this silica-based abrasive grain is preferably about 20 nm. The surface of the glass blank is mirror polished by supplying a polishing slurry containing the aforementioned abrasive to a glass blank and sliding the polishing pad relative to the glass blank.

[0086] <Chemical Reinforcing Step>

The method of manufacturing a glass substrate for HDD according to the present embodiment is preferably provided with a chemical reinforcing step. There are no particular limitations on the chemical reinforcing step provided it employs a known method. A specific example thereof is a step consisting of immersing a glass blank in a chemical reinforcing treatment liquid. As a result of doing so, a chemically reinforced layer can be formed on the surface of the glass blank, and for example, in a region 5 μm from the surface of the glass blank. The formation of a chemically reinforced layer makes it possible to not only improve impact resistance, but also improve vibration resistance, heat resistance and the like.

[0087] More specifically, the chemical reinforcing step is carried out by an ion exchange

method consisting of substituting alkaline metal ions such as lithium ions or sodium ions contained in the glass blank for alkaline metal ions such as potassium ions having a larger ionic radius by immersing the glass blank in a heated chemical reinforcing treatment liquid. Compression stress is generated in the region that has undergone ion exchange due to strain generated by the difference in ionic radius, thereby reinforcing the surface of the glass blank.

[0088] In the present embodiment, the use of a glass blank having a glass composition as previously described for the glass blank serving as the starting material of a glass substrate is thought to allow the preferable formation of a reinforced layer by this chemical reinforcing step. More specifically, this is thought to be because, among the Li_2O , Na_2O and K_2O alkaline components of the glass blank, the content of Na_2O is high, and sodium ions of this Na_2O are easily replaced by potassium ions contained in the chemical reinforcing treatment liquid. Moreover, in the polishing step carried out prior to the chemical reinforcing step, since the abrasive used in the rough polishing step is an abrasive having a composition as previously described, the amount of alkaline earth metals adhered to the surface of the glass blank is low, and this is thought to result in uniform chemical reinforcing. Accordingly, as a result of carrying out the precision polishing step on a glass blank that has undergone preferable chemical reinforcing in the manner of the present embodiment, glass substrate can be manufactured that have superior impact resistance.

[0089] There are no particular limitations on the chemical reinforcing treatment liquid provided it is a chemical reinforcing treatment liquid used in a chemical reinforcing step of a method for manufacturing a glass substrate for a magnetic data recording medium. Specific examples thereof include a molten liquid containing calcium ions and a molten liquid containing potassium ions and sodium ions.

[0090] Examples of these molten liquids include molten liquids obtained by melting potassium nitrate, sodium nitrate, potassium carbonate or sodium carbonate. Among these,

the combined use of a molten liquid obtained by melting potassium nitrate and a molten liquid obtained by melting sodium nitrate is preferable from the viewpoints of having a low melting point and preventing deformation of the glass blank. At that time, the melting liquid is preferably obtained by mixing roughly equal amounts of the molten liquid obtained by melting potassium nitrate and the molten liquid obtained by melting sodium nitrate.

[0091] <Cleaning Step>

A cleaning step may be carried out in addition to the aforementioned steps in the method of manufacturing glass substrate according to the present embodiment. This cleaning step is a step of cleaning glass substrate that have undergone the aforementioned rough polishing step.

[0092] Glass substrate following rough polishing according to the rough polishing step are preferably cleaned by a cleaning step. For example, a glass substrate is cleaned using an alkaline detergent having a pH of 13 or higher followed by rinsing the glass substrate. Next, the glass substrate is cleaned using an acidic detergent having a pH of 1 or lower followed by rinsing the glass substrate. Finally, the glass substrate is cleaned using a hydrofluoric acid (HF) solution. With respect to polishing using cerium oxide, it is most efficient to carry out cleaning in the order of alkaline cleaning, acidic cleaning and finally HF cleaning. In this case, abrasive is first dispersed and removed by the alkaline detergent, abrasive is then dissolved and removed by the acidic detergent, and finally the glass substrate is etched by HF to remove abrasive penetrating deep into the glass substrate.

[0093] In the aforementioned cleaning step, alkaline cleaning, acidic cleaning and HF cleaning are preferably carried out in separate tanks. This is because, in the case of carrying out this series of cleaning in a single tank, there are cases in which cleaning may not be efficient. In the case of containing an acidic detergent and HF in the same tank in particular, there is a tendency for etching to not proceed uniformly in the substrate since the HF etching

rate decreases at those locations where there are large amounts of abrasive. In addition, a rinsing tank is preferably used after each cleaning. A surfactant, dispersant, chelating agent or reducing agent and the like may also be added to these detergents depending on the case. In addition, each detergent preferably uses deaerated water by applying ultrasonic waves to each cleaning tank.

[0094] (Magnetic Recording Medium)

Fig. 5 is a partial cross-sectional perspective view showing a magnetic disk as an example of a magnetic recording medium that uses a glass substrate for an HDD manufactured by the manufacturing method according to the present embodiment. This magnetic disk D is provided with a magnetic film 102 formed on a main surface of a circular HDD glass substrate 101. The magnetic film 102 is formed using a formation method according to known, commonly used means. Examples thereof include a method consisting of forming the magnetic film 102 by spin-coating a thermosetting resin having magnetic particles dispersed therein on the HDD glass substrate 101 (spin coating method), a method consisting of forming the magnetic film 102 by sputtering on the HDD glass substrate 101 (sputtering method), and a method consisting of forming the magnetic film 102 by electroless plating on the HDD glass substrate 101 (electroless plating method).

[0095] A magnetic recording medium that uses the HDD glass substrate 101 for the base thereof as in the present embodiment is able to record and recover data over a long period of time and with high reliability since the HDD glass substrate 101 has impact resistance as previously described.

[0096] Furthermore, although the previous description explained the case of using the HDD glass substrate 101 of the present embodiment in a magnetic recording medium, it is not limited thereto, but rather the HDD glass substrate 101 of the present embodiment can be used in a magneto-optical disk or optical disk and the like.

[0097] Although the present description discloses various aspects of the art as previously described, the main forms of that art are summarized below.

[0098] One aspect of the present invention is a method of manufacturing a glass substrate for HDD, the method comprising: a step of obtaining a glass plate by a float method, a step of forming a glass blank by cutting the glass plate into the shape of a disk, a surface processing step of grinding and/or polishing the glass blank, and a chemical reinforcing step of carrying out ion exchange on the surface of the glass blank by immersing the surface-processed glass blank in a chemical reinforcing treatment liquid, wherein in the glass blank immediately prior to the chemical reinforcing step, in a case where the amount of retardation from a cross-section is measured when the glass blank has been cut into the shape of a strip in a direction perpendicular to the main surface thereof, a difference between a first maximum value of the amount of retardation per unit optical path length in a range from one main surface to 10 μm , and a second maximum value of the amount of retardation per unit optical path length in a range from the other main surface to 10 μm , is 10 nm/mm or less.

[0099] According to this configuration, a method of manufacturing a glass substrate for HDD having superior impact resistance can be provided. More specifically, since the difference in residual stress between one main surface and another main surface (upper and lower surfaces) is small and the distribution of stress can be said to be uniform between the upper and lower surfaces, even in the case of having undergone chemical reinforcing treatment, there is no exacerbation of the balance of compression stress between the upper and lower surfaces, thereby resulting in superior impact resistance even in the case of having been incorporated as a glass substrate for an HDD. In addition, there is no exacerbation of the balance of compression strength between the upper and lower surfaces even in the case of having undergone a chemical reinforcing step, thereby making it possible to reduce the risk of cracking even in the case of having mistakenly dropped the HDD or subjected to an impact

when carrying.

[0100] In addition, the difference between the first maximum value and the second maximum value in the aforementioned method of manufacturing a glass substrate for HDD is preferably 3 nm/mm or less.

[0101] According to this configuration, a glass substrate for HDD is obtained that have even more superior impact resistance.

[0102] In addition, an equalization step is preferably provided in the aforementioned method of manufacturing a glass substrate for HDD for equalizing the distribution of stress between one main surface and the other main surface of a glass blank immediately prior to the chemical reinforcing step.

[0103] According to this configuration, a glass substrate for HDD having superior impact resistance can be easily manufactured.

[0104] In addition, the equalization step in the aforementioned method of manufacturing a glass substrate for HDD is preferably a step for carrying out annealing treatment on a glass blank formed by the float method, followed by repeating annealing treatment after grinding the main surface of the glass blank on the side that contacts molten tin in the float method.

[0105] According to this configuration, a glass substrate for HDD having superior impact resistance can be manufactured more easily.

[0106] In addition, in the aforementioned method of manufacturing a glass substrate for HDD, the equalization step is preferably an annealing step for carrying out annealing treatment on a glass blank formed by the float method, and the annealing step is preferably carried out at different temperatures for the upper and lower surfaces.

[0107] According to this configuration, a glass substrate for HDD having superior impact resistance can be manufactured more easily.

[0108] In addition, in the aforementioned method of manufacturing a glass substrate for

HDD, the equalization step is preferably a step for carrying out annealing treatment on a glass blank formed by the float method, and the annealing step is preferably carried out over a period of one month or longer.

[0109] According to this configuration, a glass substrate for HDD having superior impact resistance can be manufactured more easily.

Examples

[0110] Although the following provides a detailed explanation of the present invention by indicating examples thereof, the present invention is not limited thereto.

[0111] [Example 1]

A glass substrate for an HDD was manufactured by carrying out the disk forming step, grinding step, re-annealing step, rough polishing step (primary polishing step), precision polishing step (secondary polishing step) and cleaning step described below.

[0112] (Disk Forming Step)

A glass blank having a thickness of 1.0 mm manufactured by the float method was cut into the shape of a quadrilateral of a prescribed size. Annealing treatment was carried out on this glass blank for 3 hours at a maximum temperature of 500°C, and after cooling, cutting lines were formed in the surface of the glass blank with a glass cutter. Circular cutting lines were respectively formed describing the approximate outer peripheral side and inner peripheral side of a region to serve as a glass substrate for a magnetic disk. Continuing, the glass blank in which the cutting lines had been formed was heated with a heater to obtain a glass substrate provided with a center hole in the central portion thereof. Furthermore, glass having a composition consisting of 69% by mass of SiO₂, 15% by mass of Al₂O₃, 4% by mass of Li₂O and 12% by mass of Na₂O was used for the molten glass used in the float method.

[0113] In addition, the thickness of the tin layer in the glass blank following the disk

forming step was 30 μm .

[0114] (Grinding Step)

Next, both sides of the glass blank were ground by 80 μm each with a double-side grinding device using a diamond abrasive grain.

[0115] (Re-annealing Step)

A re-annealing step was carried out by carrying out heat treatment for 3 hours at a maximum temperature of 500°C by heating and cooling at a temperature gradient of 3°C/min to remove residual stress from the glass blank.

[0116] (Rough Polishing Step)

Next, polishing was carried out using a double-side polishing device to remove scratches and strain remaining after the grinding step from the surface. Hard urethane foam was used for the polishing pad, cerium oxide having a mean particle diameter of 1 μm dispersed in water was used for the polishing liquid, and the polishing time was 40 minutes.

[0117] (Precision Polishing Step)

Continuing, mirror polishing processing was carried out until the surface roughness R_{max} of the glass blank became about 6 nm or less using the same double-side polishing device as that used in the rough polishing step. The polishing pad was replaced with a soft polisher, colloidal silica having a mean particle diameter of 20 nm dispersed in water was used for the polishing liquid, and the polishing time was 20 minutes.

[0118] (Cleaning Step)

The glass disk on which the precision polishing step had been completed was subjected to ultrasonic cleaning and drying by sequentially immersing in cleaning tanks respectively containing a neutral detergent, pure water, pure water, IPA and IPA (vapor drying).

[0119] The glass substrate for an HDD manufactured in the manner described above was cut

into the shape of a strip, the amounts of retardation at a depth of 10 μm were respectively measured from both recording surfaces at several points using a polarimeter (Shinko Seiki Co., Ltd.), the maximum values thereof were determined, and the difference in maximum values in the vicinity of each surface was identified.

[0120] In addition, the amounts of retardation near both recording surfaces at the corresponding locations were also measured at several points using the same polarimeter for the glass substrate on which the precision polishing had been carried out and which had also undergone a chemical reinforcing step to be subsequently described, and the difference in their maximum values was identified.

[0121] The glass substrate was evaluated for impact resistance as subsequently described after having carried out the chemical reinforcing step.

[0122] (Chemical Reinforcing Step)

The chemical reinforcing step was carried out on the glass substrate following the precision polishing step. A mixture of calcium nitrate and potassium nitrate was used for the chemical reinforcing liquid, and chemical reinforcing treatment was carried out by heating this chemical reinforcing liquid to 400°C and immersing the glass disk therein for about 1 hour.

[0123] (Example 2)

In Example 2, a glass substrate was manufactured by carrying out the same steps as Example 1 with the exception of not carrying out a re-annealing step, and carrying out annealing treatment so that heat treatment carried out on the upper and lower surfaces thereof was asymmetrical by carrying out heat treatment for 3 hours at the maximum temperature by heating and cooling at a temperature gradient of 3°C/min while holding the upper side surface of the glass substrate at 500°C and the lower side surface at 510°C in the disk forming step.

[0124] (Example 3)

In Example 3, a glass substrate was manufactured by carrying out the same steps as Example 1 with the exception of not carrying out a re-annealing step and carrying out annealing treatment in the float step for two months.

[0125] (Example 4)

In Example 4, a glass substrate was manufactured by carrying out the same steps as Example 1 with the exception of not carrying out a re-annealing step, and carrying out annealing treatment so that heat treatment carried out on the upper and lower surfaces thereof was asymmetrical by carrying out heat treatment for 3 hours at the maximum temperature by heating and cooling at a temperature gradient of 3°C/min while holding the upper side surface of the glass substrate at 500°C and the lower side surface at 505°C in the disk forming step.

[0126] (Example 5)

In Example 5, a glass substrate was manufactured by carrying out the same steps as Example 1 with the exception of not carrying out a re-annealing step and carrying out annealing treatment in the float step for one month.

[0127] (Comparative Example 1)

In Comparative Example 1, a glass substrate was manufactured using the same method as Example 1 with the exception of not carrying out a re-annealing step and carrying out annealing treatment for 12 hours prior to the grinding step.

[0128] (Comparative Example 2)

In Comparative Example 2, a glass substrate was manufactured using the same method as Example 1 with the exception of not carrying out a re-annealing step and additionally not carrying out annealing treatment in the disk forming step.

[0129] (Evaluation Method)

Magnetic films were formed on the glass substrates of Examples 1 to 5 and Comparative Examples 1 to 2 described above and then mounted on HDD followed by

evaluation of impact resistance in a drop test. In this evaluation method, the glass substrates were evaluated as being acceptable if cracks did not form in the magnetic disks when 100 of the HDD were dropped from a height equivalent to 1500 G three times each. The test results are shown in Table 1.

[0130] [Table 1]

	Maximum value of difference in amount of retardation (nm/mm)	Maximum value of difference in amount of retardation after carrying out chemical reinforcing step (nm/mm)	Dropping test acceptance rate (%)
Example 1	1	2	100
Example 2	3	3	98
Example 3	1	3	99
Example 4	6	8	95
Example 5	8	10	92
Comparative Example 1	13	38	74
Comparative Example 2	38	106	3

[0131] Based on the results of Table 1, with respect to the glass substrate for HDD of Example 1, in which the re-annealing step was carried out after the grinding step so that the distribution of stress between the upper and lower surfaces (difference in maximum values of the amount of retardation) of the glass substrate prior to the chemical reinforcing step became uniform, Examples 2 and 4, in which annealing treatment was carried out asymmetrically, and Examples 3 and 5, in which annealing treatment was carried out for a long period of time, the difference in the maximum values of the amount of retardation at a depth of 10 μm each from both recording surfaces prior to the chemical reinforcing step was 10 nm/mm or less per unit optical path length. In addition, in the glass substrates produced in Examples 1 to 3 the

difference in the maximum values of compression stress (maximum values of the amount of retardation) after carrying out the chemical reinforcing step was small, thereby resulting in superior impact resistance.

[0132] On the other hand, in Comparative Example 1, in which the re-annealing step was not carried out, the distribution of stress between the upper and lower surfaces of the glass substrate was not uniform and the difference in the maximum values of the amount of retardation at the same locations was greater than 10 nm/mm, and in the case of having carried out the chemical reinforcing step, impact resistance was inferior to that of each of the examples. Moreover, with respect to Comparative Example 2, in which annealing treatment was not carried out in the disk forming step, the difference in the maximum values of the amount of retardation became even larger, the distribution of stress became non-uniform, and as a result thereof, the balance of compression strength after the chemical reinforcing step became poor, thereby resulting in inferior impact resistance.

Industrial Applicability

[0133] According to the present invention, a method is provided of manufacturing a glass substrate for HDD that demonstrate superior impact resistance.

Claims

1. A method of manufacturing a glass substrate for HDD,
the method comprising:
a step of obtaining a glass plate by a float method,
a step of forming a glass blank by cutting the glass plate into the shape of a disk,
a surface processing step of grinding and/or polishing the glass blank, and
a chemical reinforcing step of carrying out ion exchange on the surface of the glass blank by immersing the surface-processed glass blank in a chemical reinforcing treatment liquid, wherein

in the glass blank immediately prior to the chemical reinforcing step, in a case where the amount of retardation from a cross-section is measured when the glass blank has been cut into the shape of a strip in a direction perpendicular to the main surface thereof, a difference between a first maximum value of the amount of retardation per unit optical path length in a range from one main surface to 10 μm , and a second maximum value of the amount of retardation per unit optical path length in a range from the other main surface to 10 μm , is 10 nm/mm or less.
2. The method of manufacturing a glass substrate for HDD according to claim 1, wherein the difference between the first maximum value and the second maximum value is 3 nm/mm or less.
3. The method of manufacturing a glass substrate for HDD according to claim 1 or 2, comprising an equalization step of equalizing the distribution of stress between one main surface and the other main surface of a glass blank immediately prior to the chemical reinforcing step.
4. The method of manufacturing a glass substrate for HDD according to claim 3,

wherein the equalization step is a step of carrying out annealing treatment on a glass blank formed by the float method, and carrying out re-annealing treatment after grinding the main surface of the glass blank on the side that contacts molten tin in the float method.

5. The method of manufacturing a glass substrate for HDD according to claim 3, wherein the equalization step is an annealing step of carrying out annealing treatment on a glass blank formed by the float method, and the annealing step is carried out at different temperatures for the upper and lower surfaces.

6. The method of manufacturing a glass substrate for HDD according to claim 3, wherein the equalization step is an annealing step of carrying out annealing treatment on a glass blank formed by the float method, and the annealing step is carried out over a period of one month or longer.