

DESCRIPTION

GLASS SUBSTRATE, INFORMATION RECORDING MEDIUM USING GLASS SUBSTRATE, AND METHOD FOR PRODUCING GLASS SUBSTRATE

TECHNICAL FIELD

[0001] The present invention relates to a glass substrate, an information recording medium using the glass substrate, and a method for producing the glass substrate. More specifically, the present invention relates to a glass substrate having excellent impact resistance with a low frequency of occurrence of delayed errors due to ion elution, an information recording medium using the glass substrate, and a method for producing the glass substrate.

BACKGROUND ART

[0002] Conventionally, there is widely used an aluminium substrate, as a substrate constituting an information recording medium. In the aspect of producing a compact, thin, and high-density information recording medium, there is paid attention to a glass substrate having excellent surface smoothness and less surface defects, and capable of reducing a magnetic-head floating amount, as compared with an aluminium substrate (see e.g. patent publication 1).

[0003] In recent years, there is a demand for a glass substrate having enhanced impact resistance, as the glass substrate is used for a variety of mobile devices. As a method for enhancing impact resistance, there is proposed a method for substituting alkali ions in a glass substrate for alkali ions having a larger ionic radius. Specifically, there is known a method, in which the surface of a glass substrate is immersed in a chemical reinforcing treatment solution containing nitrate (KNO_3 or NaNO_3) at a temperature of about 360°C for chemical reinforcement, and a reinforced layer including an ion exchange layer and a compressive stress layer is formed. In particular, in order to generate a large compressive stress by ion exchange, it is necessary to substitute existing ions for ions having a larger ionic radius. For instance, lithium ions are substituted for sodium ions by chemically reinforcing a glass substrate containing lithium ions by a chemical reinforcement solution containing KNO_3 and NaNO_3 , and part of sodium ions are substituted for potassium ions, whereby it is possible to generate a large compressive stress by potassium ions. In the specification, an ion exchange layer is a layer formed by substituting part of alkali ions in a glass substrate for alkali ions in a chemical reinforcing treatment solution on the surface of the glass substrate. The ion exchange layer can be measured by detecting an alkali ion concentration after the chemical reinforcement. Accordingly, the thickness of an ion exchange layer differs depending on alkali ions to be

detected. In the case where a chemical reinforcement solution contains potassium ions, and potassium ions containing sodium ions, the thickness of an ion exchange layer and the thickness of an ion exchange layer by sodium ions may differ from each other. An ion exchange layer has such a property that ions having a larger ionic radius are less likely to permeate through the layer. As a result, the thickness of an ion exchange layer by potassium ions may be smaller than the thickness of an ion exchange layer by sodium ions. On the other hand, a compressive stress layer means a portion in which a compressive stress is generated by chemical reinforcing treatment. It is possible to obtain the thickness of the compressive stress layer by optically measuring birefringence on the outer surface of a glass substrate resulting from a compressive stress generated by ion exchange. As described above, the thickness of an ion exchange layer and the thickness of a compressive stress layer do not always coincide with each other. Typically, the thickness of an ion exchange layer is smaller than the thickness of a compressive stress layer. The details on the definition of these terms will be described later. Forming a compressive stress layer on the surface of a glass substrate by the aforementioned method makes it possible to resist against a tensile stress resulting from flaws, even when the surface of the glass substrate is damaged. Thus, it is possible to prevent damage of the glass substrate, without spread of flaws.

[0004] A hard disk drive is loaded in a mobile device such as a notebook personal computer, a mobile phone, or a mobile music player. Regarding an information recording medium to be used, damage-free high impact resistance is required against drop of a mobile device, for instance. In particular, a mobile device may be used in a severe environment in which the temperature change is large such as a high-temperature environment or a low-temperature environment. Accordingly, it is necessary to keep a high strength against drop even after the mobile device is used in a severe temperature condition. In view of the above, there is a demand for a glass substrate having superior impact resistance, as compared with the impact resistance obtainable in the conventional art.

[0005] On the other hand, regarding chemical reinforcing treatment for increasing the strength of a glass substrate, patent publication 2 discloses a chemically reinforced glass substrate, in which the compressive stress depth is 50 μm or more. In patent publication 2, the thickness of a compressive stress layer formed by ion exchange is large, typically from about 10 to 150 μm , and preferably from 50 to 120 μm . Patent publication 2 is silent about the thickness of an ion exchange layer.

[0006] As described above, however, it is revealed that, in a use state of a severe temperature condition, a recording layer of an information recording medium may be damaged by elution of

ions introduced by ion exchange from an ion exchange layer formed by chemical reinforcement, a compressive stress on the surface of the glass substrate may become uneven due to ion elution, and a slight strain may be generated on the glass substrate itself by heating. In particular, it is revealed that in chemically reinforcing a glass substrate containing lithium ions, potassium ions advantageously generate a large compressive stress, but may result in large unevenness of the compressive stress of the glass substrate, because ion elution causes local large unevenness of the compressive stress. In recent years, a hard disk drive having a recording density as high as 500 GB/disk (one-side: 250 GB) has been developed by loading a DFH (Dynamic Flying Hight) mechanism. In such a high recording density hard disk, a slight change in the shape or damage of a recording layer may generate a reading error. Thus, improvement has been required.

CITATION LIST

PATENT PUBLICATION

- [0007] Patent publication 1: JP Hei 9-27150A
Patent publication 2: JP 2009-99251A

SUMMARY OF INVENTION

[0008] In view of the above, an object of the invention is to provide a glass substrate having excellent impact resistance even when used in a severe temperature condition, and having a low frequency of occurrence of delayed errors due to ion elution even when used for a high recording density hard disk drive, an information recording medium using the glass substrate, and a method for producing the glass substrate.

[0009] A glass substrate according to an aspect of the invention is a glass substrate provided with a reinforced layer on a surface of a glass material with use of a chemical reinforcing treatment solution, the reinforced layer including a potassium ion exchange layer and a compressive stress layer. The glass material contains lithium. The thickness of the compressive stress layer is 35 times or more and 100 times or less of the thickness of the potassium ion exchange layer.

[0010] Further, a method for producing a glass substrate according to another aspect of the invention is a method for producing a glass substrate provided with a chemical reinforcing step of chemically reinforcing the glass substrate by contacting the glass substrate with a chemical reinforcing treatment solution to exchange alkali metal ions on a surface of the glass substrate for alkali metal ions having an ionic radius larger than an ionic radius of the alkali metal ions contained in the chemical reinforcing treatment solution. The chemical reinforcing step

includes a chemical reinforcing treatment solution immersion step of immersing the glass substrate in the chemical reinforcing treatment solution at 450 to 550 °C for 15 to 30 minutes. The glass substrate contains Li. The chemical reinforcing treatment solution contains potassium salt and sodium salt at a mass ratio of from 8:2 to 9.5:0.5.

[0011] These and other objects, features and advantages of the present invention will become more apparent upon reading the following detailed description along with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0012] FIG. 1 is an explanatory diagram for describing the thickness of a compressive stress layer of a glass substrate (Example 1) according to an embodiment of the invention;

FIG. 2 is a graph for describing the thickness of an ion exchange layer and the content ratio of potassium ions in the glass substrate (Example 1) according to the embodiment of the invention;

FIG. 3 is an explanatory diagram for describing the thickness of a compressive stress layer of a conventional glass substrate (Comparative Example 1); and

FIG. 4 is a schematic diagram of a shock testing machine to be used in a drop impact test.

DESCRIPTION OF EMBODIMENTS

[0013] (Glass Substrate)

In the following, a glass substrate and a method for producing the glass substrate of an embodiment are described in detail.

[0014] The glass substrate of the embodiment is a glass substrate configured such that a reinforced layer including a potassium ion exchange layer and a compressive stress layer is formed on the surface of a glass material with use of a chemical reinforcing treatment solution. The glass material contains lithium. The thickness of the compressive stress layer is 35 times or more and 100 times or less of the thickness of the potassium ion exchange layer.

[0015] The glass substrate is produced by e.g. a glass melting step, a molding step, a heat treatment step, a first lapping step, a coring step, an inner diameter/outer diameter processing step, a second lapping step, an end surface polishing step, a first polishing step, a chemical reinforcing step, a second polishing step, a washing step, and an inspection step. In the following, each of the steps is described in detail.

[0016] [Glass Melting Step]

The glass melting step is a step of melting a glass material. The material for a glass substrate may contain lithium (Li_2O). Li_2O - SiO_2 -based glass or Li_2O - Al_2O_3 - SiO_2 -based glass may be used. Specifically, it is possible to use, as a glass material, a glass composition having a composition ratio such that SiO_2 : 50 to 70 % by mass, Al_2O_3 : 0 to 20 % by mass, B_2O_3 : 0 to 5 % by mass ($\text{SiO}_2+\text{Al}_2\text{O}_3+\text{B}_2\text{O}_3$: 50 to 85 % by mass), Li_2O : 2 to 10 % by mass, Na_2O : 4 to 15 % by mass, K_2O : 0.1 to 5 % by mass, and $\text{MgO}+\text{CaO}+\text{BaO}+\text{SrO}+\text{ZnO}$: 2 to 20 % by mass. The content of Li_2O is preferably from 2 to 10 % by mass, more preferably from 2 to 6 % by mass, and furthermore preferably from 3 to 5 % by mass. In the case where the content of Li_2O is less than 2 % by mass, in a chemical reinforcing step to be described later, the amount of alkali ions to be substituted for lithium ions may decrease. This may decrease the thickness of a compressive stress layer and may make it difficult to impart sufficient impact resistance. On the other hand, use of Li_2O in excess of 10 % by mass may likely to cause stress relaxation, and may deteriorate the durability. The glass melting method is not specifically limited. Generally, it is possible to employ a method for melting the aforementioned glass material at a well-known temperature and for a well-known time in a high-temperature condition.

[0017] <Molding Step>

The molding step is a step of obtaining a glass substrate (blanks) from a molten glass material. The method for obtaining blanks is not specifically limited. For instance, it is possible to employ a method for obtaining a disc-shape glass substrate (blanks) by injecting a molten glass material into a lower die, followed by press molding between the lower die and an upper die. The blanks may be formed by cutting a sheet glass obtained by a down drawing process or a floating process with use of a grinding wheel, in place of press molding. In the molding step, foreign matter or air bubbles may intrude in the vicinity of the surfaces of the blanks, or defects may be formed due to flaws on the surfaces of the blanks.

[0018] The size of the blanks is not limited. It is possible to produce blanks of various sizes, whose outer diameters are 2.5 inches, 1.8 inches, 1 inch, and 0.8 inch. When blanks of 2.5 inch-diameter are produced, it is possible to produce an HDD for use in a mobile device such as a notebook personal computer, with use of a glass substrate obtained from the blanks. The thickness of the glass substrate is not specifically limited. For instance, it is possible to form blanks of various thicknesses such as 2 mm, 1 mm, 0.8 mm, and 0.63 mm.

[0019] <Heat Treatment Step>

The heat treatment step is a step of alternately laminating a glass substrate produced by press molding or cutting, and a setter as a heat resistant member, and allowing the laminate to pass through a high-temperature electric furnace to thereby reduce a warpage of the glass

substrate or accelerate crystallization of glass.

[0020] <First Lapping Step>

The first lapping step is a step of roughly polishing both surfaces of the glass substrate for preliminary adjustment of the parallelism, the degree of flatness, and the thickness of the glass substrate. In the first lapping step, a large warpage, chipping or cracks of the glass substrate are removed so that the second lapping step that follows the first lapping step can be efficiently carried out. The surface roughness Ra of the principal surface of the glass substrate at the point of time when the first lapping step is finished is preferably from about 0.4 to 0.8 μm , and the degree of flatness of the principal surface is preferably from about 10 to 15 μm . It is possible to measure the surface roughness of the glass substrate with use of an atomic force microscope (a nanoscope produced by Digital Instruments, Inc.), and to measure the degree of flatness by a flatness measuring device.

[0021] <Coring Step>

The coring step is a step of forming a circular hole in the center portion of the glass substrate which has undergone the first lapping step. The hole is formed by e.g. drilling with use of a core drill equipped with a diamond wheel on a cutter part thereof. The size of the hole is not specifically limited, but is typically about 20 mm.

[0022] <Inner/Outer Diameter Processing Step>

The inner/outer diameter processing step is a step of roughly polishing the outer peripheral end surface and the inner peripheral end surface of the glass substrate with use of a drum-shaped grinding wheel using e.g. diamond for forming the outer diameter and the outer diameter.

[0023] <Second Lapping Step>

The second lapping step is a step of roughly polishing both surfaces of the glass substrate for finely adjusting the parallelism, the degree of flatness, and the thickness of the glass substrate.

[0024] The grinding machine to be used in the first lapping step and the second lapping step is not specifically limited. For instance, it is possible to use a dual side grinding machine utilizing a planetary gear mechanism. In the glass substrate which has undergone the second lapping step, defects such as a large warpage, chipping or cracks are substantially removed. The surface roughness Ra of the principal surface of the glass substrate is preferably from about 0.2 to 0.4 μm , and the degree of flatness of the principal surface is preferably from about 7 to 10 μm . Setting the surface state of the glass substrate as described above makes it possible to efficiently perform polishing in the first polishing step that follows the second lapping step.

[0025] Lapping solution residues or glass powders may remain on the surface of the glass substrate which has undergone the first lapping step and the second lapping step. In view of the above, it is preferable to provide a washing step. Various methods are proposed as a washing method in the washing step. For instance, only alkali washing may be performed for the glass substrate, or alkali washing may be performed after acid washing, or only acid washing may be performed.

[0026] [End Surface Polishing Step]

The end surface polishing step is a step of polishing the outer peripheral end surface and the inner peripheral end surface of the glass substrate which has undergone the second lapping step, with use of an end surface polishing machine.

[0027] [First Polishing Step]

The first polishing step is a step of polishing both surfaces of the glass substrate. Specifically, the first polishing step is a polishing step which is carried out in order to enhance the surface roughness of the surface of the glass substrate and to efficiently obtain the shape of the glass substrate as a final product so that the surface roughness finally required in the second polishing step, which is performed after the chemical reinforcing step that follows the first polishing step, is efficiently obtained.

[0028] The polishing method is not specifically limited. It is possible to polish with use of a polishing pad and a polishing solution by a dual side polishing machine having a configuration similar to the configuration of the dual side grinding machine used in the first lapping step and in the second lapping step.

[0029] The shape of a polishing surface of a polishing pad greatly changes, as the hardness of the polishing pad is lowered due to generation of heat by polishing. In view of the above, it is preferable to use a hard polishing pad, for instance, a polishing pad made of foamed polyurethane.

[0030] A polishing solution may be slurry obtained by using cerium oxide having an average particle diameter of 0.6 to 2.5 μm as abrasive grains (an abrasive material), and by dispersing the abrasive grains in water. The mixing ratio between water and abrasive grains is from about 1:9 to 3:7.

[0031] The polishing amount in the first polishing step is preferably from about 25 to 40 μm . The polishing amount of less than 25 μm may result in insufficient removal of flaws or defects. On the other hand, the polishing amount in excess of 40 μm may lower the production efficiency due to excessive polishing.

[0032] [Chemical Reinforcing Step]

The chemical reinforcing step is a step of forming a reinforced layer (an ion exchange layer and a compressive stress layer) on the principal surface, the outer peripheral end surface, and the inner peripheral end surface of the glass substrate, after a step (a chemical reinforcing treatment solution immersion step) of immersing the glass substrate in a chemical reinforcing treatment solution. Forming a reinforced layer on the principal surface of the glass substrate makes it possible to prevent warpage of the glass substrate and surface roughness of the principal surface. Forming a reinforced layer on the outer peripheral end surface and the inner peripheral end surface of the glass substrate makes it possible to improve impact resistance, vibration resistance, and heat resistance of the glass substrate.

[0033] The chemical reinforcing step is performed by an ion exchange process of substituting alkali ions (e.g. lithium ions) contained in the glass substrate and having a relatively small ionic radius for alkali metal ions (e.g. potassium ions or sodium ions) having a larger ionic radius by immersing the glass substrate in a heated chemical reinforcing treatment solution. A strain due to a difference in the ionic radius generates a compressive stress in the ion-exchanged region and in a region near the ion-exchanged region, and reinforces the principal surface, the outer peripheral end surface, and the inner peripheral end surface of the glass substrate by a compressive stress layer.

[0034] In the present specification, an ion exchange layer is a layer formed by substituting part of alkali ions in a glass substrate for alkali ions of a chemical reinforcing treatment solution on the surface and on the outer layer of the glass substrate. In particular, the thickness of an ion exchange layer by potassium ions is detected. For instance, the thickness of a potassium ion exchange layer is measured by the following method. The mass % concentration of potassium and sodium are measured with respect to each of the glass substrate before chemical reinforcement and the glass substrate after chemical reinforcement at a position deeper from the outer surface (a principal surface) of the cut glass substrate by an increment of 1 μm , with use of an energy dispersion X-ray analyzer (XMAX80 produced by Horiba Seisakusho), and the depth at which the amount (% by mass) of potassium ions relative to the total amount of sodium ions and potassium ions in the glass substrate after chemical reinforcement increases by 10% or more with respect to the amount (% by mass) of potassium ions relative to the total amount of sodium ions and potassium ions in the glass substrate before chemical reinforcement is calculated as the thickness of the potassium ion exchange layer.

[0035] The potassium amount is a value obtained by measuring the amount of potassium in the glass substrate which has undergone the chemical reinforcing step in the form of K_2O or the like by the aforementioned method, and is a value expressed in equivalents of K.

[0036] In the present specification, the compressive stress layer is a layer such that a compressive stress is generated on the surface and on the outer layer of the glass substrate, as a result of formation of the ion exchange layer, and the strength of the glass substrate is improved. It is possible to calculate the thickness of the compressive stress layer by immersing a cut glass substrate in a refractive index matching oil and transmitting linearly polarized light for measuring a phase change of the polarized light by glass internal stress from the rotation angle of an analyzer (Senarmon method); and detecting the angle (a phase difference) at which the transmitted light is maximally darkened by rotating the analyzer, with use of a polarimeter (SF-11C produced by Shinko Seiki). It is possible to calculate a compressive stress value from a photoelastic constant and an optical path length result with use of the aforementioned device.

[0037] As described above, in the embodiment, the depth of the potassium ion exchange layer is obtained by directly detecting potassium ions, and the depth of the compressive stress layer is optically obtained. In the embodiment, since a glass substrate containing lithium ions is used, an ion exchange layer by sodium ions is also formed. Although the thickness of the ion exchange layer by sodium ions is not measured, it is presumed that the thickness of the ion exchange layer by sodium ions lies between the thickness of the ion exchange layer by potassium ions and the thickness of the compressive stress layer, or coincides with the thickness of the compressive stress layer.

[0038] In the specification, the reinforced layer is a layer including the ion exchange layer and the compressive stress layer. As described above, the ion exchange layer is formed only in the outer layer, and is included in the compressive stress layer. Accordingly, the thickness of the compressive stress layer and the thickness of the reinforced layer coincide with each other.

[0039] In the embodiment, there is used a chemical reinforcing treatment solution containing potassium salt and sodium salt by the mass ratio of 8:2 to 9.5:0.5. The mass ratio is preferably from 8.2:1.8 to 9.2:0.8, and more preferably from 8.5:1.5 to 9:1. When the mass ratio of potassium salt is less than 8, the compressive stress value may be lowered. For instance, when the mass ratio is 5:5, Na having a faster diffusion velocity is substituted prior to K. Accordingly, although the thickness of the compressive stress layer increases, the compressive stress value may decrease because K is hardly substituted. On the other hand, when the mass ratio exceeds 9.5, the ion elution amount of potassium ions increases. In addition, the thickness of the compressive stress layer may decrease.

[0040] Examples of potassium salt and sodium salt are nitrate, carbonate, sulfate, and mixed molten salts thereof. Among these, it is preferable to use KNO_3 and NaNO_3 as nitrate in the aspect that these salts have a low melting point and are advantageous in preventing deformation

of a glass substrate.

[0041] A method for preparing a chemical reinforcing treatment solution is not specifically limited. For instance, a chemical reinforcing treatment solution may be prepared by putting potassium salt and sodium salt of a predetermined amount into a chemical reinforcing treatment bath, followed by heating to melt.

[0042] The temperature in the chemical reinforcing treatment solution immersion step is preferably from 450 to 550 °C, more preferably from 470 to 550 °C, and furthermore preferably from 500 to 540 °C. When the temperature is lower than 450 °C, the ion exchange efficiency may be lowered. On the other hand, when the temperature is higher than 550 °C, the ion elution amount may increase. Further, a time for the chemical reinforcing treatment solution immersion step is preferably from 15 to 60 minutes, more preferably from 20 to 50 minutes, and furthermore preferably from 30 to 40 minutes. When the immersion time is shorter than 15 minutes, the ion exchange efficiency may be lowered. On the other hand, when the immersion time is longer than 60 minutes, the ion elution amount may increase.

[0043] Further, in the aspect of efficiently performing chemical reinforcement, it is preferable to include a pre-processing step of holding the glass substrate at 450 to 550 °C for 15 to 30 minutes prior to the chemical reinforcing treatment solution immersion step, and to include a post-processing step of holding the glass substrate after immersion at 450 to 550 °C for 15 to 30 minutes after the chemical reinforcing treatment solution immersion step. As far as the temperature and time conditions in the pre-processing step and in the post-processing step lie in the aforementioned ranges, the conditions as applied in the chemical reinforcing treatment solution immersion step may be used for simplifying the production step and for enhancing the feasibility of production.

[0044] The glass substrate which has undergone the aforementioned chemical reinforcing step is a glass substrate such that the thickness of the compressive stress layer is 35 times or more and 100 times or less of the thickness of the potassium ion exchange layer. Accordingly, the glass substrate has excellent impact resistance with a low frequency of occurrence of delayed errors due to potassium ion elution. The thickness of the compressive stress layer relative to the thickness of the potassium ion exchange layer is preferably 40 times or more and 90 times or less, and more preferably 50 times or more and 80 times or less. When the thickness of the compressive stress layer relative to the potassium ion exchange layer is less than 35 times, the thickness of the potassium ion exchange layer may relatively increase. When the user uses an HDD provided with the glass substrate of the embodiment, potassium ion elution from the glass substrate may relatively increase with respect to the thickness of the glass substrate, and a strain

is likely to occur. As a result, delayed errors may occur in a drive loaded with a DFH mechanism and having a capacity of 500GB/disk. On the other hand, when the thickness of the compressive stress layer relative to the potassium ion exchange layer exceeds 100 times, the thickness of the compressive stress layer may relatively decrease, which may make it difficult or impossible to impart sufficient impact resistance.

[0045] The thickness of the potassium ion exchange layer preferably lies in the aforementioned range, taking into consideration of the thickness of the compressive stress layer. In order to securely prevent delayed errors due to potassium ion elution at the time of use by the user, the thickness of the potassium ion exchange layer is preferably from 2 to 3 μm , more preferably from 2.2 to 3 μm , and furthermore preferably from 2.5 to 3 μm .

[0046] The thickness of the compressive stress layer preferably lies in the aforementioned range, taking into consideration of the thickness of the potassium ion exchange layer. In the aspect of sufficiently imparting impact resistance, the thickness of the compressive stress layer is preferably from 70 to 300 μm , more preferably from 80 to 250 μm , and furthermore preferably from 100 to 200 μm .

[0047] Further, the ion exchange rate of potassium of the potassium ion exchange layer of the glass substrate which has undergone the chemical reinforcing step at a position deeper from the outer layer by 1 μm is preferably from 20 to 40 % by mass, more preferably from 25 to 40 % by mass, and furthermore preferably from 30 to 40 % by mass. As far as the ion exchange rate of potassium at a position deeper from the outer layer by 1 μm lies in the aforementioned range, alkali ions in a region near the outer layer of the glass substrate are substituted for potassium ions, and alkali ions in a deep region of the glass substrate are substituted for sodium ions. As a result of the ion exchange, it is possible to form a compressive stress layer at a deep position of the glass substrate, thereby increasing the compressive stress of the glass substrate.

[0048] After the chemical reinforcing treatment solution immersion step or after post-processing step which may be performed after the immersion step, it is preferable to apply a standby step of placing the glass substrate in the atmosphere or a water immersion step in order to remove the chemical reinforcing treatment solution residues adhered on the surface of the glass substrate and to make the surface of the glass substrate uniform. Applying the above steps makes it possible to form a glass substrate having a uniform reinforced layer with a uniform compressive strain, less deformation, a desirable degree of flatness, and a desirable mechanical strength. The standby time and the water temperature in the water immersion step are not specifically limited. For instance, the glass substrate may be placed in the atmosphere for 1 to 60 seconds, and may be immersed in water at a temperature of from 35 to 100 $^{\circ}\text{C}$. The

standby time and the water temperature may be optionally set according to the production efficiency.

[0049] [Second Polishing Step]

The second polishing step is a step of finely polishing both surfaces of the glass substrate which has undergone the chemical reinforcing step. In the second polishing step, a dual side polishing machine having the same configuration as the dual side polishing machine used in the first lapping step is used.

[0050] The polishing pad is preferably a soft polishing pad having a small hardness, as compared with the polishing pad to be used in the first polishing step. Preferably, the polishing pad may be made of foamed polyurethane or suede.

[0051] The polishing solution may be slurry containing cerium oxide as abrasive grains (an abrasive material) as with the case of the first polishing step. It is, however, preferable to use a polishing solution containing abrasive grains of a smaller particle diameter with less variation in particle diameter to make the surface of the glass substrate smooth. For instance, it is preferable to use, as a polishing solution, slurry obtained by dispersing colloidal silica whose average particle diameter is from 40 to 70 nm as abrasive grains (an abrasive material) in water. The mixing ratio between water and abrasive grains is preferably from about 1:9 to 3:7.

[0052] It is preferable to set the polishing amount in the second polishing step in the range of from about 2 to 5 μm . Setting the polishing amount in the aforementioned range makes it possible to desirably remove minor defects such as small roughness or warpage generated on the surface of the glass substrate, or small scratches generated in the preceding steps. Further, adjusting the polishing condition in the second polishing step as necessary makes it possible to reduce the degree of flatness of the principal surface of the glass substrate to 3 μm or less, and to reduce the surface roughness Ra of the principal surface of the glass substrate to 0.1 nm.

[0053] [Washing Step]

The washing step is a step of washing the glass substrate which has undergone the second polishing step. The washing method is not specifically limited. As far as it is possible to clean the surface of the glass substrate which has undergone the polishing step, any washing method may be used. In the present embodiment, scrub-washing is used.

[0054] A scrub-washed glass substrate is subjected to an ultrasonic cleaning step and a drying step, as necessary. The drying step is a step of removing washing solution residues from the surface of the glass substrate by using IPA (isopropyl alcohol) or the like, followed by drying the surface of the glass substrate. For instance, a scrub-washed glass substrate is subjected to a water rinsing step for 2 minutes for removing the washing solution residues. Then, an IPA

washing step is performed for 2 minutes for removing the water residues from the surface of the glass substrate by IPA. Lastly, an IPA vapor drying step is performed for 2 minutes for drying while removing the IPA solution residues adhered on the surface of the glass substrate by IPA vapor.

[0055] The glass substrate drying step is not limited to the above. A well-known drying method such as spin drying or air knife drying may be used, as a glass substrate drying method.

[0056] [Inspection Step]

The inspection step is a step of checking whether there are scratches, cracks, or adhesion of foreign matter on the glass substrate by visual observation. When it is impossible to discriminate by visual observation, inspection is carried out with use of an optical surface analyzer (e.g. "OSA6100" produced by KLA-TENCOL).

[0057] The glass substrates which have passed the inspection step are accommodated in a dedicated accommodation cassette in a clean environment to avoid adhesion of foreign matter or the like on the surfaces of the glass substrates, followed by vacuum packing and shipment.

[0058] As described above, the glass substrate of the embodiment is formed with an appropriate ratio between the thickness of a potassium ion exchange layer and the thickness of a compressive stress layer. Accordingly, the glass substrate has excellent impact resistance with a low frequency of occurrence of delayed errors due to potassium ion elution. As an index of impact resistance, it is possible to refer to a result of a drop impact test and the like. Further, as described above, for instance, it is possible to calculate a compressive stress value with use of a polarimeter from a photoelastic constant and an optical path length result. The compressive stress value is preferably from 50 to 200 MPa, more preferably from 100 to 190 MPa, and furthermore preferably from 120 to 180 MPa in the aspect of impact resistance.

[0059] Further, as described above, it is possible to select any size of blanks as necessary in the molding step. Accordingly, when the glass substrate of the embodiment is used for an HDD, it is possible to use the glass substrate for a compact HDD configured such that the size of a platter is set to 2.5 inches. The storage capacity of the HDD in the above configuration is not specifically limited, but the glass substrate may be used for a large-capacity HDD, in which the storage capacity per side of a disk is set to 250 GB.

[0060] Further, use of the glass substrate of the embodiment is not limited for producing a magnetic recording medium for an HDD. For instance, the glass substrate may be used for producing a magneto-optical disk or an optical disk.

[0061] In the embodiment, a lapping step and a polishing step are each divided into two stages. Alternatively, a lapping step and a polishing step may each be performed only one time.

Further, the chemical reinforcing step is performed prior to the second polishing step. Alternatively, the chemical reinforcing step may be performed after the second polishing step depending on a condition.

[0062] Further, it is possible to reinforce the outer peripheral end surface and the inner peripheral end surface of the glass substrate, in addition to the principal surface of the glass substrate to secure a strength against drop. Further, it is possible to immerse the glass substrate in an HF solution, as an edge alleviating process against scratches which may be formed on the glass substrate.

[0063] As described above, according to the embodiment, it is possible to provide a glass substrate having excellent impact resistance with a low frequency of occurrence of delayed errors due to potassium ion elution, and a method for producing the glass substrate.

[0064] (Information Recording Medium)

In this section, an information recording medium produced by using the glass substrate having the above configuration is described. The information recording medium of the embodiment is such that a recording layer is formed on at least one surface of the glass substrate.

[0065] The information recording medium of the embodiment is produced by forming a magnetic film as a recording layer on the principal surface of the glass substrate having the above configuration. The magnetic film may be directly or indirectly formed on the principal surface. The magnetic film may be formed on one surface or both surfaces of the glass substrate.

[0066] A conventional well-known method may be used as a magnetic film forming method. Examples of the magnetic film forming method are a method for forming a magnetic film by spin coating heat curable resin containing magnetic particles as a dispersant onto the glass substrate, and a method for forming a magnetic film by sputtering or electroless plating. The film thickness formed by a spin coating process is from about 0.3 to 1.2 μm , the film thickness formed by a sputtering process is from about 0.04 to 0.08 μm , and the film thickness formed by an electroless plating process is from about 0.05 to 0.1 μm . In the aspect of reducing the film thickness and increasing the recording density, it is preferable to form a magnetic film by a sputtering process or an electroless plating process.

[0067] A magnetic material for use in a magnetic film is not specifically limited. Any of the conventional well-known magnetic materials may be used. Among these, it is preferable to use Co-based alloy containing, as a base material, Co having a high crystalline anisotropy for obtaining a high coercive force, with addition of Ni or Cr in the aspect of adjusting the residual magnetic flux density. Specifically, it is preferable to use a composition containing Co as a

main ingredient such as CoPt, CoCr, CoNi, CoNiCr, CoCrTa, CoPtCr, CoNiPt, CoNiCrPt, CoNiCrTa, CoCrPtTa, CoCrPtB, or CoCrPtSiO.

[0068] The magnetic film may have a multilayer structure (e.g. CoPtCr/CrMo/CoPtCr or CoCrPtTa/CrMo/CoCrPtTa), in which the magnetic film is separated by a non-magnetic film (made of e.g. Cr, CrMo, or CrV) for reducing noise.

[0069] In addition to the magnetic material, the magnetic film may contain a ferrite-based material or an iron/rare earth-based material, or contain granules, in which magnetic particles of Fe, Co, FeCo, or CoNiPt are dispersed in a non-magnetic film made of SiO₂ or BN.

[0070] The magnetic film may be used in both of an internal recording medium and a vertical recording medium.

[0071] A thin coat of lubricant may be coated on the surface of the magnetic film in order to smoothly move a magnetic head. An example of the lubricant is the one obtained by diluting perfluoropolyether (PFPE) as a liquid lubricant with a Freon-based solvent.

[0072] In the embodiment, a foundation layer and a protection layer may be formed in addition to the magnetic film as a recording layer, as necessary. It is possible to select the foundation layer in a magnetic recording medium for an HDD depending on the magnetic film. An example of the material for the foundation layer is at least one or more kinds of materials selected from the group consisting of non-magnetic metals such as Cr, Mo, Ta, Ti, W, V, B, Al, and Ni. When the magnetic film contains Co as a main ingredient, use of Cr alone or Cr alloy is preferable in the aspect of improving the magnetic properties. The foundation layer is not limited to a mono layer, but a multilayer structure obtained by laminating layers of one kind or different kinds may be used. For instance, it is possible to form a foundation layer having a multilayer structure such as Cr/Cr, Cr/CrMo, Cr/CrV, NiAl/Cr, NiAl/CrMo, or NiAl/CrV.

[0073] A protection layer is formed in order to prevent wear and corrosion of the magnetic film. Examples of the protection layer are a Cr layer, a Cr alloy layer, a carbon layer, a hydrogenated carbon layer, a zirconia layer, and a silica layer. It is possible to sequentially form these protection layers together with the foundation layer and the magnetic film by an inline sputtering apparatus. Further, these protection layers may be a mono layer, or may have a multilayer structure having layers of one kind or different kinds.

[0074] It is possible to form another protection layer on or in place of the aforementioned protection layer. For instance, it is possible to form a silicon dioxide (SiO₂) layer by coating, on a Cr layer, a dispersant solution obtained by dispersing colloidal silica particles in a diluent obtained by diluting tetra alkoxy silane with an alcohol-based solvent, followed by firing, in place of forming the aforementioned protection layer.

[0075] As described above, according to the embodiment, the glass substrate having the above configuration is used as a substrate. Accordingly, it is possible to provide an information recording medium having excellent impact resistance, with a low frequency of occurrence of delayed errors due to ion elution.

[0076] The following is a summary of the technical features of the glass substrate, the method for producing the glass substrate, and the information recording medium having the above configurations.

[0077] A glass substrate according to an aspect of the invention is a glass substrate provided with a reinforced layer on a surface of a glass material with use of a chemical reinforcing treatment solution, the reinforced layer including a potassium ion exchange layer and a compressive stress layer. The glass material contains lithium. The thickness of the compressive stress layer is 35 times or more and 100 times or less of the thickness of the potassium ion exchange layer.

[0078] The glass substrate of the invention has a compressive stress layer at a deep position with respect to the thickness of a potassium ion exchange layer, which is a primary factor of compressive stress unevenness due to ion elution. Accordingly, a change in compressive stress by a temperature change is small, and a frequency of occurrence of errors resulting from compressive stress unevenness due to potassium ion elution is low. Accordingly, the glass substrate of the invention has excellent impact resistance, with a low frequency of occurrence of delayed errors due to potassium ion elution.

[0079] In the glass substrate, preferably, the thickness of the potassium ion exchange layer may be from 2 to 3 μm .

[0080] When the thickness of the potassium ion exchange layer lies in the aforementioned range, occurrence of errors due to potassium ion elution is remarkably suppressed.

[0081] In the glass substrate, preferably, the glass material may contain Li_2O in a content of from 2 to 10 % by mass with respect to a total content of glass components.

[0082] When the glass material contains LiO_2 in the content of from 2 to 10 % by mass, part of lithium ions having a relatively small ionic radius are substituted, by an appropriate amount, for alkali ions (e.g. sodium ions or potassium ions) having a larger ionic radius and contained in the chemical reinforcing treatment solution. Accordingly, an ion exchange layer of an appropriate thickness is formed.

[0083] In the glass substrate, preferably, an ion exchange rate of potassium at a depth from an outer surface of the reinforced layer by 1 μm may be from 20 to 40 % by mass.

[0084] When the ion exchange rate of potassium lies in the aforementioned range, alkali ions

in a region near the outer surface of the glass substrate are substituted for potassium ions, and alkali ions in a deep region of the glass substrate are substituted for sodium ions. As a result of the ion exchange, a compressive stress layer is formed at a deep position of the glass substrate, thereby increasing the compressive stress of the glass substrate.

[0085] In the glass substrate, preferably, a compressive stress value may be from 50 to 200 MPa.

[0086] When the compressive stress value of the glass substrate lies in the aforementioned range, not only impact resistance against drop impact but also impact resistance against bending is kept high.

[0087] In the glass substrate, preferably, the glass substrate may be used for a hard disk drive (HDD) configured such that a size of a platter is set to 2.5 inches, and a storage capacity per side of a disk is set to 250 GB.

[0088] The HDD provided with the glass substrate of the invention is advantageously equipped in a mobile device such as a notebook personal computer. Further, since the HDD is provided with the glass substrate of the invention, the HDD has a large storage capacity and excellent impact resistance, with a low frequency of occurrence of delayed errors.

[0089] Further, a method for producing a glass substrate according to another aspect of the invention is a method for producing a glass substrate provided with a chemical reinforcing step of chemically reinforcing the glass substrate by contacting the glass substrate with a chemical reinforcing treatment solution to exchange alkali metal ions on a surface of the glass substrate for alkali metal ions having an ionic radius larger than an ionic radius of the alkali metal ions contained in the chemical reinforcing treatment solution. The chemical reinforcing step includes a chemical reinforcing treatment solution immersion step of immersing the glass substrate in the chemical reinforcing treatment solution at 450 to 550 °C for 15 to 30 minutes. The glass substrate contains Li. The chemical reinforcing treatment solution contains potassium salt and sodium salt at a mass ratio of from 8:2 to 9.5:0.5.

[0090] The method for producing a glass substrate of the invention has the aforementioned configuration. Accordingly, it is possible to produce a glass substrate having excellent impact resistance, with a low frequency of occurrence of delayed errors due to potassium ion elution.

[0091] In the method for producing a glass substrate, preferably, the potassium salt may be KNO_3 , and the sodium salt may be NaNO_3 .

[0092] The potassium salt and the sodium salt have a low melting point. Accordingly, use of these salts is advantageous in preventing deformation of a produced glass substrate.

[0093] In the method for producing a glass substrate, preferably, the chemical reinforcing step

may further include a pre-processing step of holding the glass substrate at 450 to 550 °C for 15 to 30 minutes prior to the chemical reinforcing treatment solution immersion step; and a post-processing step of holding the immersed glass substrate at 450 to 550 °C for 15 to 30 minutes after the chemical reinforcing treatment solution immersion step.

[0094] The invention is provided with the aforementioned steps. Accordingly, it is possible to set the thickness of the potassium ion exchange layer relative to the thickness of the compressive stress layer of a produced glass substrate to an appropriate ratio. Thus, in the produced glass substrate, not only impact resistance against drop impact but also impact resistance against bending can be kept high.

[0095] Further, an information recording medium according to yet another aspect of the invention is provided with the glass substrate having any one of the configurations, and a recording layer formed on at least one surface of the glass substrate.

[0096] The information recording medium of the invention has the aforementioned configuration. Accordingly, the information recording medium has excellent impact resistance, with a low frequency of occurrence of delayed errors due to potassium ion elution.

EXAMPLES

[0097] In the following, the glass substrate and the information recording medium of the invention are described in detail by way of examples. It should be noted, however, that the glass substrate and the information recording medium of the invention are not limited by the following examples.

[0098] <Example 1>

Glass substrates and information recording media were produced by the following steps.

[0099] [1. Glass Melting Step and Molding Step]

Disc-shaped blanks having an outer diameter of 68 mm were produced by using a glass material whose T_g was 480 °C (the composition is as described below), and press molding the molten glass material. The thickness of the blanks was set to 0.93 mm.

[0100] [Composition of Glass Material]

SiO₂: 65 % by mass

Al₂O₃: 15 % by mass

B₂O₃: 0.1 % by mass

(SiO₂+Al₂O₃+B₂O₃: 80 % by mass)

Li₂O: 4 % by mass

Na₂O: 11 % by mass

K₂O: 0.4 % by mass

MgO+CaO+BaO+SrO+ZnO: 5 % by mass

[0101] [2. Heat Treatment Step]

An alumina setter having an outer diameter of 70 mm and a thickness of 2 mm, and blanks were alternately laminated, and warpage and internal stress of the blanks were reduced by allowing the laminate to pass through a high-temperature electric furnace set at about 430 °C for 2 hours.

[0102] [3. First Lapping Step]

Both surfaces of the blanks were roughly polished with use of a dual side grinding machine (produced by HAMAI). As a polishing condition, a #1200 mesh pellet was used as a diamond pellet, the load was set to 100 g/cm², the number of rotations of the upper surface plate was set to 20 rpm, and the number of rotations of the lower surface plate was set to 30 rpm. The degree of flatness of the produced blanks was 15 μm, and the surface roughness Ra thereof was 0.5 μm.

[0103] [4. Coring Step]

A circular hole of 18 mm-diameter was formed in the center portion of the blanks with use of a tubular core drill equipped with a diamond wheel.

[0104] [5. Inner/Outer Diameter Processing Step]

The outer peripheral end surface and the inner peripheral end surface of the blanks were processed to have an outer diameter of 65 mm and an inner diameter of 20 mm with use of a drum-shaped diamond wheel.

[0105] [6. Second Lapping Step]

Both surfaces of the blanks were roughly polished with use of a dual side grinding machine (produced by HAMAI). As a polishing condition, a #1700 mesh pellet was used as a diamond pellet, the load was set to 100 g/cm², the number of rotations of the upper surface plate was set to 20 rpm, and the number of rotations of the lower surface plate was set to 30 rpm.

[0106] [7. End Surface Polishing Step]

100 pieces of blanks produced as above were placed one over the other, and the outer peripheral end surface and the inner peripheral end surface of the blanks were polished with use of an end surface polishing machine in the above state. A brush with nylon fiber bristles having a diameter of 0.2 mm was used as a brush in the polishing machine. Surry containing cerium oxide having an average particle diameter of 3 μm as abrasive grains (an abrasive material) was used as a polishing solution.

[0107] [8. First Polishing Step]

Both surfaces of the blanks were polished with use of a dual side polishing machine (produced by HAMAI). As a polishing condition, a polishing pad made of foamed polyurethane and having an Asker-C hardness of 80 was used. The polishing solution was slurry obtained by dispersing cerium oxide having an average particle diameter of 1.5 μm as abrasive grains (an abrasive material) in water. The mixing ratio between water and abrasive grains was set to 2:8. Further, the load was set to 100 g/cm^2 , the number of rotations of the upper surface plate was set to 30 rpm, and the number of rotations of the lower surface plate was set to 50 rpm.

[0108] [9. Chemical Reinforcing Step]

A reinforced layer (a compressive stress layer and an ion exchange layer) was formed on the surfaces of the blanks by immersing the blanks in a chemical reinforcing treatment solution. The chemical reinforcing treatment solution was an aqueous solution of a mixed molten salt of KNO_3 and NaNO_3 . The mixing ratio was 9:1 by mass ratio. The temperature of the chemical reinforcing treatment solution was set to 500 $^\circ\text{C}$, and the immersion time was set to 30 minutes. The glass substrate was held at 500 $^\circ\text{C}$ for 20 minutes before and after the chemical reinforcing treatment.

[0109] The thickness of the obtained compressive stress layer was calculated by immersing a cut glass substrate in a refractive index matching oil and transmitting linearly polarized light for measuring a phase change of the polarized light by glass internal stress from the rotation angle of an analyzer (Senarmon method); and detecting the angle (a phase difference) at which the transmitted light is maximally darkened by rotating the analyzer, with use of a polarimeter (SF-11C produced by Shinko Seiki). Further, a compressive stress value was calculated from a photoelastic constant and an optical path length result. The measurement result of the glass substrate as Example 1 is illustrated in FIG. 1. FIG. 1 is an explanatory diagram for describing the thickness of the compressive stress layer of the glass substrate as Example 1. Referring to FIG. 1, the reference sign d1 denotes the thickness of the compressive stress layer of the glass substrate as Example 1. The measurement result is such that the thickness of the compressive stress layer was 80 μm .

[0110] The thickness of the obtained potassium ion exchange layer was measured by the following method. The mass concentrations of potassium and sodium were measured at a position deeper from the outer surface (a principal surface) of the cut glass substrate by an increment of 1 μm , with use of an energy dispersion X-ray analyzer (XMAX80 produced by Horiba Seisakusho), and the depth at which the mass of potassium relative to the mass of sodium increases by 10% or more with respect to the original composition was calculated, as the

thickness of the ion exchange layer (the numeral after the decimal point was rounded down). FIG. 2 illustrates only the measurement result of the glass substrate as Example 1. FIG. 2 is a graph for describing the thickness of the potassium ion exchange layer and an increase ratio of potassium ions of the glass substrate as Example 1. As illustrated in FIG. 2, when the depth from the surface was 2 μm or less, the increase ratio of the mass of potassium ions relative to the mass of sodium ions exceeded 10%. Thus, the measurement result reveals that the thickness of the ion exchange layer obtained by the chemical reinforcing step was 2 μm .

[0111] [10. Second Polishing Step]

Both surfaces of the blanks were finely polished with use of a dual side polishing machine (produced by HAMAI). As a polishing condition, a polishing pad made of foamed polyurethane and having an Asker-C hardness of 70 was used. The polishing solution was slurry obtained by dispersing colloidal silica having an average particle diameter of 60 nm as abrasive grains (an abrasive material) in water. The mixing ratio between water and abrasive grains was set to 2:8. Further, the load was set to 90 g/cm^2 , the number of rotations of the upper surface plate was set to 20 rpm, and the number of rotations of the lower surface plate was set to 30 rpm.

[0112] [11. Washing Step]

The glass substrates were scrub-washed. The washing solution was a solution obtained by diluting a mixture of KOH and NaOH at a mass ratio of 1:1 with ultrapure water (DI-water), followed by addition of a nonionic surfactant for enhancing the washing performance. The washing solution was supplied by spray atomization. After the scrub-washing, a water rinsing step was performed in an ultrasonic washing bath for 2 minutes, and an IPA washing step was performed in an ultrasonic washing bath for 2 minutes in order to remove the washing solution residues from the surfaces of the glass substrate. Lastly, the surfaces of the glass substrate were dried by IPA vapor.

[0113] The obtained glass substrate was subjected to a drop impact test and an ion elution test, after a heat shock test of placing the glass substrate stationary in an electric furnace set at 1,000 $^{\circ}\text{C}$ for 30 minutes. The test methods and the test results are illustrated in Table 1.

[0114] <Example 2>

A glass substrate was produced substantially by the same method as in Example 1 except that the reinforcement time was changed to 60 minutes and the holding time before and after the chemical reinforcing treatment solution immersion step was set to 30 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 3 μm , and the thickness of the compressive stress layer thereof was 270 μm .

[0115] <Comparative Example 1>

A glass substrate was produced substantially by the same method as in Example 1 except that the immersion time was set to 10 minutes and the holding time before and after the chemical reinforcing treatment solution immersion step was set to 10 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 0.5 μm , and the thickness of the compressive stress layer thereof was 10 μm . The measurement result of the glass substrate as Comparative Example 1 is illustrated in FIG. 3. FIG. 3 is an explanatory diagram for describing the thickness of the compressive stress layer of the glass substrate as Comparative Example 1. Referring to FIG. 3, the reference sign d2 denotes the thickness of the compressive stress layer of the glass substrate as Comparative Example 1.

[0116] <Comparative Example 2>

A glass substrate was produced substantially by the same method as in Example 1 except that the immersion time was set to 20 minutes and the reinforcement temperature was set to 450 °C in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 1 μm , and the thickness of the compressive stress layer thereof was 30 μm .

[0117] <Comparative Example 3>

A glass substrate was produced substantially by the same method as in Example 1 except that the mixing ratio between KNO_3 and NaNO_3 in the chemical reinforcing treatment solution was set to 8:2 and the immersion time was set to 30 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 1 μm , and the thickness of the compressive stress layer thereof was 110 μm .

[0118] <Example 3>

A glass substrate was produced substantially by the same method as in Example 1 except that the reinforcement temperature was set to 550 °C and the immersion time was set to 15 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 2 μm , and the thickness of the compressive stress layer thereof was 80 μm .

[0119] <Example 4>

A glass substrate was produced substantially by the same method as in Example 1 except that the reinforcement temperature was set to 550 °C and the immersion time was set to 20 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 2.5 μm , and the thickness of the compressive stress layer

thereof was 100 μm .

[0120] <Example 5>

A glass substrate was produced substantially by the same method as in Example 1 except that the reinforcement temperature was set to 550 °C and the immersion time was set to 25 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 3.5 μm , and the thickness of the compressive stress layer thereof was 140 μm .

[0121] <Example 6>

A glass substrate was produced substantially by the same method as in Example 1 except that the reinforcement temperature was set to 550 °C and the immersion time was set to 30 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 4 μm , and the thickness of the compressive stress layer thereof was 160 μm .

[0122] <Example 7>

A glass substrate was produced substantially by the same method as in Example 1 except that the immersion time was set to 20 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 1.5 μm , and the thickness of the compressive stress layer thereof was 60 μm .

[0123] <Example 8>

A glass substrate was produced substantially by the same method as in Example 1 except that the immersion temperature was set to 530 °C in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 3 μm , and the thickness of the compressive stress layer thereof was 120 μm .

[0124] <Example 9>

A glass substrate was produced substantially by the same method as in Example 1 except that the immersion time was set to 10 minutes in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 1 μm , and the thickness of the compressive stress layer thereof was 40 μm .

[0125] <Example 10>

A glass substrate was produced substantially by the same method as in Example 1 except that the mixing ratio between KNO_3 and NaNO_3 in the chemical reinforcing treatment solution was set to 8.5:1.5 in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 4 μm , and the thickness of the compressive

stress layer thereof was 160 μm .

[0126] <Example 11>

A glass substrate was produced substantially by the same method as in Example 1 except that the mixing ratio between KNO_3 and NaNO_3 in the chemical reinforcing treatment solution was set to 8.5:1.5 and the immersion temperature was set to 530 $^{\circ}\text{C}$ in the chemical reinforcing step. The thickness of the potassium ion exchange layer of the obtained glass substrate was 5 μm , and the thickness of the compressive stress layer thereof was 200 μm .

[0127] (Drop Impact Test)

First of all, an information recording medium was obtained by forming a magnetic film (a recording layer) on the principal surface of the obtained glass substrate. Specifically, a foundation layer (thickness: about 100 nm) made of Ni-Al, a recording layer (thickness: 20 nm) made of Co-Cr-Pt, and a protection layer (thickness: 5 nm) made of DLC (Diamond Like Carbon) were successively laminated in this order from the glass substrate side. 100 pieces of information recording media were produced in each of Examples 1 to 11, and Comparative Examples 1 to 3. The information recording media were loaded in an HDD, and a drop impact test was performed by the shock testing machine illustrated in FIG. 4 in order to evaluate the impact resistance of the produced information recording media. FIG. 4 is a schematic diagram illustrating the shock testing machine to be used in the drop impact test. Referring to FIG. 4, the reference sign 1 denotes a support, the reference sign 2 denotes a collision board, the reference sign 3 denotes a test object setting board, the reference sign 4 denotes an impact G value measuring device, and the reference sign X denotes an HDD (hard disk drive X) loaded with information recording media.

[0128] The drop impact test was performed by placing two pieces of information recording media in the hard disk drive X, and fixing the hard disk drive X on the test object setting board 3 together with the impact G value measuring device 4. Subsequently, the hard disk drive X was allowed to drop together with the test object setting board 3 from a height of 1 m to hit the hard disk drive X against the collision board 2. Visual observation was made as to whether the hard disk drive X was broken, and whether the information recording media cracked. It was judged that there is a crack if at least one of the two information recording media cracked. The drop impact test was performed at 1,200 G. Five hard disk drives X were placed on the test object setting board 3 at one time. The number of hard disk drives X which did not show cracks was calculated with respect to each of Examples 1 to 11 and Comparative Examples 1 to 3. The drop impact test pass rate was calculated. The results are illustrated in Tables 1 to 3.

[0129] (Ion Elution Test)

The glass substrates were immersed in 20 mL ultrapure water (80 °C) of 18 MΩ·cm, and were stationary placed for 30 minutes. At this time, the water was not agitated. During the test, the lid of the container was closed, and the test was carried out in a room according to Class 100 (FED-STD-209D by the United States Federal Standards.). After a lapse of 30 minutes, the extract was measured by ion chromatography (ICS-2100 produced by Dionex Corp.). Salt of poor solubility that partly exists in the extract was also dissolved by performing the test at 80 °C.

[0130] The evaluation criteria are as follows.

good: The elution amount of Li per glass substrate was less than 30 ppb.

fair: The elution amount of Li per glass substrate was from 31 to 60 ppb.

poor: The elution amount of Li per glass substrate was 61 ppb or more.

[0131] (Ion Exchange Condition)

Device used: ICS-2100 produced by Dionex Corp.

Column used: IonPac CS12A (produced by Dionex Corp.)

Buffer used: 20 mM methane sulfonate

[0132] [Table 1]

	Ex 1	Ex 2	C Ex 1	C Ex 2	C Ex 3
compressive stress layer/potassium ion exchange layer	40	90	1	30	110
drop impact test pass rate	90%	80%	60%	55%	65%
ion elution	good	good	poor	poor	poor
judgment	good	good	poor	poor	poor

[0133] [Table 2]

	Ex 1	Ex 3	Ex 4	Ex 5	Ex 6
compressive stress value (MPa)	150	200	140	210	300
drop impact test pass rate	90%	85%	65%	75%	70%
ion elution	good	good	good	good	good
judgment	good	good	fair	fair	fair

* compressive stress layer/potassium ion exchange layer=40

[0134] [Table 3]

	Ex 7	Ex8	Ex 9	Ex 10	Ex 11
thickness (μm) of potassium ion exchange layer	2	3	1	4	5
drop impact test pass rate	85%	90%	70%	70%	70%
ion elution	good	good	good	fair	fair
judgment	good	good	good	fair	fair

* compressive stress layer/potassium ion exchange layer=40

[0135] As illustrated in Table 1, unlike an HDD using the glass substrates of examples, in an HDD using the glass substrates of Comparative Examples 1 to 3 which do not satisfy the range such that the thickness of the compressive stress layer is 35 times or more and 100 times or less of the thickness of the potassium ion exchange layer, the result on the drop impact rest was poor,

and potassium ion elution was observed, which may likely to cause delayed errors.

[0136] As illustrated in Table 2, when the compressive stress value lies in the range of from 150 to 200 MPa, the result on the drop impact test was excellent, and ion elution was not observed. Further, even when the compressive stress value was out of the aforementioned range, the result on the drop impact test was good, and no potassium ion elution was observed.

[0137] As illustrated in Table 3, when the thickness of the potassium ion exchange layer lies in the range of from 2 to 3 μm , the test result on the drop impact test was excellent, and no ion elution was observed. Further, even when the thickness of the ion exchange layer was out of the aforementioned range, the result on the drop impact test was good, and the HDD using the glass substrates was practically usable regardless of ion elution.

REFERENCE SIGNS LIST

- [0138]
- | | |
|--------|---------------------------------------|
| 1 | support |
| 2 | collision board |
| 3 | test object setting board |
| 4 | impact G value measuring device |
| d1, d2 | thickness of compressive stress layer |
| X | hard disk drive |

CLAIMS

1. A glass substrate provided with a reinforced layer on a surface of a glass material with use of a chemical reinforcing treatment solution, the reinforced layer including a potassium ion exchange layer and a compressive stress layer, wherein
the glass material contains lithium; and
a thickness of the compressive stress layer is 35 times or more and 100 times or less of a thickness of the potassium ion exchange layer.
2. The glass substrate according to Claim 1, wherein
the thickness of the potassium ion exchange layer is from 2 to 3 μm .
3. The glass substrate according to Claim 1 or 2, wherein
the glass material contains Li_2O in a content of from 2 to 10 % by mass with respect to a total content of glass components.
4. The glass substrate according to any one of Claims 1 to 3, wherein
an ion exchange rate of potassium at a depth from an outer surface of the reinforced layer by 1 μm is from 20 to 40 % by mass.
5. The glass substrate according to any one of Claims 1 to 4, wherein
a compressive stress value is from 150 to 200 MPa.
6. The glass substrate according to any one of Claims 1 to 5, wherein
the glass substrate is used for a hard disk drive configured such that a size of a platter is set to 2.5 inches, and a storage capacity per side of a disk is set to 250 GB.
7. A method for producing a glass substrate according to Claim 1 provided with a chemical reinforcing step of chemically reinforcing the glass substrate by contacting the glass substrate with a chemical reinforcing treatment solution to exchange alkali metal ions on a surface of the glass substrate for alkali metal ions having an ionic radius larger than an ionic radius of the alkali metal ions contained in the chemical reinforcing treatment solution, wherein
the chemical reinforcing step includes a chemical reinforcing treatment solution immersion step of immersing the glass substrate in the chemical reinforcing treatment solution at

450 to 550 °C for 15 to 30 minutes,

the glass substrate contains Li, and

the chemical reinforcing treatment solution contains potassium salt and sodium salt at a mass ratio of from 8:2 to 9.5:0.5.

8. The method for producing a glass substrate according to Claim 7, wherein the potassium salt is KNO_3 , and the sodium salt is NaNO_3 .

9. The method for producing a glass substrate according to Claim 7 or 8, wherein the chemical reinforcing step further includes:

a pre-processing step of holding the glass substrate at 450 to 550 °C for 15 to 30 minutes prior to the chemical reinforcing treatment solution immersion step; and

a post-processing step of holding the immersed glass substrate at 450 to 550 °C for 15 to 30 minutes after the chemical reinforcing treatment solution immersion step.

10. An information recording medium, comprising:

the glass substrate of any one of Claims 1 to 6; and

a recording layer formed on at least one surface of the glass substrate.