

DESCRIPTION

[Title of Invention]

METHOD FOR MANUFACTURING GLASS SUBSTRATE FOR
5 INFORMATION RECORDING MEDIUM

[Technical Field]

[0001] The present invention relates to a method for manufacturing a glass substrate for an information recording medium.

10 [Background Art]

[0002] In recent years, hard disk drive (HDD) devices including a recording medium (magnetic disk) have been developed in which a 2.5-inch recording medium has a recording capacity of 500 GB (250 GB per surface) and a surface recording density of 630 Gb/inch² or more.

15 [0003] In these HDD devices, the distance between a magnetic head and a magnetic disk (flying height) has been decreasing. As the flying height decreases, requirements on the cleanliness of the substrate surface and the flatness of the substrate surface that are allowed for a magnetic disk are becoming more strict in order to suppress malfunction (head crash) caused by
20 the magnetic disk.

[0004] Furthermore, from the viewpoint of HDD device durability, an HDD device is required to be resistant to impact. In recent years, glass substrates have been used in HDD devices more often than aluminum substrates have. It is known that chemical strengthening processing is performed on a glass
25 substrate in order to improve the strength of the glass substrate. JP 2008-234823A (Patent Document 1) discloses a magnetic disk that is formed using a chemical strengthening processing step.

[Citation List]

[Patent Literature]

30 [0005] [PLT1]: JP 2008-234823A

[Summary of Invention]

[Technical Problem]

[0006] However, a case is considered in which an HDD device mounted in a recent mobile PC or the like stops operating upon receiving an impact that is
5 larger than expected. It is thought that one specific reason why the HDD device stops operating is that the magnetic disk in the HDD device breaks at a time of impact from being dropped or the like.

[0007] The present invention has been achieved in light of the foregoing problems and aims to provide a method for manufacturing a glass substrate for
10 an information recording medium, according to which a further improvement in the strength of a magnetic disk can be achieved.

[Solution to Problem]

[0008] A method for manufacturing a glass substrate for an information recording medium based on an aspect of the present invention includes:
15 forming an overall disk-shaped glass substrate having one main surface, another main surface, an inner circumferential edge surface that defines a hole, and an outer circumferential edge surface; performing inner edge polishing using cerium oxide on the inner circumferential edge surface; cleaning the glass substrate; and chemically strengthening a surface of the glass substrate after
20 performing the cleaning of the glass substrate, wherein the cleaning of the glass substrate includes cleaning the inner circumferential edge surface of the glass substrate such that a residual amount of cerium oxide with ϕ 0.1 μm or more is 3 pieces/ mm^2 or less.

[0009] In another aspect, in the cleaning of the glass substrate, a vibrating rod
25 is inserted into the hole while the glass substrate is immersed in a cleaning liquid, and the cleaning of the glass substrate is performed by applying ultrasound to the vibrating rod so as to cause the vibrating rod to vibrate.

[0010] In another aspect, a brush is attached to the vibrating rod, and the cleaning of the glass substrate is performed while the brush is in contact with
30 the inner circumferential edge surface.

[0011] In another aspect, the method includes performing at least one or more precision polishing after performing the chemical strengthening.

[0012] In another aspect, a thickness of the glass substrate is 0.65 mm or less.

[Advantageous Effects of the Invention]

5 [0013] With the method for manufacturing a glass substrate for an information recording medium based on the invention, it is possible to provide a method for manufacturing a glass substrate for an information recording medium, according to which it is possible to achieve a further improvement in the strength of a magnetic disk.

10 [Brief Description of Drawings]

[0014] FIG. 1 is a perspective view showing an information recording (HDD) device.

FIG. 2 is a plan view showing a glass substrate manufactured using a method for manufacturing a glass substrate for an information recording
15 medium.

FIG. 3 is a cross-sectional view taken along line III-III in FIG. 2 and viewed in the direction of arrows.

FIG. 4 is a plan view showing an information recording medium including a glass substrate as an information recording medium.

20 FIG. 5 is a cross-sectional view taken along line V-V in FIG. 4 and viewed in the direction of arrows.

FIG. 6 is a flowchart showing a method for manufacturing a glass substrate.

FIG. 7 is a schematic diagram showing a problem that occurs in a
25 method for manufacturing a glass substrate.

FIG. 8 is a schematic diagram of a cleaning device used for cleaning a glass substrate before chemical strengthening.

FIG. 9 is an enlarged view of a cleaning device used for cleaning a glass substrate before chemical strengthening.

30 FIG. 10 is a partially enlarged view of another cleaning device used for

cleaning a glass substrate before chemical strengthening.

FIG. 11 shows diagrams showing a brush used in a cleaning device used for cleaning a glass substrate before chemical strengthening, (A) being a full view of the brush, and (B) being a cross-sectional view.

5 FIG. 12 is an enlarged view of a cleaning device used for cleaning a glass substrate of another embodiment before chemical strengthening.

FIG. 13 is a diagram showing results of a drop impact test according to Working Examples 1 to 3 and Comparative Examples 1 to 3.

[Description of Embodiments]

10 [0015] Embodiments and working examples based on the present invention will be described hereinafter with reference to the drawings. If numbers, amounts, and the like are mentioned in the description of the embodiments and the working examples, the scope of the invention is not necessarily limited to those numbers, amounts, and the like unless specifically stated. In the
15 description of the embodiments and the working examples, equivalent components are denoted by the same reference numerals, and redundant description thereof is not included in some cases.

[0016] (Embodiment)

(Information recording device 30)

20 An information recording device 30 will be described with reference to FIG. 1. FIG. 1 is a perspective view showing an information recording device 30. The information recording device 30 includes, as an information recording medium 10, a glass substrate 1 manufactured using a method for manufacturing a glass substrate for an information recording medium
25 (hereinafter referred to simply as a glass substrate) according to an embodiment.

[0017] Specifically, the information recording device 30 includes the information recording medium 10, a housing 20, head sliders 21, suspensions 22, an arm 23, a vertical shaft 24, a voice coil 25, a voice coil motor 26, a clamp
30 member 27, and a fixing screw 28. A spindle motor (not shown) is installed on

the upper surface of the housing 20.

[0018] The information recording medium 10, which is a magnetic disk or the like, is rotatably fixed to the above-mentioned spindle motor by the clamp member 27 and the fixing screw 28. The information recording medium 10 is driven so as to rotate at a rotation rate of several thousand rpm, for example, by the spindle motor. The information recording medium 10 is manufactured by compressive stress layers 12 (see FIG. 5) and magnetic recording layers 14 (see FIGS. 4 and 5) being formed on the glass substrate 1, which will be described in detail later with reference to FIGS. 4 and 5.

[0019] The arm 23 is attached so as to be able to swing about the vertical shaft 24. The suspensions 22, which are formed in the shape of a leaf spring (cantilever), are attached to the tips of the arm 23. The head sliders 21 are attached to the tips of the suspensions 22 so as to sandwich the information recording medium 10.

[0020] The voice coil 25 is attached to the arm 23 on the side opposite to the head sliders 21. The voice coil 25 is interposed between magnets (not shown) provided on the housing 20. The voice coil motor 26 is constituted by the voice coil 25 and the magnets.

[0021] A predetermined current is supplied to the voice coil 25. The arm 23 swings about the vertical shaft 24 due to the effect of the electromagnetic force generated by the current flowing in the voice coil 25 and the magnetic field of the magnets. Due to the swinging of the arm 23, the suspensions 22 and the head sliders 21 also swing in the direction of arrows AR1. The head sliders 21 swing back and forth in a radial direction of the information recording medium 10 on the front surface and the rear surface of the information recording medium 10. The magnetic heads (not shown) attached to the head sliders 21 perform a seek operation.

[0022] While the seek operation is performed, the head sliders 21 receive lift due to air flow generated in accordance with the rotation of the information recording medium 10. The head sliders 21 travel at a constant flying height

with respect to the surface of the information recording medium 10 due to the balance between the lift and the elastic force (pressing force) of the suspensions 22. With this traveling, the magnetic heads provided on the head sliders 21 can record and reproduce information (data) on a predetermined track in the information recording medium 10. The information recording device 30, in which the glass substrate 1 is mounted as a portion of a member included in the information recording medium 10, is configured as described above.

[0023] (Glass substrate 1)

FIG. 2 is a plan view showing the glass substrate 1 manufactured using the method for manufacturing a glass substrate for an information recording medium based on the present embodiment. FIG. 3 is a cross-sectional view taken along line III-III in FIG. 2 and viewed in the direction of arrows.

[0024] As shown in FIGS. 2 and 3, the glass substrate 1 (glass substrate for an information recording medium) that is to be used as a portion of the information recording medium 10 (see FIGS. 4 and 5) has a main surface 2, a main surface 3, an inner circumferential edge surface 4 that defines a hole 5, and an outer circumferential edge surface 6, and has an overall disk shape.

[0025] The hole 5 is provided so as to penetrate from the one main surface 2 toward the other main surface 3. The inner circumferential edge surface 4 includes a linear portion 4a and chamfered portions 4b. The chamfered portions 4b include an inner circumferential edge chamfered portion that is formed between the one main surface 2 and the linear portion 4a, and an inner circumferential edge chamfered portion that is formed between the other main surface 3 and the linear portion 4a.

[0026] The outer circumferential edge surface 6 includes a linear portion 6a and chamfered portions 6b. The chamfered portions 6b include an outer circumferential edge chamfered portion that is formed between the one main surface 2 and the linear portion 6a, and an outer circumferential edge chamfered portion that is formed between the other main surface 3 and the linear portion 6a.

[0027] A glass substrate 1G has a size of, for example, 0.8 inches, 1 inch, 1.8 inches, 2.5 inches, or 3.5 inches. The glass substrate 1G has a thickness of, for example, 0.3 mm, 0.65 mm, 0.8 mm, 1 mm, 2 mm, or 2.2 mm. The thickness of the glass substrate 1G is a value calculated using the average of values measured at multiple random point-symmetrical points on the glass substrate 1G.

[0028] There is no particular limitation on the glass composition of the glass substrate 1G, as long as it is glass that can be chemically strengthened by ion exchange. For example, it is possible to use soda-lime glass containing SiO_2 , Na_2O , and CaO as main components, aluminosilicate glass containing SiO_2 , Al_2O_3 , and R_2O ($\text{R} = \text{K}, \text{Na}, \text{Li}$) as main components, borosilicate glass, Li_2O - SiO_2 -based glass, Li_2O - Al_2O_3 - SiO_2 -based glass, $\text{R}'\text{O}$ - Al_2O_3 - SiO_2 -based glass ($\text{R}' = \text{Mg}, \text{Ca}, \text{Sr}, \text{Ba}$), or the like. Among these, aluminosilicate glass containing SiO_2 in an amount of 63 to 70 mol% and containing SiO_2 and Al_2O_3 in a total amount of 70 mol% or more is preferable.

[0029] (Information recording medium 10)

FIG. 4 is a plan view showing the information recording medium 10 including the glass substrate 1 as an information recording medium. FIG. 5 is a cross-sectional view taken along line V-V in FIG. 4 and viewed in the direction of arrows.

[0030] As shown in FIGS. 4 and 5, the information recording medium 10 includes the glass substrate 1, the compressive stress layers 12, and the magnetic recording layers 14. The compressive stress layers 12 are formed so as to cover the main surfaces 2 and 3, the inner circumferential edge surface 4, and the outer circumferential edge surface 6 of the glass substrate 1. The magnetic recording layers 14 are formed so as to cover predetermined regions of the compressive stress layers 12 on the main surfaces 2 and 3. The hole 15 is formed inside of the inner circumferential edge surface 4 due to the compressive stress layers 12 being formed on the inner circumferential edge surface 4 of the glass substrate 1. The information recording medium 10 is

fixed to a spindle motor provided on the housing 20 (see FIG. 1) using the hole 15.

[0031] In the information recording medium 10 shown in FIG. 5, the magnetic recording layers 14 are formed on both the compressive stress layer 12 formed on the main surface 2 and the compressive stress layer 12 formed on the main surface 3. The magnetic recording layer 14 may be provided on only the compressive stress layer 12 formed on the main surface 2 (one surface), or may be provided on the compressive stress layer 12 formed on the main surface 3 (one surface).

[0032] The magnetic recording layers 14 are formed by spin-coating the compressive stress layers 12 on the main surfaces 2 and 3 of the glass substrate 1 with a heat-curable resin in which magnetic particles are dispersed (spin-coating method). The magnetic recording layers 14 may be formed using a sputtering method, an electroless plating method, or the like carried out on the compressive stress layers 12 on the main surfaces 2 and 3 of the glass substrate 1.

[0033] The film thickness of the magnetic recording layers 14 is about 0.3 μm to 1.2 μm in the case of the spin-coating method, about 0.04 μm to 0.08 μm in the case of the sputtering method, and about 0.05 μm to 0.1 μm in the case of the electroless plating method. From the viewpoint of reducing the thickness and increasing the recording density, it is preferable that the magnetic recording layer 14 is formed using the sputtering method or the electroless plating method.

[0034] As the magnetic material used in the magnetic recording layers 14, it is preferable to use Co, which has a high crystalline anisotropy, as the main component in order to obtain a high coercive force, and to additionally use a Co-based alloy to which Ni or Cr has been added in order to adjust the residual magnetic flux density. In recent years, Fe-Pt-based magnetic materials have come to be used as magnetic layer materials that are suitable for use in heat-assisted recording.

[0035] In order to improve the sliding of the magnetic head, the surface of the magnetic recording layer 14 may be thinly coated with a lubricant. Examples of the lubricant include a lubricant obtained by diluting perfluoropolyether (PFPE), which is a liquid lubricant, with a freon-based solvent or the like.

5 [0036] The magnetic recording layers 14 may be provided with an underlayer or a protective layer as needed. The underlayer in the information recording medium 10 is selected according to the type of the magnetic film. Examples of the material of the underlayer include at least one or more types of materials selected from non-magnetic metals such as Cr, Mo, Ta, Ti, W, V, B, Al, and Ni,
10 for example.

[0037] An underlayer provided in a magnetic recording layer 14 is not limited to being a single layer and may have a multi-layer structure in which the same or various types of layers are stacked. A multi-layer underlayer such as Cr/Cr, Cr/CrMo, Cr/CrV, NiAl/Cr, NiAl/CrMo, and NiAl/CrV may be used.

15 [0038] Examples of protective layers that prevent wearing and corrosion of the magnetic recording layer 14 include a Cr layer, a Cr alloy layer, a carbon layer, a hydrogenated carbon layer, a zirconia layer, and a silica layer. These protective layers can be formed in succession along with the underlayer, the magnetic film, and the like using an in-line sputtering apparatus. These
20 protective layers may be single layers, or may have a multi-layer structure composed of the same or different types of layers.

[0039] Another protective layer may be formed on the above-described protective layer or instead of the above-described protective layer. For example, instead of the above-described protective layer, a silicon oxide (SiO₂)
25 layer may be formed by diluting tetraalkoxysilane with an alcohol-based solvent, dispersing fine colloidal silica particles therein, coating a Cr layer therewith, and furthermore performing calcination thereon.

[0040] Note that in the description above, an exemplary case was illustrated in which the glass substrate 1 has a thickness of 0.3 mm, 0.65 mm, 0.8 mm, 1 mm,
30 2 mm, or 2.2 mm, for example, but it is particularly preferable to have a

thickness of 0.65 mm or less. If the thickness of the glass substrate decreases and the fluttering amount of the glass substrate itself increases (the fluttering amount at a thickness of 0.635 mm is twice the fluttering amount at a thickness of 0.8 mm, for example), by using the above-described configuration, the above-described durability increases significantly and it is possible to more reliably stabilize the floating characteristics of the magnetic head.

[0041] (Method for manufacturing glass substrate)

Next, a method for manufacturing the glass substrate 1 and the information recording medium 10 according to the present embodiment will be described with reference to FIG. 6. FIG. 6 is a flowchart showing a method for manufacturing the glass substrate 1 and the information recording medium 10. [0042] First, in the “glass melting step” of step 10 (hereinafter abbreviated as “S10”; the same follows for step 11 and onward), the glass raw material constituting the glass substrate is melted.

[0043] In the “press-molding step” of S11, a glass substrate was produced by pressing the melted glass raw material using an upper mold and a lower mold. Common aluminosilicate glass was used as the glass composition that was used. The method for producing the glass substrate is not limited to molding, and it is possible to perform cutting-out from plate glass, which is a known method. The glass composition is also not limited to the above description.

[0044] In the “first lapping step” of S12, lapping was performed on both main surfaces of the glass substrate. The first lapping step was performed using a double-sided lapping apparatus in which a planetary gear mechanism is used. Specifically, lapping was performed by pressing lapping surface plates onto both surfaces of the glass substrate from above and below, supplying a grinding liquid onto the main surfaces of the glass substrate, and moving the lapping surface plates relative to each other. With this lapping, a glass substrate with approximately flat main surfaces was obtained.

[0045] In the “coring step” of S13, a disk-shaped glass substrate was produced by forming a hole in the central portion of the glass substrate using a

cylindrical diamond drill. Predetermined chamfering was carried out by grinding the inner circumferential edge surface and the outer circumferential edge surface of the glass substrate using a diamond grindstone.

5 [0046] In the “inner circumference polishing step” of S14, mirror-polishing by means of brush polishing was performed on the inner circumferential edge surface of the glass substrate. A slurry containing common cerium oxide abrasive particles (average particle diameter ϕ : 2 μm) was used as the polishing abrasive particles.

10 [0047] In the “second lapping step” of S15, lapping was performed on both main surfaces of the glass substrate, similarly to the above-described first lapping step (S12). By performing the second lapping step, fine roughness formed on the main surfaces in the previous coring step and in the edge surface processing can be removed in advance. As a result, the amount of time for polishing the main surfaces in a later step can be shortened.

15 [0048] In the “outer circumference polishing step” of S16, mirror polishing by means of brush polishing was performed on the outer circumferential edge surface of the glass substrate. A slurry containing common cerium oxide abrasive particles was used as the polishing abrasive particles.

20 [0049] In the “first polishing step” of S17, main surface polishing was performed. The first polishing step is mainly for correcting damage and warping that remains on the main surfaces from the above-described first and second lapping steps (S12, S14). In the first polishing step, the main surfaces were polished using a double-sided polishing apparatus having a planetary gear mechanism. Common cerium oxide abrasive particles were used as the
25 polishing agent.

[0050] In the “pre-chemical-strengthening cleaning” of S18, cleaning was performed on the inner circumferential edge surface 4 of the glass substrate 1 such that the residual amount of cerium oxide with ϕ 0.1 μm or more is 3 pieces/ mm^2 or less. The specific cleaning method will be described later.

30 [0051] In the “chemical strengthening step” of S19, a surface strengthening

layer was formed on the main surfaces of the glass substrate 1. Specifically, chemical strengthening was performed by immersing the glass substrate 1 for about 30 minutes in a mixed solution of potassium nitrate (70%) and sodium nitrate (30%) heated to 300°C. As a result, lithium ions and sodium ions on the inner circumferential edge surface and the outer circumferential edge surface of the glass substrate were respectively replaced with sodium ions and potassium ions in the chemical strengthening solution, and a compressive stress layer was formed, as a result of which the main surfaces and the edge surfaces of the glass substrate were strengthened.

[0052] In the “second polishing step” in S20, a main surface polishing step was performed. The second polishing step is for eliminating microscopic defects and the like on the main surface that occur in the steps up to that described above and remain, so as to finish to a mirror surface, and is for eliminating warping so as to finish to a desired level of flatness. In the second polishing step, polishing was performed using a double-sided polishing apparatus having a planetary gear mechanism. Colloidal silica with an average particle diameter of about 20 nm was used as the polishing agent in order to obtain a smooth flat surface.

[0053] In the “final cleaning step” of S21, final cleaning of the main surfaces and edge surfaces of the glass substrate is carried out. Accordingly, adhering substances that remain on the glass substrate are removed.

[0054] In the “magnetic thin film layer forming step” of S22, after the cleaning of the glass substrate 1 obtained through the above-described steps, an information recording medium using a perpendicular magnetic recording method was manufactured by successively forming an adhesive layer composed of Cr alloy, a soft magnetic layer composed of CoFeZr, an orientation control underlayer composed of Ru, a perpendicular magnetic recording layer composed of CoCrPt alloy, a C-based protective layer, and a F-based lubrication layer on both main surfaces of the glass substrate 1. This configuration is an example of a configuration using a perpendicular magnetic recording method,

and a magnetic layer or the like may be included as an in-plane information recording medium. A FePt-based material may be used as a magnetic material that is suitable for use in heat-assisted recording. Thereafter, by carrying out the “post-heating processing step” of S23, the information recording medium is completed.

[0055] In the method for manufacturing the glass substrate, the “pre-chemical-strengthening cleaning” of S18 is performed after the “first polishing step” of S17, but it is possible to perform the “pre-chemical-strengthening cleaning” of S18 after the “outer circumference polishing step” of S16, perform the “first polishing step” of S17 after the “chemical strengthening step” of S19, and then perform the “second polishing step” of S20.

[0056] (Problems with method for manufacturing glass substrate observed by the inventors)

Here, problems with the method for manufacturing the glass substrate observed by the inventors will be described with reference to FIG. 7. FIG. 7 is a schematic diagram showing a problem that occurs in the method for manufacturing the glass substrate.

[0057] As described above, when an HDD device receives an impact that is larger than expected, the HDD device stops operating in some cases. It is thought that one specific reason why the HDD device stops working is that the glass substrate 1 (magnetic disk) in the HDD device breaks at a time of impact from being dropped or the like. In view of this, a broken glass substrate 1 was tested, and it was understood that the breakage location was such that a portion of the inner circumferential edge surface 4 of the glass substrate 1 (striated damage) has a high tendency to be the origin. Furthermore, as a result of the investigation, it was found that the reason striated damage occurs is as follows.

[0058] In the “inner circumference polishing step” of S14, the inner circumferential edge surface is finished to a mirror surface by using cerium

oxide as the polishing material. However, at a time of being gripped by a retaining tool 100 when transitioning to the next step, and/or when the polishing pad 110 is pressed against the inner circumferential edge surface 4 during polishing, the cerium oxide (Ce in FIG. 7) tends to pierce the inner circumferential edge surface 4 of the glass substrate 1, or react and fuse with the glass substrate 1.

[0059] If the “chemical strengthening step” of S19, which is a subsequent step, is performed in this state, the cerium oxide Ce on the inner circumferential edge surface 4 of the glass substrate 1 further adheres to the inner circumferential edge surface 4 due to the heat during the chemical strengthening (300°C or more), and in the “second polishing step” of subsequent S20, it is no longer possible to completely remove the cerium oxide Ce.

[0060] Furthermore, if a large physical force is applied to the inner circumferential surface 4 in this state, the cerium oxide Ce adhered to the glass substrate 1 up to this time is suddenly removed during handling of the inner circumferential edge surface 4 of the glass substrate 1 and/or during drive insertion, or the like. As a result, when an external apparatus 120 comes into contact with the inner circumferential edge surface 4, striated damage C1 appears on the surface of the inner circumferential edge surface 4, and thereby the stress on the inner circumferential edge surface 4 that was formed by the chemical strengthening is mitigated. It is thought that a crack C2 (breakage) tends to be formed on the glass substrate 1 with that location as the origin.

[0061] In view of this, in the present embodiment, as described above, the “pre-chemical-strengthening cleaning” of S18 is carried out before the “chemical strengthening step” of S19, and cleaning is performed on the inner circumferential edge surface 4 of the glass substrate 1 such that the residual amount of cerium oxide with ϕ 0.1 μm or more is 3 pieces/ mm^2 or less.

[0062] Hereinafter, a specific embodiment of the “pre-chemical-strengthening cleaning” of S18 will be described with reference to FIGS. 8 and 9. FIG. 8 is a schematic view of a cleaning apparatus used in the pre-chemical-strengthening

cleaning step of the glass substrate 1, and FIG. 9 is an enlarged view of the cleaning apparatus used for cleaning the glass substrate 1 before chemical strengthening.

[0063] (Cleaning step 1)

5 With this cleaning apparatus 500, a cleaning liquid W with an acidic cleaning agent at a concentration of 3% is stored in a circulation tub 501, and multiple glass substrates 1 are immersed in the cleaning liquid W.

[0064] In a substrate holding member 51, the multiple glass substrates 1 are each held in the horizontal direction, and the glass substrates 1 are held at a
10 predetermined interval in the vertical direction. Specifically, the substrate holding member 51 has frame members 55 that hold the outer circumferential edges of the glass substrates 1, and guide portions 53 that come into direct contact with the outer circumferential edges of the frame members 55 and position the glass substrates 1.

15 [0065] A vibrating rod 59 is inserted into the hole 5 of each glass substrate 1. A vibrating element 58 that applies ultrasound (US) having a predetermined frequency to the vibrating rod 59 so as to vibrate the vibrating rod 59, and a transmitter 50 are connected to the vibrating rod 59.

[0066] As shown in FIG. 9, in the present embodiment, if an opening diameter
20 I of the hole 5 of the glass substrate 1 is 20 mm, for example, it is preferable that the diameter of the vibrating rod 59 is 5 mm. The frequency applied to the vibrating rod 59 by the vibrating member 58 and the transmitter 50 is preferably 40 kHz to 60 kHz. Ultrasound (US) cleaning was carried out for about 5 minutes with the cleaning liquid W at a liquid temperature of 30°C.

25 [0067] This makes it possible to roughly remove a large amount of the cerium oxide that is lightly attached to the inner circumferential edge surfaces 4 of the glass substrates 1. In comparison with a case of using ultrasound (US) cleaning with an immersion method, in which a vibrating plate is laid out on the bottom of a normal tub, the ultrasound (US) is directly applied to the inner
30 circumferential edge surfaces 4 without standing waves being impeded, and

therefore the cleaning ability can be improved.

[0068] (Cleaning step 2)

Next, with reference to FIGS. 10 to 12, US cleaning is performed using a vibrating rod 59A instead of the vibrating rod 59. The basic configuration of the vibrating rod 59A is the same as that of the vibrating rod 59 described above, but differs therefrom in that a brush 590 is wrapped in the form of a spiral around the outer circumferential surface of the cylindrical vibrating rod 59, as shown in FIG. 10. An arrangement pitch P1 between portions of the brush 590 that are adjacent to each other in the vertical direction is set to 4 mm in the present embodiment. If the arrangement pitch P1 is too small, the replacement efficiency of the cleaning liquid W deteriorates, and if the arrangement pitch P1 is too large, the cleaning capability of the cleaning liquid W decreases. Accordingly, it is desirable that the arrangement pitch P1 of the brush 590 is changed as appropriate.

[0069] As shown in FIG. 11, the brush (channel brush) 590 has a mode in which a brush portion 592 is fixed to a base portion 591 and extends in the longitudinal direction. The cross-sectional shape of the base portion 591 is approximately square, and the length of a side (h1) is about 1.5 mm in the present embodiment. The projection length (h2) from the base portion 591 of the brush portion 592 is about 4 mm. Nylon fibers with a diameter of 0.2 mm were used as the brush hairs of the brush portion 592. In addition, it is possible to use brush hairs made of vinyl chloride or pig hair.

[0070] As shown in FIG. 12, at the time of cleaning, the glass substrates 1 are cleaned while the brush 590 is in contact with the inner circumferential edge surfaces 4. At this time, ultrasound (US) cleaning was carried out for about 5 minutes while allowing the vibrating rod 59A to rotate (direction of arrow R) and swing up and down (arrow Y). This makes it possible to remove firmly-attached cerium oxide that pierces the inner circumferential edge surfaces 4.

[0071] Preferably, the glass substrates 1 are rotated at 15 rpm and the

vibrating rod 59A is rotated at 985 rpm such that they are rotated inversely relative to each other. The relative rotation speed of the inner circumferential edge surfaces 4 and the brush 590 is preferably about 1000 rpm or more. Ultrasound (US) was carried out while the brush 590 of the vibrating rod 59A was pressed about 2 mm in one direction of the inner circumferential edge surfaces 4 and the vibrating rod 59A was swung up and down at a speed of 400 mm/min. The shape and attachment method of the brush 590 are not limited to the present embodiment.

[0072] Similarly to the case of the vibrating rod 59, vibration at 40 kHz to 60kHz was applied to the vibrating rod 59A, and ultrasound (US) cleaning was carried out for about 5 minutes in a circulation tub with the liquid temperature of the cleaning liquid W at 30°C.

[0073] (Cleaning step 3)

Next, the glass substrates 1 were immersed in the circulation tub for 3 minutes using a cleaning liquid with an HF concentration of 0.2% and a liquid temperature of 30°C. Accordingly, on all of the main surfaces 2 and 3 including the inner circumferential edge surfaces 4, the reacted cerium oxide is dissolved and removed along with portions of the glass substrates 1. In the case where the liquid temperature and time are constant, because of a chemical reaction, if the concentration is low, a sufficient effect is not obtained, and conversely, if the concentration is high, the surfaces of the glass substrates 1 roughen and the dimensions thereof change, which is not preferable. Accordingly, the HF concentration is preferably 0.1% to 0.3%.

[0074] (Cleaning step 4)

Next, using a cleaning liquid with an acid cleaning agent concentration of 3% and a liquid temperature of 30°C, US cleaning (80 KHz) with an immersion method, in which a vibrating plate is laid out at the bottom of a tub, was performed for 5 minutes, and cleaning of all surfaces of the glass substrates was performed.

[0075] (Cleaning step 5)

Thereafter, using pure water and a 1-way tub, US cleaning (80 KHz) using an immersion method, in which a vibrating plate is laid out on the bottom of the tub, was performed for 5 minutes, and a final rinse of all surfaces of the glass substrates 1 was performed.

5 [0076] (Cleaning step 6)

Finally, the glass substrates 1 were immersed in an IPA (Isopropyl Alcohol) circulation tub, and thereafter the glass substrates 1 were dried in an IPA vapor tub.

[0077] (Working examples)

10 Hereinafter, working examples of the present embodiment will be described with reference to FIG. 13. FIG. 13 is a diagram showing results of a drop impact test according to Working Examples 1 to 3 and Comparative Examples 1 to 3.

[0078] (Working Example 1)

15 In Working Example 1, a glass substrate and an information recording medium were manufactured based on the manufacturing flow shown in FIG. 6. The above-described cleaning steps 2 to 6 were carried out as the pre-chemical-strengthening cleaning (S18).

[0079] (Working Example 2)

20 In Working Example 2, a glass substrate and an information recording medium were manufactured based on the manufacturing flow shown in FIG. 6. The above-described cleaning steps 1 to 6 were carried out as the pre-chemical-strengthening cleaning (S18).

[0080] (Working Example 3)

25 In Working Example 3, a glass substrate and an information recording medium were manufactured based on the manufacturing flow shown in FIG. 6. The above-described cleaning steps 1 to 6 were carried out as the pre-chemical-strengthening cleaning (S18). However, conditions were changed as indicated below. The cleaning step 1 was carried out for double the
30 cleaning time, or in other words, for 10 minutes. A refreshing step in which a

brush is used was carried out each time before the cleaning in the cleaning step 2. That is, because the removed cerium oxide attaches also to the brush over many instances of use, a step was added in which a substrate that has completed the final cleaning step in advance is prepared and cleaned as a dummy substrate so as to remove the cerium oxide attached to the brush. The cleaning step 2 was carried out for double the cleaning time, or in other words, for 10 minutes.

[0081] (Comparative Example 1)

In Comparative Example 1, a glass substrate and an information recording medium were manufactured based on the manufacturing flow shown in FIG. 6. As the pre-chemical-strengthening cleaning (S18), only cleaning steps 4 to 6 were carried out, and cleaning steps 1 to 3 were not carried out.

[0082] (Comparative Example 2)

In Comparative Example 2, a glass substrate and an information recording medium were manufactured based on the manufacturing flow shown in FIG. 6. As the pre-chemical-strengthening cleaning (S18), only cleaning steps 3 to 6 were carried out, and cleaning steps 1 to 2 were not carried out.

[0083] (Comparative Example 3)

In Comparative Example 3, a glass substrate and an information recording medium were manufactured based on the manufacturing flow shown in FIG. 6. As the pre-chemical-strengthening cleaning (S18), only cleaning steps 3 to 6 were carried out, and cleaning steps 1 to 2 were not carried out. However, three tubs were provided, and the HF immersion cleaning of the cleaning step 3 was performed three times, for three minutes each time. In this case, the cerium oxide is further removed due to the etching effect of HF, but the cleaning tub equipment will increase in size, and there is a risk that the roughness of the edge surfaces will reach the upper limit of the specification value.

[0084] (Evaluation)

For the glass substrates produced in Working Examples 1, 2, and 3, and

Comparative Examples 1, 2, and 3, evaluation of cerium oxide existing on the inner circumferential edge surfaces 4 was performed as follows on the glass substrates resulting from S18 (before the chemical strengthening step (S19)).

[0085] The extracted inner circumferential edge surface 4 of a glass substrate was divided into several sections so as to enable observation thereof with a scanning electron microscope (SEM), attached substance observation by means of the SEM and analysis by means of an energy dispersive X-ray spectroscopy (EDX) apparatus were performed, and the number of pieces of cerium oxide with ϕ 0.1 μm or more that exist on the inner circumferential edge surface 4 was obtained. Thereafter, the residual amount (number of pieces) of cerium oxide per unit area (1 square millimeter) was obtained by dividing by the area of the inner circumferential edge surface 4.

[0086] Because roughnesses Ra of an inner diameter handling jig and a spindle shaft surface are normally mirrored surfaces of several nm (Ra measured according to JIS_01 standard, with stylus $r \approx 2 \mu\text{m}$), small attached substances with less than ϕ 0.1 μm are removed when brought into contact with the jig or the spindle and hardly ever cause damage to the inner edge, and therefore attention was given to the number of pieces of cerium oxide with ϕ 0.1 μm or more per unit area (1 square millimeter), which are thought to cause problems later.

[0087] As shown in FIG. 13, the residual amount (number of pieces) of cerium oxide per unit area before the chemical strengthening step was 3 pieces/ mm^2 in Working Example 1, 2.6 pieces/ mm^2 in Working Example 2, and 1.9 pieces/ mm^2 in Working Example 3. Also, it was 4.5/ mm^2 in Comparative Example 1, 3.8/ mm^2 in Comparative Example 2, and 3.3 pieces/ mm^2 in Comparative Example 3.

[0088] Thereafter, the final step of manufacturing the magnetic disk (information recording medium) was performed, the magnetic disk was incorporated in the HDD device, and a drop impact test was carried out. Specifically, the drop impact test was performed with the magnetic disks

produced in Working Examples 1 to 3 and Comparative Examples 1 to 3 mounted in an HDD device with a specification of 5000 rpm.

[0089] A commercially-available drop impact test machine was used as the test machine, and the test was performed by dropping HDD devices into which the magnetic disks of the Working Examples and the Comparative Examples were inserted from a certain height. In the test, after the HDD devices were dropped from a height of 1 m, the HDD devices were disassembled to visually check the existence of fractures in the magnetic disks.

[0090] The results of evaluating HDD devices with 1000 magnetic disks produced in the Working Examples and the Comparative Examples are shown in FIG. 13. The fracture occurrence rate (quality) after the drop test was determined such that an evaluation of "A" was given if fracturing occurred in 1 magnetic disk or less, an evaluation of "B" was given if fracturing occurred in 2 to 5 magnetic disks, an evaluation of "C" was given if fracturing occurred in 6 to 10 magnetic disks, and an evaluation of "F" was given if fracturing occurred in 11 magnetic disks or more.

[0091] "A" is a level of being satisfactory for actual use, "B" is a level of being sufficiently useable, "C" is a level of being unstable in actual use, and "F" is level of being unsuitable for actual use.

[0092] As shown in FIG. 13, the evaluation results were in proportion to the residual amount of cerium oxide per unit area before the chemical strengthening step, and Working Example 3, in which the residual amount (number of pieces) of cerium oxide per unit area was 1.9 pieces/mm², had the best evaluation result, receiving an evaluation of "A", Working Example 2, in which the residual amount (number of pieces) was 2.6 pieces/mm², received an evaluation of "B", and Working Example 1, in which the residual amount (number of pieces) was 3 pieces/mm², received an evaluation of "B" as well.

[0093] On the other hand, both Comparative Example 1, in which the residual amount (number of pieces) was 4.5 pieces/mm², and Comparative Example 2, in which the residual amount (number of pieces) was 3.8 pieces/mm², received

evaluations of "F", and Comparative Example 3, in which the residual amount (number of pieces) was 3.3 pieces/mm², received an evaluation of "C".

[0094] According to the description above, with the method for manufacturing a glass substrate for an information recording medium according to the present embodiment, in a step of performing cleaning of the glass substrate 1, which is carried out before a step of chemically strengthening the surface of the glass substrate 1, the inner circumferential edge surface 4 of the glass substrate 1 is cleaned such that the residual amount of cerium oxide with ϕ 0.1 μ m or more is 3 pieces/mm² or less.

[0095] Accordingly, the occurrence of striated damage that occurs in the inner circumferential edge surface 4 is suppressed, making it difficult for cracks (breakage) originating from this region to occur. As a result, it is possible to achieve a further improvement in the strength of the magnetic disk.

[0096] Also, if there is one or more polishing step (S20, S17) after the chemical strengthening step (S19), it is assumed that damage on the surface of the inner circumferential surface will occur along with the removal of cerium oxide due to the polishing pads wrapping around the edge surface during polishing. As a result, it can be predicted that stress will be released and the glass substrate will become vulnerable to a drop impact. Therefore, by employing the method for manufacturing the glass substrate for an information recording medium of the present embodiment, it is possible to obtain the effect of the present embodiment more effectively.

[0097] Furthermore, since a thinner glass substrate 1 is weak against the same impact, by employing the method for manufacturing the glass substrate for an information recording medium of the present embodiment also in the case where a glass substrate 1 is used in which the thickness of the glass substrate 1 is 0.65 mm or less, it is possible to obtain the effect of the present embodiment more effectively.

[0098] The embodiment and working examples disclosed herein are to be considered exemplary in all respects and in no way limiting. The scope of the

present invention is defined not by the above description but by the scope of the appended claims, and all changes that fall within the same essential spirit as the scope of the claims are included therein.

[Descriptions of Reference Numerals]

5	[0099]	1	Glass substrate
		2, 3	Main surface
		4	Inner circumferential edge surface
		4a, 6a	Linear portion
		4b, 6b	Chamfered portion
10		5, 15	Hole
		6	Outer circumferential edge surface
		10	Information recording medium
		12	Compressive stress layer
		14	Magnetic recording layer
15		20	Housing
		21	Head slider
		22	Suspension
		23	Arm
		24	Vertical shaft
20		25	Voice coil
		26	Voice coil motor
		27	Clamp member
		28	Fixing screw
		30	Information recording apparatus
25		50	Transmitter
		51	Substrate holding member
		53	Guide portion
		55	Frame member
		58	Vibrating element
30		59, 59A	Vibrating rod

	100	Holding tool
	110	Polishing pad
	120	External apparatus
	500	Cleaning apparatus
5	590	Brush
	591	Base portion
	592	Brush portion

CLAIMS

1. A method for manufacturing a glass substrate for an information recording medium, the method comprising:
 - 5 forming an overall disk-shaped glass substrate having one main surface, another main surface, an inner circumferential edge surface that defines a hole, and an outer circumferential edge surface;
performing inner edge polishing using cerium oxide on the inner circumferential edge surface;
 - 10 cleaning the glass substrate; and
chemically strengthening a surface of the glass substrate after performing the cleaning of the glass substrate,
wherein the cleaning of the glass substrate includes cleaning the inner circumferential edge surface of the glass substrate such that a residual amount
15 of cerium oxide with ϕ 0.1 μm or more is 3 pieces/ mm^2 or less.
2. The method for manufacturing a glass substrate for an information recording medium according to claim 1, wherein
in the cleaning of the glass substrate, a vibrating rod is inserted into the
20 hole while the glass substrate is immersed in a cleaning liquid, and the cleaning of the glass substrate is performed by applying ultrasound to the vibrating rod so as to cause the vibrating rod to vibrate.
3. The method for manufacturing a glass substrate for an information
25 recording medium according to claim 2, wherein
a brush is attached to the vibrating rod and the cleaning of the glass substrate is performed while the brush is in contact with the inner circumferential surface.
- 30 4. The method for manufacturing a glass substrate for an information

recording medium according to claim 1 or 3, comprising

performing at least one or more precision polishing after performing the chemical strengthening.

- 5 5. The method for manufacturing a glass substrate for an information recording medium according to claim 1 or 4, wherein
a thickness of the glass substrate is 0.65 mm or less.