

DESCRIPTION

[Title of Invention]

METHOD FOR MANUFACTURING MAGNETIC-DISK GLASS SUBSTRATE,
METHOD FOR MANUFACTURING MAGNETIC DISK, AND GRINDSTONE

5 [Technical Field]

[0001] The present invention relates to a method for manufacturing a magnetic-disk glass substrate, and a magnetic disk.

[Background Art]

[0002] Nowadays, personal computers, digital versatile disc (DVD) recorders,
10 and the like have a built-in hard disk drive (HDD) for data recording. In particular, a magnetic disk in which a magnetic layer is provided on a glass substrate is used in a hard disk drive that is used in a device premised on portability, such as a notebook-type personal computer, and magnetic recording information is recorded on or read from the magnetic layer with a magnetic head
15 that flies slightly above the surface of the magnetic disk. A glass substrate is unlikely to be plastically deformed compared with a metal substrate (aluminum substrate) and the like, and thus is preferably used as a substrate of the magnetic disk.

[0003] Moreover, the density of magnetic recording has been increased to meet the demand for an increase in the storage capacity of hard disk drives. For example, the magnetic recording information area (recording bit) has been made smaller using a perpendicular magnetic recording system that causes the direction of magnetization in the magnetic layer to be perpendicular to the surface of the substrate. This makes it possible to increase the storage capacity per disk substrate. Also, in order to further increase the storage capacity, the distance between the recording and reproducing element portion of the magnetic head and the magnetic recording layer is made very short by causing the element portion to project farther, thus further improving the accuracy of the recording and reproducing of information (improving the S/N ratio). It should be noted that such control of the recording and reproducing element portion of the magnetic head is called a dynamic flying height (DFH) control mechanism and a magnetic head equipped with this control mechanism is called a DFH head. A magnetic-disk glass substrate that is used in an HDD in combination with such a DFH head is produced so as to have an extremely smooth main surface in order to prevent the substrate from colliding or coming into contact with the magnetic head and the recording and reproducing element portion that projects farther therefrom.

[0004] When manufacturing a magnetic-disk glass substrate, the inner circumferential edge portion and the outer circumferential edge portion of a

disk-shaped glass substrate provided with an inner hole are chamfered. That is, chamfered surfaces that are each interposed between a main surface and a side wall surface of the glass substrate are formed. When the chamfered surfaces are formed, it is possible to prevent the occurrence of foreign matter from the glass substrate and to suppress problems such as head crash and thermal asperity when incorporating the produced magnetic disk in an HDD.

A method for grinding the edge surface of the outer circumferential portion or the inner circumferential portion of a workpiece through rotating a grindstone in which a groove portion is formed on the outer circumferential portion about a rotation axis that is inclined with respect to a rotation axis of the rotating workpiece and pressing the groove portion of the grindstone against the outer circumferential portion or the inner circumferential portion of the workpiece is known as a method for grinding the edge surface of a disk-shaped glass substrate (Patent Literature 1). With this edge surface grinding method, the edge surface is ground in a surface contact state, and impact is relieved during contact with the outer circumferential portion or the inner circumferential portion of the workpiece, thus making it possible to efficiently obtain a favorable surface quality.

[Citation List]

[Patent Literature]

[0005] [PLT1]: JP 2000-167753A

[Summary of Invention]

[Technical Problem]

[0006] When the inventors of the present invention performed the edge surface grinding on a disk-shaped glass substrate provided with an inner hole based on the edge surface grinding method described in Patent Literature 1 above, an improvement in the surface quality of the edge surface was confirmed, whereas it was found that there was a problem in that chamfering angles of a pair of chamfered surfaces (e.g., chamfered surfaces interposed between a side wall surface and a pair of main surfaces on the outer circumference in a case of the outer circumferential edge surface; the same applies the inner circumferential edge surface) were different. When a magnetic disk is incorporated in an HDD and rotated, turbulence of air flow occurs in a housing of the HDD and causes fluttering, and therefore, it is not preferable that the chamfering angles of the pair of chamfered surfaces of the magnetic-disk glass substrate are different.

When the outer circumferential edge surface of the magnetic-disk glass substrate is held in order to form a film on the glass substrate, there is also a risk that the accuracy of film thickness control decreases due to the glass substrate not being accurately held in a case where the chamfering angles of the pair of chamfered surfaces on the outer circumferential side are different from each other.

[0007] Therefore, an object of the present invention is to provide a method for manufacturing a magnetic-disk glass substrate, a method for manufacturing a

magnetic disk, and a grindstone with which the chamfering angles of the pair of chamfered surfaces can be made to be the same while favorable edge surface quality is ensured when grinding the edge surface of a disk-shaped glass substrate in a process for manufacturing a magnetic-disk glass substrate.

5 [Solution to Problem]

[0008] The inventors of the present invention intensively examined the cause of the chamfering angles of the pair of chamfered surfaces not being the same in a case where a groove portion of a grindstone with which the pair of chamfered surfaces of a glass substrate were brought into contact during processing was
10 formed so as to have the same pair of opening angles in the edge surface grinding performed on the glass substrate, in which the grindstone provided with the groove portion was rotated about a rotation axis that was inclined with respect to a rotation axis of the glass substrate and the groove portion of the grindstone was pressed against the outer circumferential portion or the inner circumferential
15 portion of the glass substrate. As a result, it was found that the chamfering angles did not become the same after the processing because the action of abrasive particles on one chamfered surface was different from the action of abrasive particles on the other chamfered surface during the processing due to the rotation axis of the glass substrate being inclined with respect to the rotation
20 axis of the grindstone.

[0009] A first aspect of the present invention is a method for manufacturing a magnetic-disk glass substrate including edge surface grinding processing performed using a rotating grindstone on an edge surface of a disk-shaped glass substrate in the center of which a circular hole is formed, the edge surface having

5 a side wall surface and chamfered surfaces each formed between the side wall surface and a main surface. In the edge surface grinding processing, a pair of chamfered surfaces of the glass substrate are simultaneously ground with a rotation axis of the grindstone inclined with respect to an axis orthogonal to the main surface of the substrate. The grindstone has a groove shape having a pair of

10 chamfered surface grinding areas for grinding the chamfered surfaces of the glass substrate. The pair of chamfered surface grinding areas include: a chamfered surface grinding area (A) that comes into contact with the chamfered surface of the glass substrate, with reference to a contact point between the glass substrate and the grindstone that is located on a straight line connecting the center of the

15 glass substrate and a rotation axis of the grindstone, on a front side in a rotation direction of the grindstone (on a side in which abrasive particles come close to the reference contact point); and a chamfered surface grinding area (B) that comes into contact with the chamfered surface of the glass substrate on a rear side in a rotation direction of the grindstone (on a side in which the abrasive particles

20 move away from the reference contact point), and an opening angle of the chamfered surface grinding area (A) is smaller than an opening angle of the

chamfered surface grinding area (B).

[0010] In the method for manufacturing a magnetic-disk glass substrate, the groove shape of the grindstone may further have a side wall surface grinding area for grinding the side wall surface of the glass substrate, and in the edge surface grinding processing, the side wall surface and the pair of chamfered surfaces of the glass substrate may be simultaneously ground.

[0011] In the method for manufacturing a magnetic-disk glass substrate, the magnetic-disk glass substrate may have a thickness of less than 0.635 mm.

[0012] In the method for manufacturing a magnetic-disk glass substrate, it is preferable that the magnetic-disk glass substrate is made of crystallized glass.

[0013] A second aspect of the present invention is a method for manufacturing a magnetic disk including processing for forming a magnetic layer on the main surface of the magnetic-disk glass substrate produced with the method for manufacturing a magnetic-disk glass substrate.

[0014] A third aspect of the present invention is a grindstone to be rotated and used in edge surface grinding processing performed on an edge surface of a disk-shaped glass substrate in the center of which a circular hole is formed, the edge surface having a side wall surface and chamfered surfaces each formed between the side wall surface and a main surface. The grindstone is constituted by a cylindrical or columnar rotation body and is provided with a groove on a circumference of the rotation body. The groove includes a side wall surface

grinding surface that comes into contact with the side wall surface of the glass substrate, a chamfered surface grinding surface (A) that comes into contact with one of the chamfered surfaces between which the side wall surface is interposed, and a chamfered surface grinding surface (B) that comes into contact with the other of the chamfered surfaces in a cross-sectional view taken along a plane including a rotation axis of the rotation body, and opening angles of the chamfered surface grinding surface (A) and the chamfered surface grinding surface (B) with respect to the side wall surface grinding surface are different from each other.

[Advantageous Effects of the Invention]

[0015] With the method for manufacturing a magnetic-disk glass substrate, the method for manufacturing a magnetic disk, and the grindstone described above, chamfering angles of a pair of chamfered surfaces can be made to be the same while favorable edge surface quality is ensured when grinding the edge surface of a disk-shaped glass substrate in a process for manufacturing a magnetic-disk glass substrate.

[Brief Description of Drawings]

[0016] FIG. 1A is a diagram showing an external shape of a magnetic-disk glass substrate according to an embodiment.

FIG. 1B is an enlarged cross-sectional view of an edge portion on the outer circumferential side of the magnetic-disk glass substrate according to the embodiment.

FIG. 2 is a diagram showing grinding processing performed on the inner circumferential edge surface of a disk-shaped glass substrate.

FIG. 3 is a diagram showing a contact surface between the glass substrate and a grindstone during the grinding processing performed on the inner
5 circumferential edge surface of the disk-shaped glass substrate.

FIG. 4 is a diagram illustrating opening angles of a groove portion of the grindstone.

FIG. 5 is a diagram showing grinding processing performed on the outer circumferential edge surface of the disk-shaped glass substrate.

10 [Description of Embodiments]

[0017] Hereinafter, a method for manufacturing a magnetic-disk glass substrate according to an embodiment of the present invention will be described in detail.

[0018] [Magnetic-disk glass substrate]

Aluminosilicate glass, soda-lime glass, borosilicate glass, or the like can
15 be used as a material for a magnetic-disk glass substrate of this embodiment. In particular, aluminosilicate glass can be preferably used because it can be chemically strengthened and used to produce a magnetic-disk glass substrate having excellent flatness of its main surfaces and excellent strength of the substrate.

20 [0019] Although there is no limitation on the composition of the glass material used in the magnetic-disk glass substrate of this embodiment, the glass substrate

of this embodiment may preferably be amorphous aluminosilicate glass that has a composition including SiO_2 , Li_2O , Na_2O , and one or more alkaline earth metal oxides selected from the group consisting of MgO , CaO , SrO and BaO as essential components, has a molar ratio of the content of CaO to the total content of MgO , CaO , SrO and BaO ($\text{CaO}/(\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO})$) of 0.20 or less, and has a glass-transition temperature of 650°C or higher.

The glass substrate of this embodiment may also be crystallized glass that contains, in terms of oxide amount in mass%, SiO_2 in an amount of 45.60 to 60%, Al_2O_3 in an amount of 7 to 20%, B_2O_3 in an amount of 1.00 to less than 8%, P_2O_5 in an amount of 0.50 to 7%, TiO_2 in an amount of 1 to 15%, RO (it should be noted that R represents Zn and Mg) in a total amount of 5 to 35%, CaO in an amount of 3.00% or less, BaO in an amount of 4% or less, no PbO component, no As_2O_3 component, no Sb_2O_3 component, no Cl^- component, no NO^- component, no SO_4^{2-} component, no F^- component, and one or more selected from RAl_2O_4 and R_2TiO_4 (it should be noted that R represents one or more selected from Zn and Mg) as a main crystal phase, the particle size of crystals in the main crystal phase being in a range of 0.5 to 20 nm, the degree of crystallization being 15% or less, and the specific gravity being 2.95 or less.

[0020] FIG. 1A shows an external shape of the magnetic-disk glass substrate of this embodiment. As shown in FIG. 1A, a thin glass substrate that has a doughnut shape with an inner hole 2 formed therein is used as the magnetic-disk

glass substrate of this embodiment. Although there is no limitation on the size of the magnetic-disk glass substrate, the magnetic-disk glass substrate is preferable for a magnetic-disk glass substrate having a nominal diameter of 2.5 inches, for example.

5 FIG. 1B is an enlarged cross-sectional view of an edge portion on the outer circumferential side of the magnetic-disk glass substrate of this embodiment. As shown in FIG. 1B, the magnetic-disk glass substrate includes a pair of main surfaces 1p, a side wall surface 1t that is disposed in a direction orthogonal to the pair of main surfaces 1p, and a pair of chamfered surfaces 1c that are disposed
10 between the pair of main surfaces 1p and the side wall surface 1t. A side wall surface and chamfered surfaces, which are not shown in the drawings, are also formed in the edge portion on the inner circumferential side of the magnetic-disk glass substrate. Angles (chamfering angles) of the chamfered surfaces 1c with respect to the side wall surface 1t are basically the same and are preferably 15 to
15 75°, for example. When the chamfering angle is set to be in this range, it is possible to preferably prevent scratches and chips in the edge portion of the substrate in a process for manufacturing a magnetic-disk glass substrate and subsequent processes for manufacturing a magnetic disk and an HDD. The chamfering angle is typically 45° as shown in the diagram. It should be noted
20 that the chamfered surfaces may be formed in an arc shape when viewed in cross section.

[0021] Although there is no particular limitation on the thickness of the magnetic-disk glass substrate of this embodiment, the thickness of a magnetic-disk glass substrate having a nominal diameter of 2.5 inches is 0.8mm or 0.635mm, for example, and the thickness of a magnetic-disk glass substrate having a nominal diameter of 3.5 inches is 0.5mm, for example. It should be noted that generally, in the case where the magnetic-disk glass substrate is used for a magnetic disk, the thinner the magnetic-disk glass substrate is, the more likely it is to flutter, and the more likely fluttering is to occur. However, the magnetic-disk glass substrate of this embodiment is produced such that the angles of the pair of chamfered surfaces are the same as will be described later, and therefore, turbulence of air flow is suppressed at the outer circumferential edge portion, and fluttering is suppressed even in the case where the thickness is reduced. That is, from the viewpoint of exhibiting an even better effect of the present invention, the thickness of the magnetic-disk glass substrate of this embodiment is preferably less than 0.635 mm, and more preferably 0.5 mm or less.

[0022] [Method for manufacturing magnetic-disk glass substrate]

Hereinafter, a method for manufacturing a magnetic-disk glass substrate of this embodiment will be described for each series of processing. It should be noted that the processing order may be changed as appropriate.

[0023] (1) Plate glass molding and rough grinding processing

After forming a sheet of plate glass by a float method, for example, a raw glass plate having a predetermined shape from which a magnetic-disk glass substrate is to be made is cut out from this sheet of plate glass. A raw glass plate may also be molded by press molding using an upper mold and a lower mold instead of a float method, for example. It should be noted that a method for manufacturing a raw glass plate is not limited to these methods and a raw glass plate can also be manufactured by a known manufacturing method such as a down draw method, a redraw method or a fusion method.

It should be noted that rough grinding processing may be performed on the two main surfaces of the raw glass plate as needed.

[0024] (2) Shaping processing

Next, shaping processing is performed. In the shaping processing, a circular hole is formed using a known processing method after molding a glass blank, and thus a disk-shaped glass substrate provided with a circular hole is obtained. Next, the edge surface of the glass substrate is ground to form chamfered surfaces having a desired shape. That is, the chamfered surfaces, which connect the side wall surface and the main surfaces, are formed on the edge portion of the glass substrate.

[0025] Hereinafter, the edge surface grinding processing performed on the inner circumferential edge surface will be described with reference to FIGS. 2 and 3.

In the edge surface grinding processing, in addition to grinding processing using a formed grindstone or without performing grinding processing using a formed grindstone, an edge surface grinding method is performed in which the edge surface of the glass substrate is brought into contact with the grindstone, which is brought into contact with the edge surface of the glass substrate, such that the locus of the grindstone is not constant. FIG. 2 is a diagram showing grinding processing performed on the inner circumferential edge surface of a glass substrate G. FIG. 3 is a diagram showing a contact surface between the glass substrate G and a grindstone 5 during the grinding processing performed on the inner circumferential edge surface of the glass substrate G.

[0026] As shown in FIG. 3, the grindstone 5 to be used in the grinding processing performed on the inner circumferential edge surface of the glass substrate G is constituted by a columnar rotation body as a whole and is provided with a groove 50 on its outer circumference. The groove 50 is formed so as to be capable of simultaneously grinding the side wall surface and chamfered surfaces C1 and C2 on the inner circumferential side of the glass substrate G. Specifically, the groove 50 is provided with a side wall surface grinding area 50t and chamfered surface grinding areas 50a and 50b that are located on the two sides of the side wall surface grinding area 50t in a circumferential direction.

In the processing of the inner circumferential edge surface of the glass substrate, the grinding processing is performed by rotating both the glass

substrate G and the grindstone 5 while the groove 50 of the grindstone 5 is brought into contact with the inner circumferential side edge surface of the glass substrate G in a state in which the glass substrate G is inclined with respect to the groove direction of the groove 50 formed in the grindstone 5, that is, in a state in which a rotation axis L1 of the glass substrate G is inclined by an angle α ($\alpha > 0$) with respect to a rotation axis L5 of the grindstone 5. That is, the grinding processing is performed while the grindstone 5 is inclined with respect to the glass substrate G such that the groove 50 of the grindstone 5 and the glass substrate G are in a skewed positional relationship. Accordingly, the locus of the groove 50 of the grindstone 5 brought into contact with the inner circumferential edge surface of the glass substrate G is not constant, and the abrasive particles of the grindstone 5 are brought into contact with and act on the edge surface of the substrate at random positions. Therefore, since impairment of the substrate such as deep scratches is reduced, the surface roughness of the ground surface is reduced, and in-plane variation is reduced, it is possible to make the ground surface smoother, that is, to finish the ground surface with a level of quality that meets the requirement for higher quality. Furthermore, the effect of improving the life of the grindstone is obtained.

[0027] Moreover, as shown in FIG. 3, in the grinding processing performed on the inner circumferential edge surface of the glass substrate G, the side wall surface and the two chamfered surfaces of the glass substrate G are simultaneously

ground. In FIG. 3, the areas in which the side wall surface grinding area 50t and the chamfered surface grinding areas 50a and 50b of the grindstone 5 are in contact with the edge surface of the glass substrate G are an area T and areas Ca and Cb, respectively. That is, the groove 50 of the grindstone 5 and the edge surface of the glass substrate G are in contact with each other in a surface contact state. Therefore, a contact length (cutting blade length) of the grindstone 5 with respect to the glass substrate G is extended, thus making it possible to maintain the sharpness of the abrasive particles. Accordingly, stable grinding performance can be ensured even in the case where the grinding processing is performed using a grindstone with fine abrasive particles that is advantageous in terms of the quality of the ground surface, and the favorable quality of the ground surface (mirror surface quality) can be stably obtained through grinding processing using mainly a plastic mode. In addition, the sharpness of the grindstone is maintained and the grinding performance for achieving the plastic mode is stably ensured, thus making it possible to ensure favorable accuracy of dimensions and shapes obtained by chamfering processing performed on the inner circumferential edge surface of the glass substrate.

[0028] Although the above-described inclination angle α of the glass substrate G with respect to the groove direction of the grindstone 5 can be set arbitrarily, it is preferable that the inclination angle α is in a range of 1 to 15° in order to more favorably exhibit the operations and effects described above.

It is preferable to use a so-called electrodeposition bond grindstone, for example, that is a high-rigidity grindstone and in which diamond abrasive particles are fixed with an electrodeposition bond in rough grinding processing as the grindstone 5 used in the above-mentioned edge surface grinding. Moreover, it is preferable to use, in final precision grinding processing, a resin bond grindstone in which a resin material such as a phenol resin, a urethane resin, a polyimide resin, a polyester resin, a fluororesin, or the like is used as a binder that binds abrasive particles, a metal bond grindstone in which a binder is a metallic binding agent such as a copper-based alloy, a cast iron-based alloy, a titanium-based alloy, or the like, or a vitrified grindstone in which a binder is a glass-based binding agent. Of these, the resin bond grindstone with a grindstone hardness that is relatively easily adjusted is particularly preferable.

Moreover, as for the particle diameter of the abrasive particles, it is preferable to use abrasive particles having an average particle diameter of 30 μm or less, for example, so that the grinding performance can be maintained throughout the life of the grindstone while the roughness is maintained. In particular, it is preferable to use abrasive particles having an average particle diameter in a range from 3 to 15 μm in the precision grinding processing. Diamond abrasive particles, for example, are preferable as the abrasive particles. The particle diameter of the abrasive particles can be measured by an electric resistance testing method, for example.

The circumferential speed of the grindstone 5 is preferably 500 to 3000 m/minute, for example, and the circumferential speed of the glass substrate G is about 1 to 30 m/minute. In addition, it is preferable that the ratio (circumferential speed ratio) of the circumferential speed of the grindstone 5 with respect to the circumferential speed of the glass substrate G is in a range of 50 to 300.

[0029] FIG. 4 is a diagram illustrating opening angles of the groove 50 of the grindstone 5 and an enlarged view of portion A of the grindstone 5 shown in FIG. 3.

It should be noted that the shape shown in FIG. 4 is the same as the shape obtained by enlarging the groove 50 in a cross-sectional view taken along a plane including the rotation axis L5 of the grindstone 5. As shown in FIG. 4, the opening angles of the chamfered surface grinding areas 50a and 50b with respect to a plane orthogonal to the side wall surface grinding area 50t are defined as θ_1 and θ_2 , respectively. The relationship $\theta_1 > \theta_2$ is satisfied in the case where the grindstone is rotated in the direction indicated in FIG. 2 and the rotation axis L1 of the glass substrate G is inclined at the inclination angle α ($\alpha > 0$ in FIG. 3) shown in FIG. 3.

[0030] The following is the reason for satisfying $\theta_1 > \theta_2$. In the case where the grindstone is rotated in the direction indicated in FIG. 2 and the rotation axis L1 of the glass substrate G is inclined at the inclination angle α ($\alpha > 0$ in FIG. 3) shown in FIG. 3, it is clear from the contact areas Ca and Cb between the

grindstone 5 and the glass substrate G that the chamfered surface grinding area 50a comes into contact with the chamfered surface of the glass substrate G on the rear side in the rotation direction of the grindstone 5 with reference to a contact point between the glass substrate G and the grindstone 5 that is located on a straight line connecting the center of the glass substrate G and the rotation axis L5 of the grindstone 5. The chamfered surface grinding area 50b comes into contact with the chamfered surface of the glass substrate G on the front side in the rotation direction of the grindstone 5 with reference to the contact point. That is, in this example, a chamfered surface grinding area (A) of the present invention corresponds to the chamfered surface grinding area 50b, and a chamfered surface grinding area (B) of the present invention corresponds to the chamfered surface grinding area 50a.

[0031] At this time, the abrasive particles strongly act on the chamfered surface C1 of the glass substrate, which is processed on the front side in the rotation direction of the grindstone 5 (i.e., in the contact area Cb on the chamfered surface grinding area 50b in FIG. 3), so as to engage with the chamfered surface C1, and therefore, the chamfering angle of the chamfered surface C1 is larger than the opening angle θ_2 of the chamfered surface grinding area 50b. On the other hand, the abrasive particles relatively smoothly act on the chamfered surface C2 of the glass substrate, which is processed on the rear side in the rotation direction of the grindstone 5 (i.e., in the contact area Ca on the chamfered surface grinding area

50a in FIG. 3), and therefore, the chamfering angle of the chamfered surface C2 is an angle obtained by transferring the opening angle θ_1 of the chamfered surface grinding area 50a (that is, the same angle as θ_1). Therefore, the opening angles of the groove 50 of the grindstone 5 are set so as to satisfy $\theta_1 > \theta_2$, thus enabling the chamfered surfaces C1 and C2 of the glass substrate G, which has undergone the edge surface grinding processing, to have the same chamfering angle. It should be noted that the difference between the opening angles θ_1 and θ_2 can be determined as appropriate based on factors such as the inclination angle α of the rotation axis L1 of the glass substrate G and the diameter of the grindstone 5 such that the chamfered surfaces C1 and C2 have the same chamfering angle.

[0032] In FIG. 4, in the case where the grindstone is rotated in the direction indicated in FIG. 2 and the rotation axis L1 of the glass substrate G is inclined at the inclination angle α ($\alpha > 0$ in FIG. 3) shown in FIG. 3, the relationship between the opening angle θ_1 of the chamfered surface grinding area 50a and the opening angle θ_2 of the chamfered surface grinding area 50b is $\theta_1 > \theta_2$. When the grindstone 5 is rotated in the reversed direction in FIG. 2, the front-rear relationship of the contact areas Ca and Cb on the glass substrate G with reference to the rotation direction of the grindstone 5 reverses as well, and therefore, $\theta_1 < \theta_2$ is preferable. Moreover, although not shown in the drawings, even in the case where the rotation direction of the grindstone shown in FIG. 2 is not changed, when the inclination angle α of the rotation axis L1 of the glass

substrate G is changed such that $\alpha < 0$ is satisfied in FIG. 3, the contact area on the chamfered surface grinding area 50a is located on the front side in the rotation direction of the grindstone 5 with respect to the contact area on the chamfered surface grinding area 50b, and therefore, $\theta_1 < \theta_2$ is preferable.

5 [0033] The grinding processing can also be performed on the outer circumferential edge surface of the glass substrate in the same manner as performed on the inner circumferential edge surface. FIG. 5 is a diagram showing the grinding processing performed on the outer circumferential edge surface of the glass substrate G. As shown in FIG. 5, a grindstone 7 used in the

10 edge surface grinding processing performed on the outer circumferential edge surface is constituted by a cylindrical rotation body and is provided with a groove on its inner circumference. As shown in FIG. 5, also in the grinding processing performed on the outer circumferential edge surface of the glass substrate G, the grinding processing is performed while the grindstone 7 is inclined with respect to

15 the glass substrate G such that the groove of the grindstone 7 and the glass substrate G are in a skewed positional relationship in the same manner as in the grinding processing performed on the inner circumferential edge surface. Moreover, also in the grinding processing performed on the inner circumferential edge surface of the glass substrate G, the side wall surface and the two chamfered

20 surfaces of the glass substrate G are simultaneously ground in the same manner as in the grinding processing performed on the inner circumferential edge surface.

It is preferable to set the inclination angle of the glass substrate G with respect to the groove direction of the grindstone 7 to be in a range of 1 to 15° in the same manner as in the grinding processing performed on the inner circumferential edge surface.

5 The opening angles of the groove of the grindstone 7 are the same as those shown in FIG. 4. That is, the groove includes a chamfered surface grinding area (A) that comes into contact with the chamfered surface of the glass substrate G on the front side in the rotation direction of the grindstone 7 with reference to a contact point between the glass substrate G and the grindstone 7 that is located
10 on a straight line connecting the center of the glass substrate G and the rotation axis of the grindstone 7, and a chamfered surface grinding area (B) that comes into contact with the chamfered surface of the glass substrate G on the rear side in the rotation direction of the grindstone 7. The opening angle of the chamfered surface grinding area (A) is set to be smaller than the opening angle of the
15 chamfered surface grinding area (B). This enables the chamfering angles of the pair of chamfered surfaces on the outer circumferential side of the glass substrate G, which has undergone the edge surface grinding processing, to be the same.

[0034] It should be noted that although the case where the grindstone 5 for the inner circumferential edge surface includes the chamfered surface grinding areas
20 50a and 50b and the side wall surface grinding area 50t and simultaneously grinds the side wall surface and a pair of chamfered surfaces of the inner

circumferential edge surface of the glass substrate G has been described in the above description, the grindstone 5 may simultaneously grind the pair of chamfered surfaces and may be prevented from grinding the side wall surface at the same time. For example, when separately performing processing for grinding the side wall surface in advance, the grinding processing using the grindstone 5 may include only a step of simultaneously grinding the pair of chamfered surfaces. However, as described above, by simultaneously grinding the side wall surface and the pair of chamfered surfaces of the inner circumferential edge surface of the glass substrate G, it is possible to obtain an effect of reducing the time for the edge surface grinding processing.

The same applies the case where the outer circumferential edge surface is ground.

[0035] (3) Edge surface polishing processing

Next, edge surface polishing processing is performed on the glass substrate. The edge surface polishing processing is processing for performing polishing by supplying a polishing liquid that contains loose abrasive particles between a polishing brush and the edge surface of the glass substrate and moving the polishing brush and the glass substrate relative to each other. In the edge surface polishing, the inner circumferential side edge surface and the outer circumferential side edge surface of the glass substrate are polished and are brought into a mirror-surface state. At this time, a polishing liquid containing

microparticles of cerium oxide or the like as the loose abrasive particles is used, for example. By performing the edge surface polishing, contamination by adhered particles of foreign matter such as dust, and impairment such as damage or scratches can be eliminated from the edge surfaces of the glass substrate.

- 5 This makes it possible to prevent thermal asperity even if this glass substrate is used to manufacture a magnetic disk.

[0036] (4) Precision grinding processing

In precision grinding processing, the main surfaces of the disk-shaped glass substrate are ground using a double-side grinding device provided with a planetary gear mechanism. The double-side grinding device has a pair of upper and lower surface plates (upper surface plate and lower surface plate), and the disk-shaped glass substrate mounted to the carrier is held between the upper surface plate and the lower surface plate. The glass substrate and the surface plates are moved relative to each other by moving one or both of the upper surface plate and the lower surface plate, thus making it possible to grind the two main surfaces of the glass substrate.

[0037] (5) First polishing (main surface polishing) processing

Next, first polishing processing is performed on the main surfaces of the glass substrate. In the first polishing processing, a double-side polishing device provided with a planetary gear mechanism is used to polish the main surfaces on the two sides of the glass substrate. In the first polishing processing, resin

polishers and loose abrasive particles such as cerium oxide abrasive particles or zirconia abrasive particles are used, for example. The first polishing is performed to eliminate cracks and distortion that remain in the main surfaces after performing the precision grinding processing, for example.

5 [0038] (6) Chemical strengthening processing

The glass substrate can be chemically strengthened as appropriate. A molten liquid obtained by heating potassium nitrate, sodium nitrate or a mixture thereof can be used as a chemical strengthening liquid, for example. By immersing the glass substrate in the chemical strengthening liquid, lithium ions
10 and sodium ions in the surface layer of the glass substrate are respectively substituted with sodium ions and potassium ions having a relatively large ion radius in the chemical strengthening liquid, and thus a compressive stress layer is formed in the surface layer portion and the glass substrate is strengthened.

Although the timing at which the chemical strengthening processing is
15 performed can be determined as appropriate, it is particularly preferable to perform polishing processing subsequent to the chemical strengthening processing because it is possible to make the surface smoother and to remove foreign matter that adheres to the surface of the glass substrate with the chemical strengthening processing. Moreover, it is sufficient to perform the
20 chemical strengthening processing as needed, and alternatively, the chemical strengthening processing need not be performed.

[0039] (7) Second polishing (final polishing) processing

Next, second polishing is performed on the glass substrate, which has undergone the chemical strengthening processing. The second polishing is performed in order to mirror polish the main surfaces. Also in the second
5 polishing, a double-side polishing device that has a configuration similar to that of the double-side polishing device used in the first polishing is used. In the second polishing processing, it is preferable to use loose abrasive particles that have a smaller particle size than those used in the first polishing processing do and resin polishers that have a smaller hardness than those used in the first
10 polishing processing do. This makes it possible to make the surface roughness of the glass substrate extremely small.

[0040] Microparticles of colloidal silica or the like are used as the loose abrasive particles to be used in the second polishing processing, for example.

Although the second polishing processing is not necessarily essential, it is
15 preferable to perform the second polishing processing because it is possible to make the level of surface unevenness of the main surfaces of the glass substrate more favorable. Thereafter, the glass substrate is cleaned to provide a magnetic-disk glass substrate.

It should be noted that it is preferable to polish the glass substrate such
20 that the surface roughness of the glass substrate, which has undergone the second polishing processing, is 0.15 nm or less at the arithmetic mean roughness

Ra in order to produce a magnetic-disk glass substrate having a small surface roughness.

[0041] It should be noted that when crystallized glass is produced, crystallization processing is performed at an intermediate stage in the above-described series of processes. In the crystallization processing, glass substrates sandwiching a disc-shaped plate called a setter between each of them are introduced into a heating furnace and subjected to heating processing, for example. The setters may be made of ceramics. In the heating processing, the glass substrate is crystallized by, for example, being held at a nucleus forming temperature for a predetermined period of time and then being held at a crystal growing temperature for a predetermined period of time. It is sufficient to set the nucleus forming temperature and the temperature and the period of time for crystal growth as appropriate depending on the glass composition of the glass substrate. When the glass substrate is cooled after being heated, it is preferable to adjust a cooling speed during slow cooling such that distortion and bending do not occur in the glass substrate.

It is possible to determine whether or not the glass substrate, which has undergone the crystallization processing, is crystallized using a diffraction intensity distribution obtained by powder X-ray diffractometry, for example. It should be noted that it is preferable to precipitate crystals whose average crystalline particle diameter in the crystal phase is 10 nm or less for the purpose

of reducing the surface roughness of the main surfaces of the glass substrate and making the main surfaces into mirror surfaces.

The crystal phase is hard and thus is difficult to process through polishing.

When the average crystalline particle diameter is larger than 10 nm, a period of
5 time for polishing processing performed on the main surfaces of the glass substrate becomes longer, and the surface roughness becomes significantly large due to crystal phase that cannot be removed by polishing. Moreover, it is preferable that the surface roughness is 1 nm or less at an arithmetic mean roughness Ra after the crystallization processing and before the second polishing
10 processing because the amount of machining allowance can be reduced in the second polishing processing.

Glass that has been crystallized (referred to as "crystallized glass" hereinafter) is a material configured to have crystals precipitated inside the glass by heating amorphous glass, and can be distinguished from amorphous glass.
15 The crystallized glass exhibits properties that are not provided in amorphous glass due to crystals that are dispersed thereinside. For example, the crystallized glass exhibits properties that cannot be realized in amorphous glass with respect to thermal properties such as Vickers hardness, a Young's modulus, mechanical strength such as fracture toughness, etching resistance, and a
20 thermal expansion coefficient. It should be understood that the crystallized glass exhibits properties different from those of ceramics configured by sintering

powder. The crystallized glass has a dense configuration that has an extremely small number of pores compared with ceramics.

In this embodiment, the Young's modulus of the glass substrate, which has undergone the crystallization processing, is preferably 100 GPa or more, and
 5 more preferably 120 GPa or more. Thus, it is possible to obtain a glass substrate with high flexural strength and high impact resistance. The flexural strength of the glass substrate, which has undergone the crystallization processing, is preferably 7 kgf or more, and particularly preferably 8 kgf or more for the purpose of enhancing the impact resistance. Thus, it is possible to obtain a
 10 magnetic-disk glass substrate that is preferable for a hard disk drive (HDD) with a high rotation speed of 10000 rpm or more.

[0042] [Magnetic disk]

A magnetic disk can be obtained as follows using the magnetic-disk glass substrate.

15 A magnetic disk has a configuration in which at least an adherent layer, a base layer, a magnetic layer (magnetic recording layer), a protecting layer and a lubricant layer are laminated on the main surface of the magnetic-disk glass substrate (referred to as merely "substrate" hereinafter) in this order from the
 main surface, for example.

20 For example, the substrate is introduced into a film deposition device that has been evacuated, and the layers from the adherent layer to the magnetic layer

are sequentially formed on the main surface of the substrate in an Ar atmosphere by a DC magnetron sputtering method. CrTi can be used in the adherent layer, and CrRu can be used in the base layer, for example. A CoPt based alloy can be used in the magnetic layer, for example. Also, a CoPt-based alloy or a
5 FePt-based alloy having an L_{10} ordered structure is formed to be the magnetic layer for thermally assisted magnetic recording. After the film deposition as described above, by forming the protecting layer using C_2H_4 by a CVD method, for example, and subsequently performing nitriding processing that introduces nitrogen to the surface, a magnetic recording medium can be formed. Thereafter,
10 by coating the protecting layer with perfluoropolyether (PFPE) by a dip coat method, the lubricant layer can be formed.

The produced magnetic disk is preferably incorporated in a magnetic-disk drive device (hard disk drive (HDD)) serving as a magnetic recording and reproduction device provided with a magnetic head equipped with a dynamic
15 flying height (DFH) control mechanism and a spindle for fixing the magnetic disk.

[0043] [Working examples and comparative examples]

The effect of the method for manufacturing a magnetic-disk glass substrate according to this embodiment was confirmed. The following is the composition of the glass used.

20 [Glass composition]

Amorphous aluminosilicate glass was used that contained, in mass%,

65.08% SiO₂, 15.14% Al₂O₃, 3.61% Li₂O, 10.68% Na₂O, 0.35% K₂O, 0.99% MgO, 2.07% CaO, 1.98% ZrO₂, and 0.10% Fe₂O₃, and had a glass-transition temperature of 510°C.

[0044] [Production of glass substrates of working examples and comparative
5 examples]

As the magnetic-disk glass substrates of working examples and comparative examples, magnetic-disk glass substrates with a nominal diameter of 2.5 inches having an inner diameter of 20 mm, an outer diameter of 65 mm, and a thickness of 0.8 mm were produced by performing each series of processing
10 of the above-described manufacturing method in the given order. In this case, in the shaping processing, a raw glass plate was cut, and disk-shaped glass substrates were obtained that had a doughnut shape provided with a circular inner hole (inner diameter: 20mm) and having a circular external shape (outer diameter: 65 mm). The edge surface grinding processing shown in FIGS. 2 to 5
15 was performed on the outer circumferential portion and the inner circumferential portion of these glass substrates to form the outer circumferential side chamfered surfaces and the inner circumferential side chamfered surfaces. At this time, when the inner circumferential edge surface was ground, α was set to be 5°, and a grindstone having an outer diameter of 15 mm was used. When the outer
20 circumferential edge surface was ground, α was set to be 5°, and a grindstone having an outer diameter of 100 mm was used. A 400# electrodeposition

diamond grindstone and a 2000# resin bond diamond grindstone were used in this order to grind the inner circumferential edge surface and the outer circumferential edge surface. The width of the side wall surface grinding area 50t (see FIG. 4) was set to be 1.0 mm.

5 The magnetic-disk glass substrates of the working examples and comparative examples were respectively produced using grindstones that had different opening angles as shown in Tables 1 and 2. It should be noted that Table 1 shows the cases where the inner circumferential side edge surface was ground, and Table 2 shows the cases where the outer circumferential side edge
10 surface was ground.

[0045] In Tables 1 and 2, the opening angle of the chamfered surface grinding area (A) that comes into contact with the chamfered surface of the glass substrate on the front side in the rotation direction of the grindstone with reference to a contact point between the glass substrate and the grindstone that is located on a
15 straight line connecting the center of the glass substrate and the rotation axis of the grindstone is defined as θ_A , and the opening angle of the chamfered surface grinding area (B) that comes into contact with the chamfered surface of the glass substrate on the rear side in the rotation direction of the grindstone is defined as θ_B . The chamfering angle of the chamfered surface of the glass substrate to be
20 ground by the chamfered surface grinding area (A) is defined as Θ_A , and the chamfering angle of the chamfered surface of the glass substrate to be ground by

the chamfered surface grinding area (B) is defined as Θ_B .

The chamfering angles Θ_A and Θ_B shown in Tables 1 and 2 are values obtained immediately after the edge surface grinding processing.

[0046] [Table 1]

	Opening angle θ_B of grindstone	Opening angle θ_A of grindstone	Chamfering angle Θ_B after edge surface grinding	Chamfering angle Θ_A after edge surface grinding
Comp. Ex. 1	45°	45°	45°	46°
Work. Ex. 1	45°	44°	45°	45°

5 [0047] [Table 2]

	Opening angle θ_B of grindstone	Opening angle θ_A of grindstone	Chamfering angle Θ_B after edge surface grinding	Chamfering angle Θ_A after edge surface grinding
Comp. Ex. 2	45°	45°	45°	46°
Work. Ex. 2	45°	44°	45°	45°

[0048] Although the magnetic-disk glass substrates were produced by performing the edge surface polishing, the first polishing for the main surfaces, and the second polishing for the main surfaces after the edge surface grinding processing, the chamfering angles were the same as the values shown in Tables 1 and 2.

It is clear from the results from the working examples shown in Tables 1 and 2 that when grinding the outer circumferential edge surface and the inner circumferential edge surface, the chamfering angles Θ_A and Θ_B of the pair of chamfered surfaces of the glass substrate, which had undergone the edge surface grinding, became the same by setting the opening angles of the grindstone such that the opening angle θ_A was smaller than the opening angle θ_B .

[0049] While the method for manufacturing a magnetic-disk glass substrate, the method for manufacturing a magnetic disk, and a grindstone according to the present invention have been described in detail, the present invention is not limited to the above-described embodiment, and it will be appreciated that various improvements and modifications can be made without departing from the gist of the present invention.

CLAIMS

1. A method for manufacturing a magnetic-disk glass substrate comprising edge surface grinding processing performed using a rotating grindstone on an edge surface of a disk-shaped glass substrate in the center of which a circular hole is formed, the edge surface having a side wall surface and chamfered surfaces each formed between the side wall surface and a main surface,

wherein in the edge surface grinding processing, a pair of chamfered surfaces of the glass substrate are simultaneously ground with a rotation axis of the grindstone inclined with respect to an axis orthogonal to the main surface of the substrate,

the grindstone has a groove shape having a pair of chamfered surface grinding areas for grinding the chamfered surfaces of the glass substrate,

the pair of chamfered surface grinding areas include:

a chamfered surface grinding area (A) that comes into contact with the chamfered surface of the glass substrate on a front side in a rotation direction of the grindstone, with reference to a contact point between the glass substrate and the grindstone that is located on a straight line connecting the center of the glass substrate and a rotation axis of the grindstone; and

a chamfered surface grinding area (B) that comes into contact with the

chamfered surface of the glass substrate on a rear side in a rotation direction of the grindstone, and

an opening angle of the chamfered surface grinding area (A) is smaller than an opening angle of the chamfered surface grinding area (B).

- 5 **2.** The method for manufacturing a magnetic-disk glass substrate according to claim 1,
- wherein the groove shape of the grindstone further has a side wall surface grinding area for grinding the side wall surface of the glass substrate, and
- in the edge surface grinding processing, the side wall surface and the pair of
- 10 chamfered surfaces of the glass substrate are simultaneously ground.
- 3.** The method for manufacturing a magnetic-disk glass substrate according to claim 1 or 2,
- wherein the magnetic-disk glass substrate has a thickness of less than 0.635 mm.
- 15 **4.** The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 3,
- wherein the magnetic-disk glass substrate is made of crystallized glass.

5. A method for manufacturing a magnetic disk comprising processing for forming a magnetic layer on the main surface of the magnetic-disk glass substrate produced with the method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 4.

5 6. A grindstone to be rotated and used in edge surface grinding processing performed on an edge surface of a disk-shaped glass substrate in the center of which a circular hole is formed, the edge surface having a side wall surface and chamfered surfaces each formed between the side wall surface and a main surface,

10 wherein the grindstone is constituted by a cylindrical or columnar rotation body and is provided with a groove on a circumference of the rotation body, the groove includes a side wall surface grinding surface that comes into contact with the side wall surface of the glass substrate, a chamfered surface grinding surface (A) that comes into contact with one of the chamfered
15 surfaces between which the side wall surface is interposed, and a chamfered surface grinding surface (B) that comes into contact with the other of the chamfered surfaces in a cross-sectional view taken along a plane including a rotation axis of the rotation body, and
opening angles of the chamfered surface grinding surface (A) and the
20 chamfered surface grinding surface (B) with respect to the side wall surface grinding surface are different from each other.