

DESCRIPTION

Title of the Invention

METHOD FOR MANUFACTURING GLASS SUBSTRATES FOR MAGNETIC
5 DISKS AND METHOD FOR MANUFACTURING MAGNETIC DISKS

Technical Field

[0001]

The present invention relates to a method for manufacturing a
10 magnetic-disk glass substrate to be provided in a magnetic disk device such as
a hard disk drive (HDD), and to a method for manufacturing a magnetic disk.

Background Art

[0002]

15 Magnetic disks are one type of information recording media provided in
magnetic disk drives such as hard disk drives (HDDs). Magnetic disks are
configured with a thin film such as a magnetic layer formed on a substrate, and
conventionally an aluminum substrate has been used as the substrate.
However, recently, in response to the pursuit of high recording density, glass
20 substrates with which the gap between the magnetic head and the magnetic disk
can be narrower than with aluminum substrates have been increasingly used.
The glass substrate surface is precisely polished such that the flying height of
the magnetic head can be lowered as much as possible to achieve a high
recording density. In recent years, the demand for HDDs with a larger storage
25 capacity at lower cost has been increasing, and in order to achieve this, further
quality improvement and cost reduction of magnetic-disk glass substrates are
also required.

[0003]

Magnetic-disk glass substrates are usually manufactured by successively performing a shape processing (edge surface grinding and chamfering) step, an edge surface polishing step, a main surface grinding step, a main surface polishing step, a chemical strengthening step, and the like on
5 glass substrates formed in a disk shape.

Magnetic disks capable of achieving a high recording density at low cost as described above are required, and high processing accuracy is required for the glass substrates in order to increase the recording density of the magnetic disks. The same applies to not only the main surfaces of the glass substrates
10 but also the shapes of the edge surfaces thereof.

[0004]

As disclosed in Patent Literature 1 below, conventionally, the edge surface of the magnetic-disk glass substrate has generally been processed by performing edge surface brushing after performing edge surface grinding using a
15 formed grindstone.

Moreover, Patent Literature 2 below discloses a method for polishing the edge surface of the magnetic-disk glass substrate by applying a magnetic field to a slurry containing ferrite-based magnetic particles and polishing abrasive
20 particles.

Prior Art Literature

Patent Literature

[0005]

Patent Literature 1: JP H11-28649 A

25 Patent Literature 2: JP 2005-50501 A

Summary of the Invention

Problem to be Solved by the Invention

[0006]

As described above, magnetic disks capable of achieving a high recording density at low cost are required. To achieve this, it is required that both high quality based on demand for a decrease in contamination factors such as the occurrence of corrosion on the main surface of a medium and high accuracy for reducing disk flutter (fluttering) be realized in relation to an outer diameter edge surface of the substrate.

[0007]

However, in the above-described conventional method for processing the edge surface of the glass substrate by performing edge surface brushing after performing edge surface grinding using a formed grindstone, an edge angle between the chamfered surface and the side wall surface of the edge surface of the substrate, in particular, varies widely. This causes OD (outer diameter) edge damage (minute blemishes) at a level that was previously not a problem, and foreign matter such as abrasive particles is caught therein, thus reducing the yield of the magnetic disks and the hard disk drives (HDDs). In other words, even if an effort was made to elaborate the edge shape using a formed grindstone, variation in the degree of roundness of the edge arose due to subsequent brushing, thus leading to variation in the above-described edge angle. Moreover, OD edge damage is caused by contact between the side wall surface of the substrate and a carrier during main surface polishing, and studies found that when the edge angle varies widely or the side wall surface is not inclined orthogonally to the main surface or is short in length, the side wall surface comes into strong contact locally with the carrier, and thus OD edge damage is likely to occur. In particular, in the edge surface brushing, pressure applied to the back side of the chamfered surface (near the main surface) and pressure applied to the side wall surface are different from each other due to differences in the bending of a brush hair material, and therefore, there has been

a problem in that machining allowance is likely to be nonuniform and the edge angle between the chamfered surface and the side wall surface is likely to vary. In addition, in the edge surface brushing, there has been a problem in that although the edge surface can be polished into a mirror surface, linear polishing marks are likely to remain.

[0008]

Moreover, in the method, disclosed in the above Patent Literature 2, for polishing the edge surface of the magnetic-disk glass substrate by applying a magnetic field to a slurry containing ferrite-based magnetic particles and polishing abrasive particles, the configuration of the device is complicated regarding the arrangement of magnets, and the like, and the processing rate is low because there is a great distance between the magnets and magnetic particles and the slurry cannot be sufficiently held. Furthermore, in this method, there is a problem in that the outer circumferential side edge surface of the substrate cannot be polished.

[0009]

In recent years, from the viewpoint of further increasing an information recording density, demand for quality of the magnetic-disk glass substrate, such as accuracy of the dimensions and shape of the edge surface of the glass substrate and quality of a surface finished by chamfering, has further increased from before, and there is a problem in that in the case where a large number of magnetic-disk glass substrates are manufactured using a conventional grinding method and polishing method, it has gradually become difficult to stably meet the increasing demand for quality of the glass substrate.

[0010]

Therefore, from the viewpoint of meeting demand for increasing the recording density of a magnetic disk in which reliability for achieving a high recording density urgently needs to be secured, an object of the present

invention is to provide a method for manufacturing a magnetic-disk glass substrate that particularly enables stable processing capable of finishing the edge surface of a magnetic-disk glass substrate so as to have a highly accurate shape and high quality, and a method for manufacturing a magnetic disk using
5 the glass substrate provided by this method.

Means to Solve the Problem

[0011]

In order to solve the aforementioned problems, the present invention
10 includes the following aspects.

(Aspect 1)

An aspect of the present invention is a method for manufacturing a magnetic-disk glass substrate comprising edge surface processing for processing an edge surface of a glass substrate, wherein the edge surface
15 processing includes first processing forming magnetic field lines using a magnetism generating means, holding a magnetic slurry containing a magnetic material and polishing abrasive particles with the magnetic field lines to form a mass of the magnetic slurry, and processing the edge surface of the glass substrate in a state in which the edge surface is brought into contact with the
20 mass of the magnetic slurry, and second processing performed as preprocessing of the first processing, and for using a grindstone having a groove shape formed so as to be capable of simultaneously processing both a side wall surface of the edge surface of the glass substrate and a chamfered surface between a main surface of the glass substrate and the side wall surface to
25 perform processing in a state in which the glass substrate is inclined with respect to a groove direction of the groove shape formed in the grindstone.

[0012]

(Aspect 2)

In the method for manufacturing a magnetic-disk glass substrate according to aspect 1, processing for forming the chamfered surface on the edge surface of the glass substrate is performed before the second processing.

(Aspect 3)

5 In the method for manufacturing a magnetic-disk glass substrate according to aspect 2, the chamfered surface forming processing and the second processing are performed at different angles of a groove direction of the grindstone to the substrate from each other.

[0013]

10 (Aspect 4)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 3, the edge surface of the glass substrate that has undergone the edge surface processing has a surface roughness of 0.2 μm or less in R_{max} .

15 (Aspect 5)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 4, the glass substrate to be introduced into the edge surface processing has a thickness of 0.5 mm or less.

[0014]

20 (Aspect 6)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 5, the glass substrate is constituted by crystallized glass.

(Aspect 7)

25 Another aspect of the present invention is a method for manufacturing a magnetic disk including forming at least a magnetic recording layer on the magnetic-disk glass substrate manufactured by the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 6.

Effects of the Invention

[0015]

With the present invention, from the viewpoint of meeting demand for
5 increasing a recording density of a magnetic disk, accuracy of the dimensions
and shape of the edge surface of a magnetic-disk glass substrate, quality of a
surface finished by chamfering processing, and the like can be secured, and it is
possible to stably perform edge surface processing capable of finishing the edge
10 surface so as to have a highly accurate shape and high quality, thus making it
possible to stably provide a magnetic-disk glass substrate in which the edge
surface of the substrate is finished so as to have a highly accurate shape and
high quality.

[0016]

Furthermore, since the edge surface of the substrate is finished so as to
15 have a highly accurate shape and high quality by using the magnetic-disk glass
substrate manufactured by this method of manufacturing a magnetic-disk glass
substrate, it is possible to provide a magnetic disk that can prevent impairment
caused by the state of the edge surface of the substrate, such as anti-corrosion
measures, that can achieve a higher recording density, and that is highly
20 reliable.

Brief Description of Drawings

[0017]

FIGS. 1(A) and 1(B) show a magnetic-disk glass substrate according to
25 the present invention. FIG. 1(A) is a side view in which a portion thereof is
shown in cross-section, and FIG. 1(B) is a plan view.

FIGS. 2(A) and 2(B) show an embodiment of second processing of the
present invention. FIG. 2(A) is a cross-sectional side view showing a state in

which an outer circumferential side edge surface of a magnetic-disk glass substrate is processed using a grindstone, and FIG. 2(B) is a plan view (partial cross-sectional plan view).

FIG. 3(A) is a cross-sectional side view showing a state in which an
5 inner circumferential side edge surface of a magnetic-disk substrate is processed using a grindstone, and FIG. 3(B) is a cross-sectional plan view of the grindstone.

FIGS. 4(a) to 4(c) are diagrams illustrating first processing of the present invention.

10 FIG. 5 is a perspective view illustrating a state in which the first processing of the present invention is performed.

FIG. 6 is a cross-sectional view showing a shape of an edge surface of a magnetic-disk glass substrate.

15 Mode for Embodying the Invention [0018]

Hereinafter, an embodiment of the present invention will be described in detail.

A magnetic-disk glass substrate is generally manufactured through a
20 substrate preparation step, a shape processing step, an edge surface polishing step, a main surface grinding step, a main surface polishing step, a chemical strengthening step, and the like.

A method for manufacturing a magnetic-disk glass substrate of the present invention includes edge surface processing for processing the edge
25 surface of the glass substrate. This edge surface processing includes the following first processing and second processing, which is performed as a preceding step of the first processing.

[0019]

In the first processing, magnetic field lines are formed using a magnetism generating means, a magnetic slurry containing a magnetic material and polishing abrasive particles is held with the magnetic field lines to form a mass of the magnetic slurry, and the edge surface of the glass substrate is
5 processed in a state in which the edge surface is in contact with the mass of the magnetic slurry.

The second processing is performed before the first processing, and in the second processing, a grindstone having a groove shape that is formed so as to be capable of simultaneously processing both a side wall surface of the edge
10 surface of the glass substrate and a chamfered surface between the main surface of the glass substrate and the side wall surface is used to perform processing in a state in which the glass substrate is inclined with respect to the groove direction of the groove shape formed in the grindstone.

[0020]

15 Details of the first processing and the second processing will be specifically described later. It should be noted that the second processing may also be referred to as "inclined grinding" or "inclined grinding processing" for the sake of convenience in the description. In addition, the first processing may also be referred to as "MRF processing" or "MRF processing treatment". Here,
20 MRF is an abbreviation for "magnetorheological fluid".

In the present invention, the shape processing (edge surface grinding and chamfering) step and the edge surface polishing step can be performed by the edge surface processing including the first processing and the second processing, which is performed as preprocessing of the first processing before
25 the first processing. Conventionally, the shape processing step was performed by grinding using a formed grindstone, and the edge surface polishing step was performed by subsequent brushing.

It should be noted that the edge surface processing in the present

invention is processing for chamfering the edge surface of the substrate and elaborating the edge surface of the substrate including the chamfered surface and the side wall surface into the desired edge surface shape (processing for achieving high shape accuracy).

5 [0021]

An embodiment of the edge surface processing of the present invention includes performing the above-described shape processing step using the inclined grinding (second processing) as preprocessing of the first processing and subsequently performing the above-described edge surface polishing step using the MRF processing (first processing). With such an embodiment, the variation in the finished angle of the edge (see portion A in FIG. 6) between a chamfered surface 12b and a side wall surface 12a of the edge surface of a glass substrate 1 is reduced, thus making it possible to finish the edge surface into a high-quality edge surface that has no marks such as polishing marks.

15 [0022]

Although the MRF processing enables high-quality polishing, in the case where processing using a conventional formed grindstone (in which the substrate is not inclined with respect to the groove direction of the grindstone) is performed as pretreatment (preprocessing), the ground surface has high roughness. Therefore, the machining allowance becomes large (about 50 μm , which is similar to the machining allowance when conventional brushing is performed) in order to obtain a surface having low roughness using the MRF processing, and the shape of the edge surface greatly differs from the shape elaborated using the formed grindstone, that is, the edge becomes largely rounded, for example. Accordingly, when the edge surface of the substrate is finished into a semi-mirror surface state, which is difficult to achieve using the conventional processing using a formed grindstone (in which the substrate is not inclined with respect to the groove direction of the grindstone), before the MRF

processing is performed, it is possible to prevent the deterioration of shape accuracy due to the rounded edge and to improve mass productivity. With the edge surface processing of the present invention, it is possible to finish the edge surface of the substrate into a semi-mirror surface state before the MRF

5 processing is performed.

It should be noted that in the conventional processing using a formed grindstone in which the substrate is not inclined with respect to the groove direction of the grindstone, the locus of the grindstone abutting the edge surface is constant, and therefore, the substrate is easily damaged. Also, since the locus of the grindstone is constant, the grindstone is easily dulled or clogged, and therefore, the size of the abrasive particles used in the grindstone cannot be reduced. Due to these factors, in the conventional processing using a formed grindstone in which the substrate is not inclined with respect to the groove direction of the grindstone, it is difficult to finish the processed substrate into a semi-mirror surface.

[0023]

In this embodiment, processing machining allowance of the side wall surface of the edge surface of the substrate in the above-described inclined grinding is about 10 to 1000 μm . Moreover, it is preferable that the processed surface that has undergone the inclined grinding has a roughness of 1.5 μm or less in R_{max} , and that the processed surface that has undergone the MRF processing has a roughness of 0.5 μm or less in R_{max} .

It should be noted that R_{max} is calculated in accordance with JIS B0601:1982. In addition, the roughness measurement conditions of the present invention are as follows.

Measurement device: Laser microscope

Measurement region: 50 μm ×50 μm

[0024]

Moreover, another embodiment of the edge surface processing of the present invention includes performing processing for chamfering the edge surface of the glass substrate using a grindstone such as a formed grindstone. That is, the above-described shape processing step is performed using the
5 chamfering processing on the edge surface with a grindstone such as a formed grindstone and the subsequent inclined grinding, and then an edge surface polishing step is performed using the MRF processing.

With such an embodiment, it is possible to reduce the load on the inclined grinding and to use smaller abrasive particles in the inclined grinding,
10 and therefore, the edge surface of the substrate is likely to be finished into a semi-mirror surface, thus making it possible to reduce the machining allowance in the subsequent MRF processing. As a result, it is possible to further improve the finished shape accuracy. Specifically, variation in the finished angle of the edge (see portion A in FIG. 6) between the chamfered surface 12b and the side
15 wall surface 12a of the edge surface of the glass substrate 1 is reduced, and in addition, variation in the finished angle of the edge (see portion B in FIG. 6) between a main surface 11 and the chamfered surface 12b of the glass substrate 1 is reduced, thus making it possible to finish the edge surface into a higher-quality edge surface that has no marks such as polishing marks (when
20 observed using a microscope).

It should be noted that in the case where the processing using a formed grindstone is performed before the inclined grinding, it is preferable to perform the processing using a formed grindstone such that the substrate is not inclined with respect to the groove direction of the grindstone. Alternatively, the
25 processing using a formed grindstone may be performed such that the substrate is inclined at an angle different by 2 degrees or more from the inclination angle in the inclined grinding. By doing this, the loci of the grindstones in the processing using a formed grindstone and the inclined grinding become different from each

other, and therefore, marks due to the two pieces of processing cancel out each other, thus making it possible to further improve the quality of the edge surface and to improve production efficiency. In the case where the difference in the inclinations is smaller than 2 degrees, the above canceling out effect becomes
5 small, and the quality of the edge surface may not be improved. It should be noted that the inclination angle may be substantially changed by rotating the substrate and the grindstone in the opposite directions.

In this embodiment, it is preferable that the processed surface that has undergone the inclined grinding has a roughness of about $1.5\text{ }\mu\text{m}$ or less in
10 R_{max} , and that the processed surface that has undergone the MRF processing has a roughness of about $0.5\text{ }\mu\text{m}$ or less in R_{max} .

It should be noted that a known method can be used in the processing using a formed grindstone in which the substrate is not inclined with respect to the groove direction of the grindstone. It is preferable to use a grindstone
15 including 100# to 1000# diamond abrasive particles.

[0025]

It should be noted that the present invention is undoubtedly not limited to the above-described embodiment. For example, the above-described inclined grinding can also be applied to the edge surface polishing by changing the
20 processing conditions for grinding.

[0026]

FIGS. 1(A) and 1(B) show an entire magnetic-disk glass substrate 1 to which the present invention is applied. FIG. 1(A) is a side view in which a portion thereof is shown in cross-section, and FIG. 1(B) is a plan view. The
25 glass substrate 1 has a circular hole in the central portion and is formed into a disk shape as a whole. The glass substrate 1 has main surfaces 11 on both the front and back sides, and an outer circumferential side edge surface 12 and an inner circumferential side edge surface 13 that are formed between the main

surfaces 11.

The outer circumferential side edge surface 12 of the glass substrate 1 is formed into a shape including a side wall surface 12a that is orthogonal to the main surfaces 11, and two chamfered surfaces (surfaces that is chamfered) 12b
 5 that are respectively formed between the side wall surface 12a and both the front and back main surfaces 11. Also, the inner circumferential side edge surface 13 of the glass substrate 1 is formed into a shape including a side wall surface 13a that is orthogonal to the main surfaces 11, and two chamfered surfaces (surfaces that is chamfered) 13b that are respectively formed between
 10 the side wall surface 13a and both the front and back main surfaces 11.

In the case of a magnetic disk, e.g., a 2.5-inch disk, the glass substrate 1 is finished so as to have an outer diameter of 65 mm and an inner diameter of 20 mm. Here, the inner diameter refers to as the inner diameter of the circular hole in the central portion of the glass substrate 1.

15 [0027]

Moreover, the main surfaces 11, the outer circumferential side edge surface 12, and the inner circumferential side edge surface 13 are polished (mirror-polished) and finished so as to have a predetermined surface roughness. Both the outer circumferential side edge surface 12 and the inner circumferential
 20 side edge surface 13 are generally required to be finished into an edge surface having a shape as described above, and into a mirror surface state in which the surface roughness is 1 μm or less in R_{max} and 0.1 μm or less in R_a .

[0028]

As described above, the magnetic-disk glass substrate 1 is
 25 manufactured by successively performing the above-described steps on a glass substrate (glass disk) 10 that is shaped into a disk shape by direct pressing, for example.

Here, the inclined grinding (second processing) performed as

preprocessing of the above-described MRF processing (first processing) will be described in detail.

FIGS. 2(A) and 2(B) show an embodiment of the second processing (inclined grinding) of the present invention. FIG. 2(A) is a cross-sectional side view showing a state in which an outer circumferential side edge surface of a magnetic-disk glass substrate is processed using a grindstone, and FIG. 2(B) is a plan view (it should be noted that the grindstone is shown by a cross-sectional plan view taken along line II-II in FIG. 2(A)). As described above, in the present invention, the second processing is applied to the shape processing step, and can also be applied to the edge surface polishing step. Here, the case where the second processing is applied to the shape processing step is mainly described.

[0029]

A grindstone 2 used to grind the outer circumferential side edge surface of the above-described glass substrate 10 is formed in a cylindrical shape as a whole and has a shape of a groove 3 on the inner circumferential side. The groove 3 is formed so as to be capable of simultaneously grinding both the side wall surface of the outer circumferential side edge surface of the glass substrate 10 and the chamfered surface between the main surface and the side wall surface of the glass substrate. Specifically, the groove 3 has a groove shape including a side wall portion (side wall surface grinding portion) 3a and chamfering portions (chamfered surface grinding portions) 3b that are located on both sides of the side wall portion 3a. The side wall portion 3a and the chamfering portions 3b of the groove 3 are formed so as to have predetermined dimensions and shapes in consideration of the finishing target dimensions and shapes of the ground surfaces of the glass substrate 10.

[0030]

In this embodiment, the grinding is performed in a state in which the

glass substrate 10 is inclined with respect to the groove direction of the shape of the groove 3 formed on the inner circumferential side of the grindstone 2.

This will be described with reference to FIG. 2. The glass substrate 10 has a rotation axis L_{10} passing through the center O_{10} thereof, and the
 5 grindstone 2 has a rotation axis L_2 passing through the center O_2 thereof. The grinding is performed by rotating both the glass substrate 10 and the grindstone 2 while bringing the outer circumferential side edge surface 12 of the glass substrate 10 into contact with the inner circumferential side of the grindstone 2 in a state in which the glass substrate 10 is inclined with respect to the groove
 10 direction of the shape of the groove 3 formed on the inner circumferential side of the grindstone 2, that is, in a state in which the rotation axis L_{10} of the glass substrate 10 is inclined by an angle α with respect to the rotation axis L_2 of the grindstone 2.

[0031]

15 By performing the grinding in a state in which the glass substrate 10 is inclined by a predetermined angle α , for example, with respect to the groove direction of the shape of the groove 3 formed on the inner circumferential side of the grindstone 2 in this manner, the locus of the grindstone 2 abutting against the edge surface of the glass substrate 10 is not constant and the projecting
 20 portions (abrasive particles) of the grindstone 2 abut against and act on the random positions of the edge surface of the substrate, thus making it possible to reduce damage to the substrate and to finish the ground surface into a smoother surface. Furthermore, vectors of grinding force applied to the abrasive particles, which serve as cutting blades, are distributed, and therefore, the damage can be
 25 reduced while the sharpness is maintained. Therefore, the effect of improving the life of the grindstone is obtained. When the life of the grindstone is improved, changes in the grinding over time are reduced, and therefore, shape accuracy is also improved.

Although the above-described inclination angle α of the glass substrate 10 with respect to the groove direction of the grindstone on the inner circumferential side can be set arbitrarily, it is preferable that the inclination angle α is in a range of 2 to 15 degrees, for example, in order to more favorably exhibit the operations and effects described above. It is more preferable to set the inclination angle α to 10 degrees or less.

[0032]

It should be noted that in this embodiment, the edge surface of the glass substrate is ground by bringing the outer circumferential side edge surface 12 of the glass substrate 10 into contact with the inner circumferential side of the grindstone 2, and therefore, the size of the cylinder of the grindstone 2 need only be determined as appropriate in consideration of the outer diameter, for example, of the glass substrate.

[0033]

Although the edge surface of the glass substrate is ground by bringing the outer circumferential side edge surface 12 of the glass substrate 10 into contact with the inner circumferential side of the grindstone 2 and by moving the glass substrate 10 and the grindstone 2 relative to each other, it is advantageous to perform the grinding by bringing the outer circumferential side edge surface 12 of the glass substrate 10 into contact with the inner circumferential side of the grindstone 2 and by rotating both the glass substrate 10 and the grindstone 2, in order to improve mass productivity, for example.

[0034]

Although, in this case, the circumferential speeds (speeds in a tangential direction) of the grindstone 2 and the glass substrate 10 at a processing point need not be particularly limited, it is preferable that the circumferential speed of the grindstone 2 (referred to as "A") is 1000 to 3000 m/minute and the circumferential speed of the glass substrate 10 (referred to as "B") is about 5 to

30 m/minute, for example, from the viewpoint of grindability and processing efficiency. Accordingly, in the present invention, a ratio A/B of the circumferential speed of the grindstone 2 with respect to the circumferential speed of the glass substrate 10 is preferably 80 or more, and more preferably in
5 a range of 100 to 300.

It should be noted that the grindstone 2 and the glass substrate 10 may be rotated in the down-cutting direction or the up-cutting direction.

[0035]

A resin grindstone including abrasive particles and a resin can be used
10 as the grindstone 2 used in the present invention. It is preferable to use a resin grindstone containing diamond abrasive particles as the grindstone in order to chamfer the edge surface of the magnetic-disk glass substrate. In addition, a metal grindstone including abrasive particles and a binding material made of metal, a vitrified grindstone including abrasive particles and a binding material
15 made of glass, and a composite grindstone in which those binding materials are mixed can also be used. In particular, as the resin grindstone, a grindstone can be used that is obtained by binding diamond abrasive particles using a phenol resin, an epoxy resin, a polyethylene resin, a polystyrene resin, a polyimide resin, or the like while adding an appropriate filler as needed and by molding them into
20 a predetermined shape. Alumina abrasive particles, cubic boron nitride abrasive particles or the like can also be used. It is preferable to use abrasive particles having a grit of 2000# to 3000# or even smaller abrasive particles than these. In the present invention, also in the case where a grindstone with minute abrasive particles that is advantageous from the viewpoint of improvement of
25 quality of a processed surface, it is possible to maintain the sharpness of the grindstone, to secure stable grindability, and to stably obtain favorable quality of the ground surface (mirror surface quality) and favorable accuracy of dimensions and shapes.

[0036]

It should be noted that as described above, it is preferable to form a grindstone by binding diamond abrasive particles with a resin bond in the inclined grinding, and furthermore, it was found that it is particularly important to control the bond strength between the abrasive particles and the resin in that case. It was found that this bond strength greatly affects the grindability (processability) and surface quality in the inclined grinding.

Here, the index is represented as a "grindstone elastic modulus".

A preferable range of the grindstone elastic modulus is 1500 to 3500 [N/mm]. This parameter is like a spring constant, and when the grindstone elastic modulus is large, the grindability is favorable and the dimension accuracy is improved, but blemishes are likely to occur. On the other hand, when the grindstone elastic modulus is small, the surface quality is improved, but the grinding rate decreases.

By changing this grindstone elastic modulus, it is possible to control whether the shape accuracy or the surface quality is prioritized in the inclined grinding. That is, in the case where the grindstone elastic modulus is increased, it is advantageous for the shape accuracy and the processing rate. On the other hand, in the case where the grindstone elastic modulus is reduced, it is advantageous for the surface quality.

It should be noted that the grindstone elastic modulus can be evaluated using an HRF indenter with a load of 15 kgf in a flexural strength measurement test machine.

[0037]

Since a glass material has processing properties of being likely to be affected by heat generated in the grinding, it is desirable that a cooling effect of a grinding liquid (coolant) supplied to the edge surface portion of the glass substrate is enhanced to reduce the influences of heat generated in the grinding

as much as possible in order to enable stable grinding. Although there is no particular limitation on the grinding liquid (coolant) used in the present invention, it is particularly preferable to use a water-soluble grinding liquid that exhibits a high cooling effect and has high safety in a production site. It should be noted
5 that when a groove is formed on the inner side of a cylindrical grindstone and a coolant is supplied thereto as in the present invention, the ability to hold the coolant is enhanced, and the grindstone is unlikely to be dulled or clogged.

[0038]

As described above, the inclined grinding can also be applied to an edge
10 surface mirror-polishing step. In this case, the inclined grinding can be performed in the same manner as in the above-described grinding, except that the grindstone elastic modulus of a resin bond grindstone, the type of grindstone and grinding liquid, the ratio of the circumferential speed of the grindstone with respect to the circumferential speed of the glass substrate are different from
15 those in the above-described grinding.

In the case where the grindstone elastic modulus of a resin bond grindstone is changed, the grindstone elastic modulus of 1500 to 2500 [N/mm] is preferable when the edge surface of the substrate is mirror-polished using the inclined grinding because the mirror surface quality is improved. Moreover, the
20 grindstone elastic modulus of 2500 to 3500 [N/mm] is preferable when the grinding is performed using the inclined grinding because the shape accuracy and grindability are improved.

[0039]

On the other hand, also in the grinding performed on the inner
25 circumferential side edge surface 13 of the glass substrate 10, it is preferable that the grinding is performed in a state in which the glass substrate 10 is inclined with respect to the groove direction of a shape of a groove 5 formed in a grindstone 4 as shown in FIG. 3.

FIG. 3(A) is a cross-sectional side view showing a state in which the inner circumferential side edge surface of the magnetic-disk substrate is ground using a grindstone, and FIG. 3(B) is a cross-sectional plan view of the grindstone (cross-sectional plan view taken along line III-III in FIG. 3(A)).

5 [0040]

The grindstone 4 used to grind the inner circumferential side edge surface of the glass substrate 10 has a shape of the groove 5. The groove 5 is formed so as to be capable of simultaneously grinding both the side wall surface of the inner circumferential side edge surface of the glass substrate 10 and the
10 chamfered surface between the main surface of the glass substrate and the side wall surface. Specifically, the groove 5 has a groove shape including a side wall portion (side wall surface grinding portion) 5a and chamfering portions (chamfered surface grinding portions) 5b that are located on both sides of the side wall portion 5a.

15 [0041]

This will be described with reference to FIG. 3. The grinding is performed by rotating both the glass substrate 10 and the grindstone 4 while bringing the grindstone 4 into contact with the inner circumferential side edge surface 13 of the glass substrate 10 in a state in which the glass substrate 10 is
20 inclined with respect to the groove direction of the shape of the groove 5 formed on the grindstone 4, that is, in a state in which the rotation axis L_{10} of the glass substrate 10 is inclined by an angle β with respect to the rotation axis L_4 of the grindstone 4.

[0042]

25 By performing the grinding in a state in which the glass substrate 10 is inclined by a predetermined angle β , for example, with respect to the groove direction of the shape of the groove 5 of the grindstone 4 in this manner, it is possible to reduce damage to the substrate and to finish the ground surface into

a smoother surface as in the above-described grinding performed on the outer circumferential side edge surface of the glass substrate. Furthermore, the effect of improving the life of the grindstone is also obtained.

[0043]

5 Although the above-described inclination angle β of the glass substrate 10 with respect to the groove direction of the grindstone 4 can be set arbitrarily, it is preferable that the inclination angle β is in a range of 2 to 15 degrees, for example, as in the above-described grinding performed on the outer circumferential side edge surface in order to more favorably exhibit the
10 operations and effects described above. It is more preferable to set the inclination angle β to 10 degrees or less.

It should be noted that the type of grindstone 4 and grinding liquid used to grind the inner circumferential side edge surface need only be the same as those used to grind the above-described outer circumferential side edge surface.

15 In addition, the circumferential speeds of the grindstone 4 and the glass substrate 10, and a circumferential speed ratio need only be set as appropriate so as to be preferable for the grinding performed on the inner circumferential side edge surface.

[0044]

20 Next, the above-described MRF processing treatment, which is performed subsequently to the inclined grinding processing, will be described in detail.

FIGS. 4(a) to 4(c) are diagrams illustrating the first processing (MRF processing) of the present invention, and FIG. 5 is a perspective view illustrating
25 a state in which the first processing of the present invention is performed.

A device 20 used in the MRF processing of the present invention polishes the edge surface of the glass substrate using a magnetism generating means and a magnetic slurry. FIGS. 4(a) to 4(c) and FIG. 5 show a case where

the outer circumferential side edge surface of the glass substrate is polished.

An outline of the device 20 will be described. As shown in FIG. 4(a), the device 20 includes a pair of magnets 21 and 22, which are permanent magnets, a spacer 23, and an exterior member 24 that has a hollow columnar shape and is made of a non-magnetic material such as stainless steel. The magnets 21 and 22 and the spacer 23 are incorporated into the exterior member 24.

It should be noted that in the case where a contact amount between the magnetic slurry and the glass substrate is increased in order to adjust the processing rate and the like, the edge portion of the glass substrate can be inserted between the magnets 21 and 22 to be processed. In this case, the exterior member 24 is not provided.

[0045]

The glass substrate 10 that has undergone the inclined grinding processing is horizontally held by a holder (not shown). The glass substrate 10 held by the holder is brought close to the exterior member 24, and furthermore, a mass 26 of the magnetic slurry (see FIG. 4(c) and FIG. 5), which will be described later, and the outer circumferential side edge surface of the glass substrate 10 are brought into contact with each other. The exterior member 24 of the device 20 and a holder (not shown) for holding the glass substrate 10 are connected to a driving motor (not shown). By rotating the exterior member 24 and the holder to move the outer circumferential side edge surface of the glass substrate 10 and the mass 26 of the magnetic slurry relative to each other, it is possible to polish the outer circumferential side edge surface of the glass substrate 10. For example, the exterior member 24 and the holder for holding the glass substrate 10 are rotated in opposite directions (see FIG. 5) preferably at a relative circumferential speed between the exterior member 24 and the glass substrate 10 of 40 to 100 m/minute. It should be noted that one of the

glass substrate 10 and the mass 26 of the magnetic slurry may be fixed and the other may be rotated, or both the glass substrate 10 and the mass 26 of the magnetic slurry may be rotated in the same direction, as long as the outer circumferential side edge surface of the glass substrate 10 and the mass 26 of the magnetic slurry can be moved relative to each other.

[0046]

The MRF processing will be described more specifically. The pair of the magnet 21 and the magnet 22 are close to each other, serves as a magnetism generating means, and thus forms magnetic field lines 25 as shown in FIG. 4(b). The magnetic field lines 25 extend so as to project outward from the center between the magnets 21 and 22, and extend in the thickness direction of the glass substrate 10. In the example shown in FIG. 4(b), a pair of magnets that are disposed in a separated state in the thickness direction of the glass substrate 10 such that the surface on the N-pole side and the surface on the S-pole side are opposed to each other is used as the magnetism generating means. The spacer 23 made of a non-magnetic material is provided between the magnets 21 and 22 such that the distance between the end surface on the N-pole side of the magnet 21 and the end surface on the S-pole side of the magnet 22 is set to a distance determined in advance. The distance between the end surface on the N-pole side of the magnet 21 and the end surface on the S-pole side of the magnet 22 is set to a distance determined in advance, in order to form the mass 26 of the magnetic slurry as shown in FIG. 4(c) around the outer circumference of the exterior member 24 by causing the magnetic field lines 25 to project outward as shown in FIG. 4(b). It should be noted that as described above, a mass of the magnetic slurry may be formed between the magnets 21 and 22 and the edge portion of the glass substrate may be brought into contact with the mass without the exterior member 24. Since the mass 26 of the magnetic slurry is a portion that comes into contact with the outer

circumferential side edge surface of the glass substrate 10 and that moves relative to the edge surface, the magnetic force desirably has a certain degree of strength from the viewpoint of ensuring the rigidity of the mass 26 of the magnetic slurry. Therefore, it is preferable that the distance between the end surface on the N-pole side of the magnet 21 and the end surface on the S-pole side of the magnet 22 is short. However, in the case where the distance is excessively short, it is difficult to insert the glass substrate between the magnets. Therefore, it is preferable that the distance between the end surface on the N-pole side of the magnet 21 and the end surface on the S-pole side of the magnet 22 is determined to be in a predetermined certain range.

[0047]

It should be noted that although permanent magnets are used as a magnetism generating means in the example shown in FIGS. 4(a) to 4(c) and FIG. 5, electromagnets can also be used, for example. Moreover, although the spacer 23 is used in order to ensure a constant distance between the end surface on the N-pole side of the magnet 21 and the end surface on the S-pole side of the magnet 22, the magnets 21 and 22 can be fixed to the exterior member 24 to ensure the constant distance between the end surface on the N-pole side of the magnet 21 and the end surface on the S-pole side of the magnet 22 without the spacer 23.

It should be noted that in the case where the inner circumferential side of the glass substrate is polished, the inner circumferential side can be polished in the same manner as the outer circumferential side by reducing the sizes of the above-described magnets and exterior member and inserting them into the circular hole. The polishing conditions may be the same as those for the outer circumferential side.

[0048]

In the MRF processing, the magnetic material is held with the magnetic

field lines, and the surface of the substrate is processed by the magnetic material by pressing the glass substrate against the magnetic material. It should be noted that the magnetic material may include non-magnetic polishing abrasive particles. In this case, the polishing rate and polishing quality can be improved by the polishing abrasive particles attached to the magnetic material. A magnetic fluid and a magnetorheological fluid that contain microparticles of the magnetic material, for example, can be used as the magnetic material.

A fluid containing non-polar oil or polar oil that contains microparticles of the magnetic material including a Fe (iron) component having a particle diameter of 0.1 to 10 μm in an amount of 3 to 5 g/cm^3 and a surfactant, for example, is used as the magnetorheological fluid of the magnetic slurry used in the edge surface polishing. Non-polar oil or polar oil has a viscosity of 100 to 1000 (mPa·second) at room temperature (20°C), for example.

[0049]

It is preferable that the mass 26, which is made from the magnetic slurry, contains the polishing abrasive particles as well as particles of the magnetic material when the mass is made from the magnetorheological fluid containing microparticles of the magnetic material on the magnetic field lines. The polishing abrasive particles in the magnetorheological fluid are pushed out to a portion in which magnetic force gradient is low by a magnetic levitation effect, and are thus present more toward the vicinity of the edge surface of the glass substrate that is to be polished. In addition, the mass having relatively high elastic properties is formed by the magnetic field lines, and therefore, it is possible to efficiently perform polishing by pressing the edge surface of the glass substrate against the mass 26. That is, the processing rate can be increased, and the polishing can thus be performed efficiently.

[0050]

Known glass substrate polishing abrasive particles such as cerium oxide,

colloidal silica, zirconia oxide, alumina abrasive particles, or diamond abrasive particles can be used as the polishing abrasive particles contained in the magnetic slurry. The polishing abrasive particles have a particle diameter of 0.5 to 3 μm , for example. Using the polishing abrasive particles having a

5 particle diameter in this range makes it possible to favorably polish the edge surface of the glass substrate. The polishing abrasive particles are contained in the magnetic slurry in an amount of 3 to 15 vol%, for example.

[0051]

It is preferable that the concentration of the magnetorheological fluid is

10 adjusted such that the magnetic slurry has a viscosity of 1000 to 2000 [mPa·second] at room temperature (20°C) because this allows the mass 26 of the magnetic slurry to be formed and edge surface polishing to be efficiently performed. If the viscosity is low (the concentration of the magnetorheological fluid is low), the mass 26 is not readily formed, and it may be difficult to perform

15 polishing by moving the mass 26 and the edge surface of the glass substrate 10 relative to each other in a state in which the mass 26 is pressed against the edge surface. On the other hand, in the case where the magnetic slurry has an excessively high viscosity, force is weak that restores the mass 26 from a state in which the mass 26 is recessed in line with the shape of the edge portion of the

20 glass substrate 10 to a state in which the mass 26 is in line with the original magnetic field lines during polishing, and it may be difficult to form a uniformly pressed state. Moreover, it is preferable that the magnetic flux density in the magnetism generating means is 0.3 to 0.8 [tesla] because this allows the mass 26 of the magnetic slurry to be formed and the edge surface polishing to be

25 efficiently performed. Furthermore, the yield stress of the magnetic slurry containing the magnetorheological fluid and the polishing abrasive particles is preferably 30 kPa or more in a state in which the magnetic field of 0.4 [tesla] is applied, and more preferably 30 to 60 kPa.

[0052]

The yield stress (yield shearing stress) of the magnetorheological fluid can be determined by the following method, for example. The relationship between the shearing speed and the shearing stress of the magnetorheological fluid is determined using a device obtained by incorporating a magnetic field applying means (e.g., permanent magnets or electromagnets) that can apply a magnetic field of 0.4 [tesla] in a rotational viscometer, and the determined relationship between the shearing speed and the shearing stress is approximated using the known Casson's equation, thus making it possible to determine the yield stress of the magnetorheological fluid.

[0053]

The above-described yield stress affects the pressure that is applied to the glass substrate from the magnetic slurry, that is, shearing stress when the magnetic slurry held with the magnetic field and the edge portion of the glass substrate are moved relative to each other. Accordingly, the higher the yield stress of the magnetic slurry is (the higher the shearing stress when the magnetic slurry flows is), the more efficiently polishing by the contact between the polishing abrasive particles and the glass substrate is performed, thus making it possible to increase the processing rate.

[0054]

By performing the first processing using the MRF processing described above on the edge surface of the substrate, it is possible to particularly process a portion that is difficult to process by conventional edge surface brushing from the back side of the chamfered surface of the edge surface of the substrate to the side wall surface with a constant pressure, thus making it possible to mirror-polish the edge surface without disturbing the shape of the edge portion. When using a brush, a bending amount (winding amount) of a hair material varies depending on a position of the substrate with which the brush comes into

contact, and therefore, the edge surface cannot be processed with a constant pressure. Also, when using a brush, as the frequency of processing increases, a hair material tends to remain bent or curved, and therefore, there is a problem in that the pressure changes over time. Therefore, during mass production, the
 5 shape of the edge surface is likely to vary widely.

On the other hand, in the MRF processing, the magnetic field lines are used instead of a brush, and therefore, it is possible to process the portion from the back side of the chamfered surface to the side wall surface with a constant pressure. Moreover, the pressure does not change over time. The
 10 processing machining allowance of the MRF processing is 50 μm or less, for example, and preferably about 1 to 7 μm . Furthermore, it is more preferable that the machining allowance is set to 5 μm or less because the shape accuracy is further improved.

[0055]

15 Although the polishing performed on the outer circumferential side edge surface of the glass substrate 10 has been described, the inner circumferential side edge surface of the glass substrate 10 can be polished by the same method. That is, the above-described exterior member 24 is inserted into the circular hole in the central portion of the glass substrate 10 and the mass 26 of the magnetic
 20 slurry is brought into contact with the inner circumferential side edge surface of the glass substrate 10, thus making it possible to also polish the inner circumferential side edge surface.

Moreover, by disposing a plurality of magnets in a state in which the magnets are separated from each other in the vertical direction, forming a mass
 25 of the magnetic slurry between these magnets, and bringing the edge portions of a plurality of glass substrates into contact with a plurality of masses of the magnetic slurry in a state in which the glass substrates are stacked, the edge surfaces of the stacked glass substrates can be processed simultaneously.

[0056]

In the present invention, by performing the edge surface processing using the first processing (MRF processing) described above and the second processing (inclined grinding), which is performed as preprocessing of the first processing, in combination, it is possible to achieve a more highly accurate shape and higher-quality surface of the edge surface of the substrate than those obtained by a conventional method.

Moreover, even when the thickness of the glass substrate to be introduced into the edge surface processing is small, e.g., 0.5 mm or less, the edge surface quality can be secured at the same level as that of a thick plate (e.g., 0.635 mm or more), and therefore, the edge surface processing of the present invention using the first processing and the second processing in combination is particularly preferable for processing performed on the edge surface of a thin plate.

[0057]

In the present invention, it is preferable that the (type of) glass constituting the glass substrate is amorphous aluminosilicate glass.

Mirror-polishing the surface of such a glass substrate can yield a smooth mirror-finished surface, and the post-processing strength is favorable. A

preferable example of such aluminosilicate glass is glass that contains SiO_2 as a main component and Al_2O_3 in an amount of 20 wt% or less. Furthermore, glass that contains SiO_2 as a main component and Al_2O_3 in an amount of 15 wt% or less is more preferable. Specifically, it is possible to use phosphorus oxide-free amorphous aluminosilicate glass that contains as main components SiO_2 in an amount of 62 wt% or more to 75 wt% or less, Al_2O_3 in an amount of 5 wt% or more to 15 wt% or less, Li_2O in an amount of 4 wt% or more to 10 wt% or less, Na_2O in an amount of 4 wt% or more to 12 wt% or less, and ZrO_2 in an amount of 5.5 wt% or more to 15 wt% or less, and has an $\text{Na}_2\text{O}/\text{ZrO}_2$ weight ratio of 0.5

or more to 2.0 or less and an $\text{Al}_2\text{O}_3/\text{ZrO}_2$ weight ratio of 0.4 or more to 2.5 or less.

[0058]

As heat resistant glass, it is preferable to use, for example, glass that
 5 contains SiO_2 in an amount of 50 to 75 mol%, Al_2O_3 in an amount of 0 to 5 mol%,
 BaO in an amount of 0 to 2 mol%, Li_2O in an amount of 0 to 3 mol%, ZnO in an
 amount of 0 to 5 mol%; Na_2O and K_2O in a total amount of 3 to 15 mol%, MgO ,
 CaO , SrO and BaO in a total amount of 14 to 35 mol%, and ZrO_2 , TiO_2 , La_2O_3 ,
 Y_2O_3 , Yb_2O_3 , Ta_2O_5 , Nb_2O_5 and HfO_2 in a total amount of 2 to 9 mol%, and that
 10 has a molar ratio $[(\text{MgO}+\text{CaO})/(\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO})]$ in a range of 0.85 to 1
 and a molar ratio $[\text{Al}_2\text{O}_3/(\text{MgO}+\text{CaO})]$ in a range of 0 to 0.30.

The glass may also contain SiO_2 in an amount of 56 to 75 mol%, Al_2O_3 in
 an amount of 1 to 9 mol%, alkali metal oxide(s) selected from the group
 consisting of Li_2O , Na_2O , and K_2O in a total amount of 6 to 15 mol%, alkaline
 15 earth metal oxide(s) selected from the group consisting of MgO , CaO , and SrO
 in a total amount of 10 to 30 mol%, and oxide(s) selected from the group
 consisting of ZrO_2 , TiO_2 , Y_2O_3 , La_2O_3 , Gd_2O_3 , Nb_2O_5 , and Ta_2O_5 in a total
 amount of more than 0 and 10 mol% or less.

In the present invention, it is preferable that the Al_2O_3 content in the
 20 glass composition is 15 wt% or less. Furthermore, it is more preferable that the
 Al_2O_3 content is 5 mol% or less.

Moreover, the present invention is particularly preferable for processing
 performed on the edge surface of a glass substrate made of crystallized glass.
 Since crystallized glass is harder than amorphous glass, it tends to take a longer
 25 time to polish the crystallized glass, and the shape is likely to fluctuate with a
 conventional polishing method using a brush. Crystallized glass has a
 structure in which a crystal portion and an amorphous portion are mixed, and the
 polishing rates of these portions are different. Therefore, when polishing is

performed for a long period of time, the amorphous portion is polished first, and thus the surface roughness is unlikely to be reduced. On the other hand, in the present invention, the inclined grinding is performed as preprocessing of the MRF processing, and therefore, it is possible to reduce the machining allowance
5 in the polishing using the MRF processing and to uniformly polish both the chamfered surface and the side wall surface, thus obtaining more favorable results than before.

[0059]

After finishing the edge surface processing of the present invention
10 including the above-described first processing and second processing, main surface grinding for improving the dimensional accuracy and shape accuracy is performed on this glass substrate. In this main surface grinding, a double-side grinding device is generally used to grind the main surfaces of the glass
15 substrate with hard abrasive particles such as diamond particles. By grinding the main surfaces of the glass substrate in this manner, the glass substrate is processed so as to have a predetermined thickness and flatness and to attain a predetermined surface roughness.

[0060]

After this main surface grinding, mirror-polishing is performed to obtain a
20 highly smooth main surface.

It is preferable to perform a mirror-polishing method on the glass substrate using a polishing pad with a polisher made of polyurethane or the like while supplying a slurry (polishing liquid) containing an abrasive that is made of a metal oxide such as cerium oxide or colloidal silica. A highly smooth glass
25 substrate can be obtained by polishing the glass substrate using a cerium oxide-based abrasive (first polishing) and final-polishing (mirror-polishing) the glass substrate using colloidal silica abrasive particles (second polishing), for example.

[0061]

In the present invention, the main surface of the glass substrate that has undergone the mirror-polishing is preferably a mirror surface having an arithmetic mean surface roughness R_a of 0.2 nm or less, and more preferably a
5 mirror surface having an arithmetic mean surface roughness R_a of 0.13 nm or less. It should be noted that R_a and R_{max} in the present invention both denote roughness that is calculated in accordance with Japanese Industrial Standards (JIS) B 0601.

From a practical viewpoint, the surface roughness (e.g., maximum
10 roughness R_{max} and arithmetic mean roughness R_a) in the present invention is preferably the surface roughness of a surface shape that is measured using an atomic force microscope (AFM).

[0062]

In the present invention, it is preferable to perform chemical
15 strengthening after the first polishing and before the second polishing. As a method for chemical strengthening, it is preferable to use a low-temperature ion-exchange method that performs ion exchange in a temperature range not exceeding the glass transition point, for example. The chemical strengthening is processing in which the glass substrate is brought into contact with a molten
20 chemical strengthening salt so that an alkali metal element having a relatively large atomic radius in the chemical strengthening salt and an alkali metal element having a relatively small atomic radius in the glass substrate are ion-exchanged, and thus the alkali metal element having a relatively large atomic radius permeates through the surface layer of the glass substrate, and
25 compressive stress is generated on the surface of the glass substrate. A glass substrate that has undergone the chemical strengthening has excellent impact resistance, and therefore, it is particularly preferable to mount the glass substrate in an HDD for mobile use, for example. An alkali metal nitrate such

as potassium nitrate or sodium nitrate can be preferably used as the chemical strengthening salt.

The magnetic-disk glass substrate according to the present invention is manufactured as described above.

5 [0063]

The present invention also provides a method for manufacturing a magnetic disk using the above-described magnetic-disk glass substrate. In the present invention, the magnetic disk is manufactured by forming at least a magnetic layer on the magnetic-disk glass substrate according to the present
10 invention. A hexagonal-system CoCrPt-based or CoPt-based ferromagnetic alloy with a large anisotropic magnetic field can be used as a material of the magnetic layer. It is preferable to form the magnetic layer on the glass substrate by a sputtering method such as a DC magnetron sputtering method. Interposing a base layer between the glass substrate and the magnetic layer
15 makes it possible to control the orientation direction and size of magnetic particles in the magnetic layer. For example, use of a cubic-system base layer made of Cr-based alloy or the like makes it possible to orient, for example, the direction of easy magnetization of the magnetic layer along the magnetic disk surface. In this case, the magnetic disk of a longitudinal magnetic recording
20 type is manufactured. In addition, for example, use of a hexagonal-system base layer containing Ru and Ti makes it possible to orient, for example, the direction of easy magnetization of the magnetic layer along the normal of the plane of the magnetic disk. In this case, the magnetic disk of a perpendicular magnetic recording type is manufactured. The base layer can be formed by a
25 sputtering method in the same manner as the magnetic layer.

[0064]

It is preferable to form a protective layer and a lubricant layer in this order on the magnetic layer. An amorphous hydrogenated carbon-based

protective layer is preferable as the protective layer. The protective layer can be formed by a plasma CVD method, for example. As the lubricant layer, a lubricant that has a functional group at the terminal of the main chain of a perfluoropolyether compound can be used. In particular, it is preferable that the lubricant contains, as a main component, a perfluoropolyether compound that has a hydroxyl group as a polar functional group at the terminal. The lubricant layer can be coated and formed by a dipping method.

The edge surface of the substrate is finished so as to have a highly accurate shape and high quality by using the glass substrate obtained according to the present invention, it is possible to provide a magnetic disk that can prevent impairment caused by the state of the edge surface of the substrate, such as anti-corrosion measures, that can achieve a higher recording density, and that is highly reliable.

Examples

[0065]

Hereinafter, the embodiment of the present invention will be described in detail by way of examples. It should be noted that the present invention is not limited to the following examples.

(Example 1)

A magnetic disk glass substrate of this example was manufactured through (1) a substrate preparation step, (2) a shape processing and an end surface polishing step, (3) a main surface grinding step, (4) a main surface polishing step (first polishing step), (5) a chemical strengthening step, and (6) a main surface polishing step (second polishing step) as described below.

[0066]

(1) Substrate preparation step

First, a disk-shaped glass substrate (glass disk) made of aluminosilicate

glass and having a diameter of 66 mm ϕ and a thickness of 1 mm was obtained from molten glass by direct pressing using upper, lower, and drum molds. It should be noted that in this case, a disk-shaped glass substrate may be obtained by using a grindstone to cut a glass sheet formed by a down draw

5 method or a float method other than using direct pressing. As the aluminosilicate glass, glass for chemical strengthening containing SiO₂ in an amount of 62 to 75 wt%, ZrO₂ in an amount of 5.5 to 15 wt%, Al₂O₃ in an amount of 5 to 15 wt%, Li₂O in an amount of 4 to 10 wt%, and Na₂O in an amount of 4 to 12 wt% was used.

10 [0067]

(2) Shape processing and end surface polishing step

Next, a diamond grindstone was used to make a hole in the central portion of the glass substrate, and predetermined chamfering was performed on the outer circumferential edge surface and the inner circumferential edge

15 surface.

In this example, the outer circumferential edge surface of the substrate was chamfered using a conventional formed grindstone without inclining the substrate. At this time, a grindstone containing 325# diamond particles was used. Then, the second processing (inclined grinding) of the present invention

20 was performed according to the above-described method shown in FIG. 2, and the outer circumferential edge surface of the substrate was ground. A grindstone obtained by binding 3000# diamond abrasive particles with a phenol resin and molding them into a predetermined cylindrical shape shown in FIG. 2 was used in the second processing. It should be noted that a predetermined

25 groove shape was formed on the inner circumferential side of this grindstone. Moreover, a water-soluble grinding liquid (at 20°C) was used as the grinding liquid.

Both the side wall surface and the chamfered surface of the outer

circumferential side edge surface of the glass substrate were ground by bringing the outer circumferential side edge surface of the glass substrate into contact with the inner circumferential side of the grindstone and rotating both the glass substrate and the grindstone while supplying the grinding liquid to the outer circumferential side edge surface portion of the glass substrate. It should be noted that the circumferential speed of the grindstone was 2000 m/minute and the circumferential speed of the glass substrate was 20 m/minute (as a result, a ratio of the circumferential speed of the grindstone with respect to the circumferential speed of the glass substrate was 100).

10 In this manner, the inclined grinding was performed for 30 seconds. At this time, the side wall surface and the chamfered surface of the outer circumferential side edge surface of the glass substrate both had a surface roughness of about 1.2 μm in R_{max} .

Moreover, the inner circumferential side edge surface of the substrate was chamfered using a predetermined formed grindstone in a conventional manner.

[0068]

Next, the outer circumferential side edge surface of the glass substrate was polished. In this embodiment, the edge surface polishing was performed by performing the first processing (MRF processing) of the present invention on the outer circumferential edge surface of the substrate according to the above-described method shown in FIGS. 4 and 5.

As shown in FIG. 4, a polishing device in which a cylindrical exterior member incorporated with two magnets was disposed was used. The incorporated magnets had a diameter of 216 mm and a thickness of 60 mm. Permanent magnets that both had a magnetic flux density of 6000 gauss were used. Moreover, these two magnets were fixed to the exterior member, and a predetermined distance was secured between the magnets. A magnetic slurry

was used that was obtained by dispersing cerium oxide having an average diameter of 2 μm at the concentration of 5 vol% in a magnetorheological fluid obtained by dispersing Fe (iron) microparticles having an average size of 2 μm at a density of 3 g/cm^3 in non-polar oil.

5 The magnetic slurry was supplied along the surface of the exterior member, and a mass of the magnetic slurry that protruded from the surface of the exterior member was formed. The rotation rate of the exterior member was adjusted as appropriate in a range of 20 to 2000 rpm, and the rotation rate of the glass substrate was set to 4000 rpm. The exterior member and the glass
10 substrate were rotated in the opposite directions as shown in FIG. 5. The processing time was set to about 3 minutes.

 In this manner, the outer circumferential edge surface was polished by the MRF processing. After the processing, the side wall surface and the chamfered surface of the outer circumferential edge surface of the substrate
15 both had a surface roughness of about 0.1 μm in R_{max} .
[0069]

 Moreover, the inner circumferential side of the glass substrate was polished using a conventional polishing brush. In this case, 6-6 nylon was used as a material of a brush hair of the polishing brush. The rotation rate of the
20 polishing brush was set to 1400 rpm, and the glass substrate was rotated at a rotation rate of 60 rpm in the direction opposite to that of the polishing brush. Moreover, cerium oxide was used as the abrasive, and the polishing liquid containing cerium oxide at about 30°C was supplied. In this manner, the inner circumferential side of the glass substrate was polished so as to have a surface
25 roughness of about 0.5 μm in R_{max} .

 Then, the surface of the glass substrate that had undergone the edge surface polishing was cleaned with water.

[0070]

One hundred glass substrates produced in the same manner were evaluated for variation (Max-Min) in the radius of curvature of the edge portion using an outline shape measurement machine as an evaluation of variation in the edge angle formed by the chamfered surface and the side wall surface of the outer circumferential edge surface of the substrate that had undergone the edge surface polishing. A variation among the one hundred substrates of 0.03 mm or less was evaluated as "Good". A variation of more than 0.03 mm and 0.05 mm or less was evaluated as "Fair". A variation of more than 0.05 mm was evaluated as "Poor". Table 1 shows the results.

In addition, the outer circumferential edge surface was observed using a microscope at a predetermined magnification. If marks and the like were not observed and the outer circumferential edge surface was finished into a mirror surface, the evaluation was "Excellent". If a few marks and the like were observed but there was no problem, the evaluation was "Good". If many marks or a large amount of undulation was observed, the evaluation was "Fair". If marks and the like were clearly observed, the evaluation was "Poor". Table 1 shows the results.

[0071]

(3) Main surface grinding step

This main surface grinding was performed using a double-side grinding device in which the glass substrate held by a carrier was set between the upper and lower surface plates to which diamond pads were attached. The diamond pads with diamond abrasive particles having an average particle diameter of about 2.5 μm were used. Moreover, the main surface grinding was performed while using a lubricant.

It should be noted that in the present invention, the average particle diameter of abrasive particles denotes a particle diameter at which a cumulative curve reaches 50% when the cumulative curve is determined by setting the total

volume of powder particles in the particle size distribution measured by a laser diffraction method to 100% (referred to as "cumulative average particle diameter (50% diameter)" hereinafter). In the present invention, specifically, the cumulative average particle diameter is a value obtained by measuring the particle diameter using a particle diameter/particle size distribution measurement device, for example.

[0072]

Specifically, the rotation rate of the surface plates was selected as appropriate in a range of 10 to 100 rpm, and a load applied to the glass substrate was set to 100 g/cm². Both surfaces of the glass substrates accommodated in the carrier were simultaneously ground by rotating a sun gear and an internal gear of the above-described lapping device.

Ultrasonic cleaning was performed on the glass substrate that had undergone the above-described grinding while the glass substrate was sequentially immersed in respective cleaning baths (to which ultrasonic waves were applied) of a neutral detergent and water.

[0073]

(4) Main surface polishing step (first polishing step)

Next, a first polishing step to remove blemishes and distortion remaining after the above-described main surface grinding was performed using a double-side polishing device. In the double-side polishing device, a glass substrate that is held by a carrier is tightly placed between the upper and lower surface plates to which polishing pads have been attached, the carrier is engaged with the sun gear and the internal gear, and the glass substrate is pressed between the upper and lower surface plates. Then, a polishing liquid is supplied between the polishing pads and the glass substrate surfaces to be polished, the upper and lower surface plates are rotated, and thus the glass substrate revolves while rotating on the surface plates so that both main

surfaces of the glass substrate are polished simultaneously. Specifically, the first polishing step was performed using a hard polisher (hard urethane foam) as a polisher. Water in which cerium oxide was dispersed as an abrasive was used as a polishing liquid, and the first polishing step was performed with a load of 100 g/cm². The glass substrate that had undergone the first polishing step was cleaned and dried.

[0074]

(5) Chemical strengthening step

Next, chemical strengthening was performed on the glass substrate that had undergone the above-described cleaning. Chemical strengthening was performed by preparing a chemical strengthening liquid obtained by mixing and melting potassium nitrate and sodium nitrate, and immersing the glass substrate in the chemical strengthening liquid.

[0075]

(6) Main surface polishing step (second polishing step)

Next, a second polishing step was performed using the same double-side polishing device as used in the above-described first polishing step, but polishing pads with a soft polisher (suede) were used. This second polishing step is mirror-polishing processing to finish the main surfaces of the glass substrate into smooth mirror surfaces having a surface roughness of about 0.2 nm or less in Ra, for example, while maintaining the flat surfaces obtained in the first polishing step described above. Water in which colloidal silica was dispersed was used as a polishing liquid, and the second polishing step was performed with a load of 100 g/cm². The glass substrate that had undergone the second polishing step was cleaned and dried.

[0076]

Moreover, the surface roughness of the main surfaces of the glass substrate obtained through the above-described steps was measured using an

atomic force microscope (AFM), revealing that a glass substrate with an ultra-smooth surface of 1.53 nm in Rmax and 0.13 nm in Ra was obtained. In addition, when the glass substrate surfaces were analyzed using an atomic force microscope (AFM) and an electron microscope, the glass substrate had mirror surfaces and no surface defects such as projections or blemishes were observed.

The resulting glass substrate had an outer diameter of 65 mm, an inner diameter of 20 mm, and a thickness of 0.635 mm.

In this manner, the magnetic-disk glass substrate of this example was obtained.

[0077]

(Comparative example 1)

Only the MRF processing was performed after the processing using a formed grindstone, in the shape processing and edge surface polishing step of example 1. The conditions for the MRF processing were the same as those in example 1.

The magnetic-disk glass substrate was obtained in the same manner as in example 1, except for the shape processing and edge surface polishing step.

[0078]

(Comparative example 2)

Only the inclined grinding was performed after the processing using a formed grindstone in the shape processing and edge surface polishing step of example 1. The conditions for the inclined grinding were the same as those in example 1.

The magnetic-disk glass substrate was obtained in the same manner as in example 1, except for the shape processing and edge surface polishing step.

[0079]

(Comparative example 3)

Only a conventional brushing was performed after the processing using a formed grindstone, in the shape processing and edge surface polishing step of example 1. The conditions for the brushing were the same as those for inner circumferential edge surface polishing in example 1.

5 The magnetic-disk glass substrate was obtained in the same manner as in example 1, except for the shape processing and edge surface polishing step. [0080]

(Comparative example 4)

10 In the shape processing and edge surface polishing step of example 1, the inclined grinding and a conventional brushing were performed after the processing using a formed grindstone. The conditions for the inclined grinding and the brushing were the same as those in example 1.

The magnetic-disk glass substrate was obtained in the same manner as in example 1, except for the shape processing and edge surface polishing step.

15 In the same manner as in example 1, the outer circumferential edge surface of the substrate of each of the above-described comparative examples was evaluated for variation in the radius of curvature of the edge portion located between the chamfered surface and the side wall surface, and the outer circumferential edge surface was observed using a microscope. Table 1 shows
20 the results.

[0081]

[Table 1]

Table 1	Shape processing and edge surface polishing method (first processing using a formed grindstone is not described)	Variation in radius of curvature of edge between chamfered surface and side wall surface	Microscope observation
Example 1	MRF processing after inclined grinding	Good	Excellent
Comparative Example 1	Only MRF processing	Good	Poor
Comparative Example 2	Only inclined grinding	Good	Poor
Comparative Example 3	Only brushing	Poor	Fair
Comparative Example 4	Brushing after inclined grinding	Fair	Fair

[0082]

5 The following points were revealed by the results shown in Table 1 above.

1. In example 1 on which the edge surface processing of the present invention in which the inclined grinding was performed as preprocessing of the MRF processing was performed, variation in the radius of curvature of the edge
10 portion between the chamfered surface and the side wall surface of the edge surface of the substrate that had undergone the processing was small, and the edge surface was finished to have a favorable surface state. Thus, a highly accurate shape and a high-quality surface could be achieved.

2. In contrast, in comparative example 1 on which only the MRF
15 processing was performed after the processing using a formed grindstone, and comparative example 2 on which only the inclined grinding was performed after the processing using a formed grindstone, marks such as polishing marks

remained particularly in microscope observation. Moreover, in comparative example 3 (conventional example) on which the brushing was performed after the processing using a formed grindstone, the machining allowance was not constant particularly during the brushing, and therefore, variation in the radius of curvature of the edge portion between the chamfered surface and the side wall surface was deteriorated. In addition, marks such as polishing marks were observed in microscope observation. Furthermore, in comparative example 4 on which the inclined grinding and the brushing were performed after the processing using a formed grindstone, variation in the radius of curvature of the edge portion between the chamfered surface and the side wall surface was slightly improved compared with comparative example 3, but marks such as polishing marks were observed in microscope observation.

That is, both a highly accurate shape and a high-quality surface cannot be achieved by methods other than the edge surface processing of the present invention in which the inclined grinding is performed as preprocessing of the MRF processing.

It should be noted that when grinding was performed using a resin bond grindstone having the same groove shape as in the processing using a formed grindstone and the same grit as in the inclined grinding without inclining the substrate after the processing using a formed grindstone in the shape processing and edge surface polishing step of example 1, the surface of the second formed grindstone was clogged and dulled during the manufacture, and the stable processing could not be performed.

[0083]

(Example 2)

In the shape processing and edge surface polishing step of example 1, the first processing using a formed grindstone was eliminated and only the inclined grinding and MRF processing were performed. The conditions for the

inclined grinding and MRF processing were the same as those in example 1, except that the processing time was increased in order to allow for a sufficient machining allowance in the inclined grinding.

The magnetic-disk glass substrate was obtained in the same manner as in example 1, except for the shape processing and edge surface polishing step.

As in example 1, one hundred produced glass substrates were evaluated for variation (Max-Min) in the radius of curvature of the edge portion using an outline shape measurement machine as an evaluation of variation in the edge angle between the main surface and the chamfered surface of the outer circumferential edge surface of the substrate that had undergone the edge surface polishing. A variation of 0.02 mm or less was evaluated as "Excellent". A variation of more than 0.02 mm and 0.03 mm or less was evaluated as "Good". Table 2 shows the result.

In addition, the glass substrate of example 1 was evaluated in the same manner. Table 2 shows the result.

[0084]

[Table 2]

Table 2	Shape processing and edge surface polishing method	Variation in radius of curvature of edge between main surface and chamfered surface
Example 1	Inclined grinding after processing using formed grindstone, then MRF processing	Excellent
Example 2	MRF processing after inclined grinding	Good

[0085]

It was found from the results shown in Table 2 that by performing the processing using a formed grindstone before the inclined grinding, variation in the radius of curvature of the edge portion between the main surface and the

chamfered surface was reduced, thus making it possible to improve the shape accuracy. It was thought that this was because a load applied to the grindstone for the inclined grinding was reduced due to the processing using a formed grindstone and highly accurate processing could be continued for a long period of time. Also, it was thought that a factor was that grinding marks cancelled out each other due to the difference in the inclinations of the two types of grinding.

In the case where the inclined grinding is performed without performing the processing using a formed grindstone, a sharp edge between the main surface and the edge surface of the substrate that is not chamfered before processing directly comes into contact with the surface of the grindstone for the inclined grinding. Then, this is repeated, and therefore, the grindstone at the boundary between the main surface and the chamfered surface (edge between the main surface and the chamfered surface) is particularly likely to be damaged. It is thought that the shape of the edge portion between the main surface and the chamfered surface tended to vary for this reason.

[0086]

(Example 3)

The magnetic-disk glass substrate was manufactured by performing the shaping processing and edge surface polishing step in the same manner as in example 1, except that a glass substrate having a thickness of 0.5 mm was used.

Variation in the radius of curvature of the edge portion between the chamfered surface and the side wall surface of the outer circumferential edge surface of the substrate that had undergone the edge surface polishing was evaluated in the same manner as in example 1. Table 3 shows the results.

[0087]

(Comparative example 5)

The magnetic-disk glass substrate was manufactured by performing the

shaping processing and edge surface polishing step in the same manner as in comparative example 3, except that a glass substrate having a thickness of 0.5 mm was used.

Variation in the radius of curvature of the edge portion between the chamfered surface and the side wall surface of the outer circumferential edge surface of the substrate that had undergone the edge surface polishing was evaluated in the same manner as in example 1. Table 3 shows the results.

Table 3 also shows the evaluation results of example 1 and comparative example 3 in which the glass substrate having a thickness of 0.635 mm was used, the evaluation results being obtained in the same manner.

[0088]

[Table 3]

Table 3	Variation in radius of curvature of edge between chamfered surface and side wall surface by conventional processing (Comparative Example 3)	Variation in radius of curvature of edge between chamfered surface and side wall surface by processing of the present invention (Example 1)
Thickness 0.635 mm	Poor (Comparative Example 3)	Good (Example 1)
Thickness 0.5 mm	Deteriorated compared with Comparative Example 3 (Comparative Example 5)	Equal to Example 1 (Example 3)

[0089]

It was found from the results shown in Table 3 that the same quality as that of a thick plate could be secured even in a thin plate with the edge surface processing of the present invention, whereas variation was deteriorated in a thin plate with a conventional processing method and thus sufficient processed shape accuracy could not be obtained.

[0090]

(Example 4)

A magnetic disk for perpendicular magnetic recording was manufactured by performing the following film forming step on the magnetic-disk glass substrates obtained in example 1 described above.

Specifically, an adherent layer consisting of a Ti-based alloy thin film, a
 5 soft magnetic layer consisting of a CoTaZr alloy thin film, a base layer consisting of a Ru thin film, a perpendicular magnetic recording layer made of a CoCrPt alloy, a carbon protecting layer, and a lubricant layer were sequentially formed on the glass substrate. The protective layer is to prevent degradation of the magnetic recording layer caused by contact with the magnetic head. The
 10 protective layer is composed of hydrogenated carbon and yields wear resistance. The lubricant layer was formed by a dipping method using an alcohol-modified perfluoropolyether liquid lubricant.

The resulting magnetic disk was incorporated into an HDD equipped with a DFH head, and then subjected to load/unload durability testing for one
 15 month while operating the DFH function in a high temperature and high humidity environment at a temperature of 80°C and a humidity of 80%RH. This resulted in no particular failures, and favorable results were obtained.

Description of Reference Numerals

- 20 [0091]
- | | |
|-------|--|
| 1 | Magnetic-disk glass substrate |
| 2 | Grindstone for outer circumferential side edge surface |
| 4 | Grindstone for inner circumferential side edge surface |
| 3, 5 | Groove |
| 25 10 | Disk-shaped glass substrate (glass disk) |
| 11 | Main surface of glass substrate |
| 12 | Outer circumferential side edge surface of glass substrate |
| 12a | Side wall surface |

	12b	Chamfered surface
	13	Inner circumferential side edge surface of glass substrate
	13a	Side wall surface
	13b	Chamfered surface
5	20	Edge surface polishing device
	21, 22	Magnet
	23	Spacer
	24	Exterior member
	26	Mass of magnetic slurry

CLAIMS

1. A method for manufacturing a magnetic-disk glass substrate comprising edge surface processing for processing an edge surface of a glass substrate,

5 wherein the edge surface processing includes
first processing forming magnetic field lines using a magnetism generating means, holding a magnetic slurry containing a magnetic material and polishing abrasive particles with the magnetic field lines to form a mass of the magnetic slurry, and processing the edge surface of the glass substrate in a state in which the edge surface is brought into contact with the mass of the magnetic slurry, and

second processing performed as preprocessing of the first processing, and for using a grindstone having a groove shape formed so as to be capable of simultaneously processing both a side wall surface of the edge surface of the glass substrate and chamfered surfaces between the side wall surface and each main surface of the glass substrate to perform processing in a state in which the glass substrate is inclined with respect to a groove direction of the groove shape formed in the grindstone.

20 2. The method for manufacturing a magnetic-disk glass substrate according to claim 1,

wherein processing for forming the chamfered surface on the edge surface of the glass substrate is performed before the second processing.

3. The method for manufacturing a magnetic-disk glass substrate according to claim 2,

25 wherein the chamfered surface forming processing and the second processing are performed at different angles of a groove direction of the grindstone to the substrate from each other.

4. The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 3,

wherein the edge surface of the glass substrate that has undergone the edge surface processing has a surface roughness of 0.2 μm or less in R_{max} .

5 5. The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 4,

wherein the glass substrate to be introduced into the edge surface processing has a thickness of 0.5 mm or less.

10 6. A method for manufacturing a magnetic disk comprising forming at least a magnetic recording layer on the magnetic-disk glass substrate manufactured by the method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 5.