

DESCRIPTION

Title of the Invention

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

Technical Field

[0001]

The present invention relates to a grindstone used in edge surface
10 grinding in the manufacture of a glass substrate for a magnetic disk to be
provided in a magnetic recording device such as a hard disk drive (abbreviated
to "HDD" hereinafter), a method for manufacturing a magnetic-disk glass
substrate in which the edge surface of a substrate is ground using the grindstone,
and a method for manufacturing a magnetic disk using a glass substrate
15 manufactured with the method for manufacturing a magnetic-disk glass
substrate.

Background Art

[0002]

20 Nowadays, accompanying rapid development of the IT industry, there
has been demand for dramatic technological innovation in information recording
technology, and particularly magnetic recording technology. In order to meet
the requirements for an increase in capacity, a technique according to which it is
possible to realize an information recording density of 750 GB or more per
25 magnetic disk is required in a magnetic disk that is a recording medium to be
provided in a magnetic recording device such as an HDD.

[0003]

Incidentally, aluminum-based alloy substrates have conventionally been

widely used as substrates for an information recording medium such as a magnetic disk, but recently, glass substrates have been increasingly used as magnetic-disk substrates that are suitable for increasing the recording density.

The glass substrates have a higher rigidity than the aluminum alloy-based

5 substrates and thus are suitable for achieving high-speed revolution in a magnetic disk device. In addition, the glass substrates can be formed to have a smooth surface, thus making it easy to reduce the flying height of a magnetic head. This makes it possible to improve the S/N ratio of recording signals. For these reasons, the glass substrates are preferable.

10 [0004]

Moreover, glass substrates need to be processed with greater precision in order to increase the recording density of the magnetic disks. The same applies to not only the main surfaces of the glass substrates but also the shapes of the edge surfaces thereof.

15 Magnetic-disk glass substrates are usually manufactured by successively performing steps of grinding and polishing an edge surface, steps of grinding and polishing a main surface, a step of chemically strengthening, and the like on raw glass plates that have been shaped into a disk shape.

[0005]

20 As a conventional method for processing the edge surfaces of the glass substrates, while supplying a grinding liquid to the edge surface portions of a raw glass plate (glass substrate) shaped into a disk shape, grindstones are brought into contact with the outer circumferential side edge surface and the inner circumferential side edge surface of the glass substrate and rotated to grind
25 these edge surfaces, and then predetermined chamfering processing is performed on the outer circumferential side edge surface and the inner circumferential side edge surface of the glass substrate (Patent Document 1, for example). In this case, the grindstone, which is also generally called a formed

grindstone, has a groove for shaping the edge surface of the glass substrate, and the shape of the groove of the grindstone is transferred to the edge surface of the glass substrate by bringing the grindstone into contact with the edge surface of the glass substrate and processing the edge surface. Furthermore, 5 after this chamfering processing, brushing is performed to process the edge surface of the glass substrate into a mirror surface.

Prior Art Document

Patent Document

10 [0006]

Patent Document 1: JP-A-2000-185927

Patent Document 2: JP-A-2006-294099

Summary of the Invention

15 Problem to be Solved by the Invention

[0007]

Demand for an increase in the recording density of the magnetic disks has been increasing as society becomes more information-oriented. Further improvement in surface quality (e.g., smoothness) and processing accuracy 20 (e.g., shape accuracy) has also been required for the shapes of the edge surfaces of the magnetic-disk glass substrates.

This is because it is required that high accuracy of the dimensions of an inner diameter and an outer diameter for obtaining accurate positioning of a magnetic head when a magnetic disk is provided in an HDD, and higher quality 25 of an outer diameter edge surface based on demand for a decrease in contamination factors such as the occurrence of corrosion on the main surface of a medium are realized, for example.

[0008]

Conventionally, in the grinding processing performed on the edge surface of the substrate, first, rough grinding processing, such as chamfering processing, for shaping the edge surface is performed, and then, precision grinding processing (final grinding processing) for ensuring the shape and the dimensions of the edge surface and ensuring the surface roughness quality is performed. A hard electrodeposition bond grindstone or the like is often used in the above-mentioned rough grinding processing.

[0009]

On the other hand, in the above-mentioned precision grinding processing, a resin bond grindstone that is softer than a grindstone for rough grinding processing is often used in order to ensure the quality of the finished edge surface of the substrate. However, actual grindstones vary in their grinding performance when used in processing performed in mass production, which causes a large number of problems, and thus desired quality cannot be stably achieved.

[0010]

Conventionally, hardness testing using an Okoshi-type testing machine, hardness evaluation using a Rockwell hardness tester, and the like are known as methods for testing the hardness of a grindstone. However, as a result of research by the inventors of the present invention, a clear correlation was not observed between the hardness of a grindstone evaluated by these methods and its grinding performance (grinding speed, ground surface roughness, accuracy of the shape and dimensions, and the like) when the edge surface of a substrate was actually ground using the grindstone, and in the end, it was found that whether or not a grindstone is good cannot be judged until the grindstone is actually used.

[0011]

Patent Document 2 states that a processed surface can be finished to

have a roughness Ra of 100 nm or less by using a resin bond grindstone in which diamond abrasive particles, and a urethane resin, a urea resin, or the like as a binding agent (binder) are used, but only the component materials of the grindstone components are shown, and the specific specifications of the grindstone, particularly, the hardness indices of the grindstone that affect the grinding performance, are not disclosed. Even if the same component materials are used, the differences in hardness cause differences in grinding speed and in the quality of the processed surfaces, thus making it difficult to achieve stable quality in processing performed in mass production.

10 [0012]

As described above, from the viewpoint of an increase in a recording density and the like, 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 in a state in which there are no indices with which the performance of a grindstone can be appropriately evaluated, and the performance of a grindstone cannot be judged until the grindstone is actually used, it becomes difficult to stably meet demand for quality of the glass substrate that will further increase in future.

20 [0013]

Therefore, from the viewpoint of meeting demand for increasing the recording density of a magnetic disk in which reliability urgently needs to be ensured, a first object of the present invention is to provide a grindstone that can efficiently finish the edge surface of a magnetic-disk glass substrate to a high quality and also achieve stable quality in processing performed in mass production. A second object is to provide a method for manufacturing a magnetic-disk glass substrate in which the edge surface can be ground so as to also achieve stable quality even in processing performed in mass production.

Furthermore, a third object is to provide a method for manufacturing a magnetic disk using the glass substrate provided by this method.

Means to Solve the Problem

5 [0014]

The inventors achieved the present invention as a result of carrying out intensive research to solve the foregoing problems.

That is, in order to solve the foregoing problems, the present invention includes the following aspects.

10 (Aspect 1)

An aspect of the present invention is a grindstone for precisely grinding an edge surface of a disk-shaped glass substrate having a circular hole in a central portion, and the grindstone includes abrasive particles, and a binder for binding the abrasive particles, wherein a binder portion on a surface of the grindstone has a hardness in a range from 0.4 to 1.7 GPa, measured by
15 nano-indentation testing using a Berkovich indenter under a condition that an indentation load of 250 mN is applied.

[0015]

(Aspect 2)

20 In the grindstone according to aspect 1, the abrasive particles have an average particle diameter in a range from 2 to 15 μm .

[0016]

(Aspect 3)

In the grindstone according to aspect 1 or 2, the grindstone is a rotary
25 grindstone to be used in processing in which the grindstone is brought into contact with the edge surface of the glass substrate in a state in which a rotation axis of the grindstone is inclined with respect to an axis orthogonal to a main surface of the glass substrate and grinds the edge surface of the glass

substrate.

Here, "inclined" mentioned above means that the rotation axis is inclined such that all of the side wall surface and two chamfered surfaces of the glass substrate simultaneously come into contact with a groove provided in the surface of the grindstone.

(Aspect 4)

Another aspect of the present invention is a method for manufacturing a magnetic-disk glass substrate including performing grinding processing on the edge surface of the glass substrate using the grindstone according to any of aspects 1 to 3.

[0017]

(Aspect 5)

Yet another aspect of the present invention is a method for manufacturing a magnetic-disk glass substrate including grinding processing for precisely grinding an edge surface of a disk-shaped glass substrate having a circular hole in a central portion using a grindstone, wherein the grindstone includes abrasive particles and a binder for binding the abrasive particles, a correlation is determined in advance between hardness of a binder portion on a surface of the grindstone, measured by nano-indentation testing using a Berkovich indenter under a condition that an indentation load of 250 mN is applied, and a grinding speed when the grindstone is used to grind the edge surface of the glass substrate under a certain condition, and a grindstone that has a hardness with which a desired grinding speed is obtained is selected based on the determined correlation, and the grinding processing is performed using the selected grindstone.

[0018]

(Aspect 6)

In the method for manufacturing a magnetic-disk glass substrate

according to aspect 5, in the grindstone, the binder is made of a resin material, and hardness measured by the nano-indentation testing is in a range from 0.4 to 1.7 GPa.

[0019]

5 (Aspect 7)

In the method for manufacturing a magnetic-disk glass substrate according to aspect 5 or 6, the selected grindstone is used in processing in which the grindstone is brought into contact with the edge surface of the glass substrate in a state in which a rotation axis of the grindstone is inclined with

10 respect to an axis orthogonal to a main surface of the glass substrate, and grinds the edge surface of the glass substrate.

[0020]

(Aspect 8)

In the method for manufacturing a magnetic-disk glass substrate

15 according to any of aspects 4 to 7, the edge surface of the glass substrate is ground so as to have a surface roughness Ra of 0.1 μm or less.

(Aspect 9)

Yet another aspect of the present invention is a method for

manufacturing a magnetic disk including forming at least a magnetic recording

20 layer on the magnetic-disk glass substrate manufactured by the method for manufacturing a magnetic-disk glass substrate according to any of aspects 4 to 8.

Effect of the Invention

25 [0021]

With the grindstone according to the present invention, the edge surface of a magnetic-disk glass substrate can be efficiently finished to a high quality, and stable quality can also be achieved in processing performed in mass

production. Accordingly, it is possible to meet demand for increasing the recording density of a magnetic disk in which reliability urgently needs to be ensured.

Moreover, with the method for manufacturing a magnetic-disk glass substrate according to the present invention, it is possible to use this grindstone to grind the edge surface so as to also achieve stable quality in processing performed in mass production, and as a result, the edge surface of the magnetic-disk glass substrate can be finished to a high quality.

[0022]

Furthermore, with the method for manufacturing a magnetic disk using the magnetic-disk glass substrate provided by this method for manufacturing a magnetic-disk glass substrate, it is possible to finish the edge surface of the substrate to a high quality, to prevent malfunction caused by the surface state and the processing accuracy of the edge surface of the substrate, and provide a highly reliable magnetic disk with which a further increase in the recording density can be realized.

Brief Description of the Drawings

[0023]

FIG. 1 shows one embodiment of a method for grinding edge surfaces. FIG. 1(a) is a perspective view, and FIG. 1(b) is a front view, as viewed from a side different from that in FIG. 1(a).

FIG. 2 shows another embodiment of a method for grinding edge surfaces. FIG. 2(a) is a perspective view, and FIG. 2(b) is a front view, as viewed from a side different from that in FIG. 2(a).

FIG. 3 is a cross-sectional view illustrating an example of the shape of a groove of a grindstone to be used in the embodiment in FIG. 2.

FIG. 4 is a cross-sectional view illustrating an example of the shape of

an edge surface of a glass substrate.

FIG. 5 is a diagram illustrating a correlation between load and displacement in a grindstone measured by nano-indentation testing.

FIG. 6 is a diagram illustrating an example of a correlation between the
5 hardness of a grindstone measured by the nano-indentation testing and a grinding speed when this grindstone is used to grind the edge surface of a glass substrate under a certain condition.

FIG. 7 shows yet another embodiment of a method for grinding edge surfaces. FIG. 7(a) is a perspective view, and FIG. 7(b) is a front view, as
10 viewed from a side different from that in FIG. 7(a).

Mode for Embodying the Invention

[0024]

Hereinafter, embodiments of the present invention will be described in
15 detail.

FIG. 4 is a cross-sectional view of the outer circumferential side edge portion of a magnetic-disk glass substrate 1 to which the present invention is applied. Although not shown in FIG. 4, the glass substrate 1 has a circular hole 4 in its central portion and is formed into a disk shape as a whole (see FIG. 1
20 etc.). The glass substrate 1 has main surfaces 1a on both the front and back sides, and an outer circumferential side edge surface and an inner circumferential side edge surface that are formed between the main surfaces 1a.

The outer circumferential side edge surface of the glass substrate 1 is formed into a shape including a side wall surface 1b that is orthogonal to the
25 main surfaces 1a, and two chamfered surfaces (surfaces that are chamfered) 1c that are respectively formed between the side wall surface 1b and both the front and back main surfaces 1a. Also, although not illustrated, the inner circumferential side edge surface of the glass substrate 1 is formed into a shape

including a side wall surface that is orthogonal to the main surfaces 1a, and two chamfered surfaces (surfaces that are chamfered) that are respectively formed between this side wall surface and both the front and back main surfaces 1a.
[0025]

5 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.
[0026]

10 All of the main surfaces 1a, the outer circumferential side edge surface, and the inner circumferential side edge surface of the magnetic-disk glass substrate 1 are polished (mirror-polished) and finished to a final predetermined surface roughness. Both the outer circumferential side edge surface and the inner circumferential side edge surface of the glass substrate 1 are usually
15 required to be finished to an edge surface having a shape as described above, and to a mirror surface state in which the surface roughness is 0.1 μm or less at R_{max} and 0.01 μm or less at R_{a} .

 Here, in the present invention, R_{a} and R_{max} denote arithmetic mean roughness and maximum roughness conforming to Japanese Industrial
20 Standards (JIS) B0601:1982, respectively. Moreover, in the present invention, the surface roughness of the edge surface is measured in a measurement region of 50 μm $\times$ 50 μm under a laser microscope with an observation power of 3000 $\times$.
[0027]

25 The magnetic-disk glass substrate 1 is usually manufactured by successively performing steps of grinding and polishing (mirror-polishing) edge surfaces, steps of grinding and mirror-polishing main surfaces, a step of chemically strengthening, and the like on a glass substrate (glass disk) 1 that

has been shaped into a predetermined disk shape by direct pressing, for example.

First, the steps of grinding and polishing the edge surfaces of the glass substrate 1 will be described.

5 It should be noted that in this specification, a glass disk that is shaped into a predetermined disk shape by direct pressing, a glass substrate serving as an end product that is manufactured by performing processing, treatment, and the like on this glass disk, and the like are all called a glass substrate or a magnetic-disk glass substrate for the sake of convenience in the description.

10 [0028]

First, the above-mentioned step of grinding edge surfaces will be described. FIG 1 shows one embodiment of the method for grinding edge surfaces. FIG. 1(a) is a perspective view, and FIG. 1(b) is a front view, as viewed from a side different from that in FIG. 1(a).

15 In the glass substrate 1 on which drilling processing has been performed and that is provided with the circular hole 4 in its central portion, its outer circumferential side edge surface is processed using a grindstone 7, and its inner circumferential side edge surface is processed using a grindstone 8. The grindstone 7 is formed into a disk shape having a predetermined size as shown
20 in the diagram, and has a groove for shaping the edge surface of the glass substrate on its outer circumferential side. Specifically, the groove is shaped so as to transfer the shapes of both the side wall surface and the chamfered surfaces to the outer circumferential side edge surface of the glass substrate. Moreover, the grindstone 8 is formed into a cylindrical shape having a
25 predetermined size as shown in the diagram, and has a groove for shaping the edge surface of the glass substrate on its outer circumferential side. Specifically, the groove is shaped so as to transfer the shapes of both the side wall surface and the chamfered surfaces to the inner circumferential side edge

surface of the glass substrate. That is, both the grindstone 7 and the grindstone 8 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 1.

5 [0029]

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 7 and grindstone 8 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
10 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 is particularly preferable in which the hardness of the grindstone is relatively easily adjusted.

Moreover, as for the particle diameter of the abrasive particles, it is
20 preferable to use abrasive particles having an average particle diameter of 30 μm or less, for example, such that the grinding performance can be maintained throughout the life of the grindstone while maintaining the roughness. In particular, it is preferable to use abrasive particles having an average particle diameter in a range from 2 to 15 μm in the precision grinding processing.

25 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 particle diameter of the abrasive particles in the present invention is

the average value (median diameter (D50)) measured by the electric resistance testing method.

It should be noted that the edge surfaces preferably have a surface roughness of 1 μm or less at Ra after the rough grinding processing. Moreover, the surface roughness is preferably 0.1 μm or less at Ra after the precision grinding processing.

[0030]

Incidentally, in the present invention, as described in the above-mentioned aspect 1, the grindstone for precisely grinding the edge surface of the glass substrate includes abrasive particles, and a binder for binding the abrasive particles, wherein a binder portion on a surface of the grindstone has a hardness in a range from 0.4 to 1.7 GPa, measured by nano-indentation testing using a Berkovich indenter under a condition that an indentation load of 250 mN is applied.

[0031]

As described below, the inventors of the present invention inferred the reason why a clear correlation was not observed between the hardness of a grindstone evaluated by the conventional method such as a hardness test using an Okoshi-type testing machine, hardness evaluation using a Rockwell hardness tester, or the like and its grinding performance (grinding speed, ground surface roughness, accuracy of the shape and dimensions, and the like) when the grindstone was used to actually grind the edge surface of a substrate.

It is thought that in the conventional hardness testing for a grindstone, an indenter destroys the surrounding structure of the grindstone in the process of sinking into the grindstone during the measurement, and the structure in the compressed state is evaluated, as a result of which a density element is involved, and thus the overall strength of the grindstone structure is measured, and therefore, the hardness for causing the grindstone to exhibit the grinding

performance, namely, mechanical strength of the binder for holding the abrasive particles that directly leads to the grinding performance of the grindstone cannot be appropriately evaluated.

[0032]

5 The inventors of the present invention inferred that even if the grindstones have the same components, their grinding performance differs depending on the difference in the strength of their structures, particularly, the strength between the abrasive particles and the binder (binding agent) for binding the abrasive particles, namely, the strength to hold the abrasive particles, and there is a high likelihood that this causes the variation in the quality of the edge surfaces. Therefore, the inventors of the present invention recognized that the hardness of the grindstone, particularly, the binding strength between the abrasive particles and the binder is extremely important as the performance or processing properties of the grindstone, and considered nano-indentation testing as a method for appropriately evaluating the binding state between the abrasive particles and the binder, namely, the strength to hold the abrasive particles in a grindstone that has been finished into a product. Then, they found that a clear correlation was observed between the hardness measured by the nano-indentation testing under a predetermined condition and the grinding performance (grinding speed, ground surface roughness, accuracy of the shape and dimensions, and the like) when the grindstone was used to actually grind the edge surface of a substrate. Specifically, they found that by using a grindstone whose binder portion on the surface of the grindstone had a hardness in a range from 0.4 to 1.7 GPa, measured by the nano-indentation testing using a Berkovich indenter under a condition that the indentation load of 250 mN was applied, favorable grinding performance was exhibited particularly in the final precision grinding, as a result of which the edge surfaces of the magnetic-disk glass substrate could be efficiently finished to a high quality, and stable quality

could be achieved in processing performed in mass production.

[0033]

Next, a nano-indentation testing method for measuring the hardness of a grindstone will be described.

5 FIG. 5 shows a relationship between the load and the displacement when load is applied at 1 nm/second to the binder portion on the surface of the grindstone, which is a measurement target, using a Berkovich indenter with a tip end having a quadrangular pyramid shape, the load is increased to 250 mN, the load is held for a predetermined period of time (e.g., for 10 seconds) as is, and
10 then pressure is reduced at an unloading speed similar to the speed of the increase in pressure. It should be noted that the mechanical strength of the binder can be appropriately evaluated under this pressure increasing condition.

Here, three characteristic curves corresponding to three different grindstones are shown as examples. These curves indicate dynamic hardness
15 properties, and indicate properties closer to the properties in actual use than hardness evaluation indicating conventional static hardness properties does.

[0034]

From the results of the curves of the dynamic hardness properties shown in FIG. 5, the hardness of the grindstone by the nano-indentation testing
20 is determined according to the following equation.

$$H=F/A_c$$

where H is the hardness of a grindstone, F is load, and A_c is the area of an indentation.

The area A_c of an indentation is expressed by the following relational
25 expressions.

$$A_c=f(h_c)\propto 24.5\cdot h_c^2$$

$$h_c=h_{\max}-\epsilon\cdot F/S$$

where h_c is an indentation depth, $h_{\max}$ is a depth when the maximum load is

applied, h_s is an indentation depth when unloading starts, h_o is an indentation depth after the unloading is finished, ϵ is a shape factor intrinsic to an indenter (e.g., 0.75 in a case of a Berkovich indenter), S is a proportional coefficient between load and displacement, and m is a slope (dF/dh).

5 [0035]

The grindstone according to the present invention has a hardness in a range from 0.4 to 1.7 GPa, measured by the nano-indentation testing, and more preferably in a range from 1.2 to 1.6 GPa.

[0036]

10 In the edge surface grinding processing, as shown in FIG. 1, the processing is performed with a positional relationship in which the rotation axis of the glass substrate 1 extends parallel to the rotation axis of the grindstone 7 or grindstone 8. The grindstone 7 comes into contact with the outer circumferential side edge surface of the glass substrate 1 in the direction
15 indicated by an arrow 19 (cutting direction) in the diagram, and the grindstone 8 comes into contact with the inner circumferential side edge surface of the glass substrate 1 in the direction indicated by an arrow 20 (cutting direction) in the diagram.

In this case, it is preferable to perform the processing while rotating the
20 grindstone 7 or grindstone 8 and the glass substrate 1 in predetermined directions, and the circumferential speeds of the grindstone 7 or grindstone 8 and the glass substrate 1, and a circumferential speed ratio need only be set as appropriate so as to be preferable for the grinding processing performed on the inner and outer circumferential side edge surfaces. Although, in FIG. 1, the
25 glass substrate 1 is rotated in the direction indicated by an arrow 10, the grindstone 7 is rotated in the direction indicated by an arrow 17, and the grindstone 8 is rotated in the direction indicated by an arrow 18, the rotation directions are not limited to these. The grindstone 7 or grindstone 8 and the

glass substrate 1 may be rotated in the same direction (counter direction) or different directions (anti-counter direction) in the processing portion.

[0037]

From the viewpoint of grindability and processing efficiency, it is preferable to set the circumferential speed of the grindstone 7 at the processing portion to 800 to 1700 m/minute, for example. It is preferable to set the circumferential speed of the grindstone 8 at the processing portion to 200 to 700 m/minute. It is preferable to set the circumferential speed of the glass substrate 1 at the processing portion to 3 to 10 m/minute.

Moreover, it is preferable to set a thrust grinding force to 2 to 40 N/mm during the grinding processing. The thrust grinding force is a parameter related to processing pressure. It should be noted that the thrust grinding force can be measured using a grinding dynamometer, for example.

Although there is no particular limitation on a grinding liquid (coolant) to be used, 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.

[0038]

FIG. 2 shows another embodiment of a method for grinding the edge surfaces. FIG. 2(a) is a perspective view, and FIG. 2(b) is a front view, as viewed from a side different from that in FIG. 2(a).

In the edge surface processing method shown in FIG. 2, grindstones are brought into contact with the edge surfaces of the glass substrate in a state in which the rotation axes of the grindstones are inclined with respect to an axis orthogonal to the main surfaces of the glass substrate, and grind the edge surfaces of the glass substrate. This grinding method can improve shape accuracy and processing quality such as surface roughness and thus is particularly preferable for the precision grinding processing subsequent to the rough grinding processing using a formed grindstone, for example. It should be

noted that the grinding method can be used in the rough grinding processing.
[0039]

In a glass substrate in which the inner and outer circumferential side edge surfaces are each provided with both a side wall surface and chamfered surfaces by the rough grinding processing using a formed grindstone, for example, its outer circumferential side edge surface is processed using a grindstone 2, and its inner circumferential side edge surface is processed using a grindstone 3. The grindstone 2 is formed into a disk shape having a predetermined size as shown in the diagram, and has a groove on a surface that comes into contact with the edge surface of the glass substrate, on its outer circumferential side. As shown in FIG. 3, for example, this groove has a recessed shape 6 that is recessed toward the inside when viewed in cross section. It should be understood that the shape shown in FIG. 3 is an example, and the shape is not to be construed as being limited to this. Moreover, the grindstone 3 is formed into a cylindrical shape having a predetermined size as shown in the diagram, and has a groove (having a recessed shape shown in FIG. 3, for example) on a surface that comes into contact with the edge surface of the glass substrate, on its outer circumferential side.

[0040]

In this processing method, the edge surface of the glass substrate is brought into contact with the grindstone such that a locus of the grindstone, which is brought into contact with the edge surface of the glass substrate, is not constant, and is processed. In this processing method, the entire edge surface (three surfaces of the side wall surface and the two chamfered surfaces adjacent to the side wall surface) is simultaneously ground.

For example, as shown in FIG. 2, the outer circumferential side of the substrate is processed with the grindstone 2 in a state in which the plane direction of the grindstone 2 is inclined with respect to the plane direction of the

glass substrate 1 by an angle α . Moreover, the inner circumferential side of the substrate is processed with the grindstone 3 in a state in which the plane direction of the grindstone 3 is inclined with respect to the plane direction of the glass substrate 1 by an angle β , namely, in a state in which the rotation axis of the grindstone 3, which is a rotary grindstone, is inclined with respect to a direction orthogonal to the main surfaces of the glass substrate. The grindstone 2 comes into contact with the outer circumferential side edge surface of the glass substrate 1 in the direction indicated by an arrow 13 (cutting direction) in the diagram, and the grindstone 3 comes into contact with the inner circumferential side edge surface of the glass substrate 1 in the direction indicated by an arrow 14 (cutting direction) in the diagram. Also in this case, it is preferable to perform the processing while rotating the grindstone 2 or grindstone 3 and the glass substrate 1 in predetermined directions, and their circumferential speeds and a circumferential speed ratio need only be set as appropriate so as to be preferable for the processing performed on the inner and outer circumferential side edge surfaces. Although, in FIG. 2, the glass substrate 1 is rotated in the direction indicated by an arrow 10, the grindstone 2 is rotated in the direction indicated by an arrow 11, and the grindstone 3 is rotated in the direction indicated by an arrow 12, the rotation directions are not limited to these. The grindstone 2 or grindstone 3 and the glass substrate 1 may be rotated in the same direction (counter direction) or different directions (anti-counter direction).

[0041]

From the viewpoint of grindability and processing efficiency, it is preferable to set the circumferential speed of the grindstone 2 at the processing portion to 1200 to 1700 m/minute, for example. It is preferable to set the circumferential speed of the grindstone 3 at the processing portion to 300 to 700 m/minute. It is preferable to set the circumferential speed of the glass substrate

1 at the processing portion to 3 to 10 m/minute. Moreover, it is preferable to set a thrust grinding force to 2 to 40 N/mm during the grinding processing.

[0042]

In the processing method shown in FIG. 2, the locus of the grindstone 2 brought into contact with the edge surface of the glass substrate 1 is not constant and the projecting portions (abrasive particles) of the grindstone 2 are brought into contact with and act on the random positions of the edge surface of the substrate, thus making it possible to reduce damage to the substrate, to reduce surface roughness and in-plane variation of the ground surface, and to finish the ground surface to a smoother surface.

Accordingly, it is preferable to apply the grindstone of the present invention described above to the grindstone 2 and the grindstone 3 used in this processing method in which the precision grinding is performed in a state in which the grindstone is inclined with respect to the glass substrate.

[0043]

FIG. 7 shows yet another embodiment of a method for grinding the edge surfaces. FIG. 7(a) is a perspective view, and FIG. 7(b) is a front view, as viewed from a side different from that in FIG. 7(a).

Although a method for processing the inner circumferential side edge surface of the glass substrate is the same as that of the embodiment shown in FIG. 2, a processing method using a grindstone 5 that is formed into a cylindrical shape having a size inside which the glass substrate is contained as shown in FIG. 7 can also be applied to the method for processing the outer circumferential side edge surface. The grindstone 5 has a groove on a surface that comes into contact with the edge surface of the glass substrate, on its inner circumferential side. This groove has the above-mentioned recessed shape 6 as shown in FIG. 3, for example.

Also in this embodiment, it is preferable that the outer circumferential

side edge surface of the glass substrate 1 is processed while in contact with the inner circumferential side of the grindstone 5 in a state in which the plane direction of the grindstone 5 is inclined with respect to the plane direction of the glass substrate 1 by an angle α such that a locus of the grindstone 5, which is brought into contact with the edge surface of the glass substrate 1, is not constant. In the processing method shown in FIG. 7, the locus of the grindstone 5 brought into contact with the edge surface of the glass substrate 1 is not constant and the projecting portions (abrasive particles) of the grindstone 5 are brought into contact with and act on the random positions of the edge surface of the substrate, thus making it possible to reduce damage to the substrate, to reduce surface roughness and in-plane variation of the ground surface, and to finish the ground surface to a smoother surface. Accordingly, it is preferable to apply the grindstone of the present invention described above to the grindstone 5 used in this processing method shown in FIG. 7.

It should be noted that although there is no particular limitation on the type of glass used in the magnetic-disk glass substrate, examples of the material of the glass substrate include aluminosilicate glass, soda-lime glass, soda-aluminosilicate glass, aluminoborosilicate glass, borosilicate glass, quartz glass, chain silicate glass, and glass ceramics such as crystallized glass. In particular, amorphous aluminosilicate glass is particularly preferable because it has excellent impact resistance and vibration resistance.

[0044]

Also, the present invention provides an invention according to the following favorable embodiment related to the above-mentioned embodiments.

That is, a correlation is determined in advance between the hardness of the binder portion on the surface of a grindstone including abrasive particles and a binder for binding the abrasive particles, measured by the nano-indentation testing using a Berkovich indenter under the condition that an indentation load of

250 mN is applied, and the grinding speed when this grindstone is used to grind the edge surface of a glass substrate under a certain condition. Then, a grindstone that has a hardness with which a desired grinding speed is obtained is selected based on the determined correlation. This selected grindstone is used to perform the precision grinding processing on the edge surface of the glass substrate.

[0045]

As described above, the inventors of the present invention recognized that the hardness of the grindstone, particularly, the binding strength between the abrasive particles and the binder was extremely important as the performance or processing properties of the grindstone, and found that a clear correlation was observed between the hardness measured by the nano-indentation testing under a predetermined condition and its grinding performance (grinding speed, ground surface roughness, accuracy of the shape and dimensions, and the like) when the grindstone was used to actually grind the edge surface of the substrate. Specifically, a correlation was determined in advance between the hardness of the binder portion on the surface of a grindstone, measured by the nano-indentation testing using a Berkovich indenter under the condition that an indentation load of 250 mN is applied, and the grinding speed when this grindstone was used to grind the edge surface of a glass substrate under a predetermined condition. Then, they found that when a grindstone that had a hardness with which a desired grinding speed was obtained was selected based on the determined correlation and this selected grindstone was used to grind the edge surface of the glass substrate, favorable grinding performance was exhibited particularly in the final precision grinding, as a result of which the edge surface of a magnetic-disk glass substrate could be efficiently finished to a high quality, and stable quality could also be achieved in processing performed in mass production.

[0046]

It should be noted that since a method for measuring the hardness of a grindstone by the nano-indentation testing is as described above, the description is omitted here.

5 [0047]

FIG. 6 shows an example of a correlation, determined by using a plurality of grindstones, between the hardness of a grindstone, measured by the above-mentioned nano-indentation testing, and a grinding speed when this grindstone is used to grind the edge surface of a glass substrate under a predetermined condition. It should be noted that FIG. 6 shows the results of working examples, which will be described later, and details will be described in the section of Working Examples.

Based on the correlation shown in FIG. 6, a range A in which a desired grinding speed, e.g., 0.5 $\mu\text{m}/\text{sec}$ or more, is achieved is used as an optimum range. When a grindstone having a hardness in the optimum range A is selected and this selected grindstone is used to perform the precision grinding on the edge surface of a glass substrate, favorable grinding performance can be exhibited.

[0048]

20 On the other hand, when a grindstone having a hardness in a range B in which the hardness of a grindstone is lower than that in the optimum range is selected, the strength to hold the abrasive particles is low, and the abrasive particles increasingly fall off and a breaking state is entered during the processing. Therefore, a desired grinding speed is not obtained, resulting in a shear drop shape, and therefore, the quality of the edge surface deteriorates.

25 When a grindstone having a hardness in a range C in which the hardness of a grindstone is higher than that in the optimum range is selected, the strength to hold the abrasive particles is too large, and a spontaneous edge

sharpening action caused by the abrasive particles falling off does not progress. Therefore, the grindstone is clogged due to grinding chips accumulating on the surface of the grindstone and is dulled due to the abrasive particles being worn, and thus a desired grinding speed is not obtained, and the quality of the processed surface deteriorates due to dimming and staining.

[0049]

The inventors of the present invention found that the hardness measured by the above-mentioned nano-indentation testing was preferably in a range from 0.4 to 1.7 GPa in a resin bond grindstone in which the binder was made of a resin material, for example, and that particularly in the final precision grinding, a desired grinding speed, e.g., 1.0 $\mu\text{m}/\text{sec}$ or more, was obtained, favorable grinding performance could be exhibited, and stable quality could also be achieved in processing performed in mass production. It is particularly preferable that the resin bond grindstone has a hardness in a range from 1.2 to 1.6 GPa.

[0050]

It is preferable to apply the grindstone selected based on a correlation between the hardness of a grindstone measured by the above-mentioned nano-indentation testing and the grinding speed when this grindstone is used to grind the edge surface of a glass substrate under a predetermined condition to the above-mentioned grindstone 2 and the grindstone 3 used in the processing method in which the precision grinding is performed in a state in which the grindstone is inclined with respect to the glass substrate as shown in FIG. 2 and FIG. 7 above.

[0051]

The edge surface polishing by brushing or the like is performed on the glass substrate in which the outer and inner circumferential side edge surfaces of the substrate have undergone the grinding processing, and thus the edge

surfaces are processed into a mirror surface. The magnetic-disk glass substrate 1 as shown in FIG. 4 is obtained by subsequently performing the mirror-polishing step, the chemical strengthening step, and the like on the main surfaces.

5 [0052]

The present invention also provides a method for manufacturing a magnetic disk including forming at least magnetic layers on the main surfaces of the magnetic-disk glass substrate manufactured by the above-mentioned method for manufacturing a magnetic-disk glass substrate according to the
10 present invention.

That is, a magnetic disk is obtained by forming at least magnetic layers on the magnetic-disk glass substrate obtained according to the above-mentioned embodiments of the present invention, for example. In general, a magnetic disk obtained by providing an adherent layer, a soft
15 magnetic layer, a base layer, a magnetic layer, a protecting layer, and a lubricant layer on the glass substrate, for example, is preferable.

[0053]

For example, the magnetic layer formed in a perpendicular magnetic recording medium is made of an alloy having a Co-based hcp crystal structure,
20 for example, or the like.

An example of the protecting layer is preferably a carbon-based protecting layer. Moreover, an example of a lubricant for forming the lubricant layer on the protecting layer is a PFPE (perfluoropolyether)-based compound.

A known sputtering method and the like can be used as a method for
25 forming the above-mentioned layers on the glass substrate. A plasma CVD method is also preferably used to form the carbon-based protecting layer. Moreover, a dipping method can be used to form the lubricant layer.

When a magnetic disk is manufactured using the magnetic-disk glass

substrate manufactured by the method for manufacturing a magnetic-disk glass substrate according to the present invention, it is possible to finish the edge surfaces of the substrate to a high quality, to prevent malfunction caused by the state and the processing accuracy of the edge surfaces of the substrate, and to
5 provide a highly reliable magnetic disk with which the further increase in the recording density can be realized.

Working Examples

[0054]

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

(Working examples 1 to 7 and comparative examples 1 to 3)

First, a disk-shaped glass substrate (glass disk) made of amorphous aluminosilicate glass and having a diameter of 66 mmφ was obtained from
15 molten glass by direct pressing using upper, lower, and drum molds.

[0055]

Next, a lapping step was performed on the glass substrate to improve the dimensional accuracy and shape accuracy. This lapping step was performed using a double-side lapping machine.

20 [0056]

Next, a cylindrical grindstone was used to make a hole in the central portion of the glass substrate, and the rough grinding processing was performed on the inner circumferential side edge surface according to a processing method using a formed grindstone as shown in FIG. 1 above. Subsequently, the
25 precision grinding processing was performed according to a method in which processing was performed in a state in which the grindstone was inclined with respect to the glass substrate and was brought into contact with the glass substrate as shown in FIG. 2 above.

An electrodeposition bond grindstone in which diamond abrasive particles were fixed with an electrodeposition bond was used in the above-mentioned rough grinding processing. Moreover, a resin bond grindstone in which diamond abrasive particles having an average particle diameter (D50) of 5 μm were used and a binder for binding the abrasive particles was made of a phenol resin was used in the above-mentioned precision grinding processing. Resin bond grindstones that were composed of the same component materials but differed in hardness were prepared. The hardness of the grindstone was measured by the above-mentioned nano-indentation testing.

The rough grinding processing was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 1, and the precision grinding processing was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 2. The inclination angle α of the grindstone with respect to the glass substrate was set to 10 degrees. Moreover, the circumferential speeds, rotation directions, and processing pressures of the glass substrate and the grindstone were set as appropriate.

[0057]

In this manner, the inner circumferential side edge surfaces of one hundred glass substrates were ground.

In order to confirm the accuracy of the shapes and dimensions of the side wall surfaces and the chamfered surfaces of the inner circumferential side edge surfaces of the obtained one hundred glass substrates, the radius of curvature of a corner portion A formed by the side wall surface and the chamfered surface and the radius of curvature of a corner portion B formed by the main surface and the chamfered surface (see FIG. 4) were measured using a small outline shape measurement machine. The radius of curvature was measured at two points in total, one on the front side and another on the back

side, per substrate, and the average value was used as the measurement value of the substrate. This was repeated for the one hundred substrates, and the variation (difference between the maximum value and the minimum value) was calculated. The results were evaluated relatively according to the following four ranks and are shown in Table 1. "Excellent", "Good", and "Fair" are acceptable for practical purposes.

Excellent: the variation is 0.015 mm or less.

Good: the variation is 0.025 mm or less.

Fair (roughly acceptable): the variation is 0.045 mm or less.

10 Poor (not acceptable): the variation is greater than 0.045 mm.

In addition, the surface roughness Ra of the chamfered surface was calculated based on the value measured using a laser microscope, and the results are also shown in Table 1.

15 Table 1 also shows the grinding speeds during the above-mentioned precision grinding.

[0058]

[Table 1]

Table 1	Grindstone hardness (GPa)	Edge surface roughness Ra (μm)	Accuracy of shape and dimensions of edge portion	Grinding speed ($\mu\text{m}/\text{sec}$)
Comparative Example 1	0.24	0.12	Poor	0.31
Working Example 1	0.41	0.10	Good	0.60
Working Example 2	0.57	0.10	Good	0.80
Working Example 3	0.79	0.09	Good	0.98
Working Example 4	0.98	0.08	Good	1.00
Working Example 5	1.20	0.06	Excellent	1.10
Working Example 6	1.59	0.06	Excellent	1.30
Working Example 7	1.70	0.08	Good	1.05
Comparative Example 2	1.82	0.12	Poor	0.40
Comparative Example 3	2.23	0.15	Poor	0.20

5 [0059]

As is clear from the results shown in Table 1 above, when the precision grinding was performed on the inner circumferential side edge surface of the substrate using the grindstones of working examples 1 to 7 that had a hardness in a range from 0.4 to 1.7 GPa, measured by the nano-indentation testing,

10 favorable results were obtained for the roughness of the edge surface and the accuracy of the shape and dimensions of the edge portion. It should be noted that the grinding speeds were also favorable.

In contrast, when the grindstone of comparative example 1 that had a

hardness smaller than 0.4 GPa, measured by the nano-indentation testing, was used, favorable results were not obtained for the quality of the edge surface and the grinding speed. That is, it is thought that in the region in which the hardness was too low, the strength to hold the abrasive particles was low, the abrasive particles increasingly fell off and a breaking state was entered during the processing, and therefore, a desired grinding speed was not obtained, resulting in a shear drop shape, whereby the quality of the edge surface deteriorated.

Moreover, when the grindstone of comparative examples 2 and 3 that had a hardness greater than 1.7 GPa, measured by the nano-indentation testing, was used, it is thought that the strength to hold the abrasive particles was too large, a spontaneous edge sharpening action by the abrasive particles falling off did not progress, and therefore, the grindstone was clogged due to grinding chips accumulating on the surface of the grindstone and was dulled due to the abrasive particles being worn, and thus a desired grinding speed was not obtained, and the quality of the processed surface deteriorated due to dimming and staining.

Furthermore, it was confirmed from the above results that it is ideal to use the hardness measured by the nano-indentation testing as an index when evaluating grinding performance of a grindstone.

[0060]

(Working examples 8 to 13)

For the above-mentioned precision grinding processing, six types of grindstones were prepared that were resin bond grindstones in which diamond abrasive particles were used and a binder for binding the abrasive particles was made of a phenol resin, had a hardness of 1.3 GPa, measured by the nano-indentation testing, and differed in the average particle diameter in a range from 1.5 to 25 μm .

The grinding processing was performed on the inner circumferential side edge surfaces of the glass substrates in the same manner as in working example 1, except that the above grindstones were used. The obtained glass substrates were evaluated in the same manner as in the working example 1, and the results are shown in Table 2.

[0061]

[Table 2]

Table 2	Average particle diameter of abrasive particles (μm)	Edge surface roughness Ra (μm)	Accuracy of shape and dimensions of edge portion
Working Example 8	25	0.10	Good
Working Example 9	15	0.08	Excellent
Working Example 10	8	0.07	Excellent
Working Example 11	5	0.06	Excellent
Working Example 12	2	0.05	Excellent
Working Example 13	1.5	0.10	Good

10 [0062]

As is clear from the results shown in Table 2 above, even when grindstones had the same level of hardness, the grindstones in which the abrasive particles had an average particle diameter in a range from 2 to 15 μm were advantageous because particularly favorable results were obtained for the roughness of the edge surface and the accuracy of the shape and dimensions of the edge portion. It should be noted that when the average particle diameter was 1.5 μm , slight grinding marks were observed on the surface.

When the precision grinding processing was performed on the outer

diameter edge portion using grindstones having the same specifications as those of working examples 8 to 13, in the case where the abrasive particles had an average particle diameter in a range from 2 to 15 μm , particularly favorable results were obtained for the roughness of the edge surface and the accuracy of the shape and dimensions of the edge portion as in the cases shown in Table 2 regardless of whether the glass substrate was inclined or not, and whether the processing was an external contact-type (see FIG. 1 and FIG. 2) or an internal contact-type (see FIG. 7).

[0063]

10 (Working examples 101 to 103 and comparative examples 101 and 102)

First, in the same manner as in the above-mentioned working examples, a disk-shaped glass substrate (glass disk) made of aluminosilicate glass and having a diameter of 66 mm ϕ was obtained from molten glass by direct pressing using upper, lower, and drum molds. Next, a lapping step was performed on the glass substrate to improve the dimensional accuracy and shape accuracy.

[0064]

Next, a cylindrical grindstone was used to make a hole in the central portion of the glass substrate, and the rough grinding processing was performed on the edge surfaces according to a processing method using a formed grindstone as shown in FIG. 1 above. Subsequently, the precision grinding processing was performed according to a method for performing processing in a state in which the grindstone was inclined with respect to the glass substrate and was brought into contact with the glass substrate as shown in FIG. 2 above.

An electrodeposition bond grindstone in which diamond abrasive particles were fixed with an electrodeposition bond was used in the above-mentioned rough grinding processing. Moreover, a resin bond grindstone including diamond abrasive particles having an average particle diameter of 5 μm and a phenol resin as a binder was used in the

above-mentioned precision grinding processing. Ten types of resin bond grindstones that were composed of the same component materials but differed in the hardness of the binder portion were prepared. The hardness of the binder portion of the grindstone was measured by the above-mentioned nano-indentation testing.

[0065]

Prior to main processing, the grinding processing was performed in advance on the edge surface of the glass substrate using the above-mentioned ten types of resin bond grindstones for the precision grinding under the same conditions as those in the main processing, and a correlation between the hardness of the grindstone measured by the above-mentioned nano-indentation testing and the grinding speed was determined and shown in FIG. 6. In FIG. 6, the range A in which the grinding speed of 0.5 $\mu\text{m}/\text{sec}$ or more was obtained was used as an optimum range, and three types of grindstones having a hardness in this optimum range A were selected. Furthermore, one type of grindstone having a hardness in the range B in which the hardness of a grindstone is lower than that in the optimum range was selected, and one type of grindstone having a hardness in the range C in which the hardness of a grindstone is higher than that in the optimum range was selected. It should be noted that the above-mentioned optimum range was from 0.4 to 1.7 GPa.

[0066]

Then, five types of grindstones in total selected in this manner were used to perform the main processing. The rough grinding processing was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 1, and the precision grinding processing was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 2. The inclination angle α of the grindstone with respect to the glass substrate was set

to 10 degrees. Moreover, the circumferential speeds, rotation directions, and processing pressures of the glass substrate and the grindstone were set as appropriate.

[0067]

- 5 The grinding processing was performed on the edge surfaces of the glass substrate in this manner, and one hundred glass substrates were manufactured.

10 The accuracy of the shapes and dimensions of the side wall surfaces and the chamfered surfaces of the edge surfaces of the obtained one hundred glass substrates was evaluated in the same manner as in the above-mentioned working examples, and the results are shown in Table 3. Also, the results from the surface roughness Ra of the chamfered surfaces and the grinding speed are shown in Table 3.

[0068]

- 15 [Table 3]

Table 3	Grindstone hardness (GPa)	Grinding speed ($\mu\text{m}/\text{sec}$)	Edge surface roughness Ra (μm)	Accuracy of shape and dimensions of edge portion
Working Example 101	1.00	1.0	0.08	Good
Working Example 102	1.20	1.1	0.06	Excellent
Working Example 103	1.56	1.3	0.06	Excellent
Comparative Example 101	0.24	0.31	0.12	Poor
Comparative Example 102	2.23	0.20	0.15	Poor

[0069]

As is clear from the results shown in Table 3, when the precision

grinding was performed on the edge surfaces of the substrate using the grindstone selected from the optimum range based on the correlation shown in FIG. 6 (working examples 101 to 103), favorable grinding speed was obtained. Favorable results were also obtained for the roughness of the edge surface and
5 the accuracy of the shape and dimensions of the edge portion.

In contrast, when the grindstone selected from the range in which the hardness was lower than that in the optimum range was used (comparative example 101), favorable results were not obtained for the grinding speed. Favorable results were also not obtained for the roughness of the edge surface
10 and the accuracy of the shape and dimensions of the edge portion. That is, it is thought that in the region in which the hardness was low, the strength to hold the abrasive particles was low, the abrasive particles increasingly fell off and a breaking state was entered during the processing, and therefore, a desired grinding speed was not obtained, resulting in a shear drop shape, whereby the
15 quality of the edge surface deteriorated.

Furthermore, when the grindstone selected from the range in which the hardness was higher than that in the optimum range was used (comparative example 102), favorable grinding speed was not obtained. Favorable results were also not obtained for the roughness of the edge surface and the accuracy
20 of the shape and dimensions of the edge portion. In this case, it is thought that the strength to hold the abrasive particles was too large, a spontaneous edge sharpening action caused by the abrasive particles falling off did not progress, and therefore, the grindstone was clogged due to grinding chips accumulating on the surface of the grindstone and was dulled due to the abrasive particles
25 being worn, and thus a desired grinding speed was not obtained, and the quality of the processed surface deteriorated due to dimming and staining.

It was confirmed from the above results that when grinding performance of a grindstone is evaluated, it is ideal to determine in advance a correlation

between the hardness measured by the nano-indentation testing and the grinding speed when this grindstone was used to grind the edge surface of a glass substrate under a certain condition and to select a grindstone based on the determined correlation.

5 [0070]

(Working examples 201 to 212 and comparative examples 201 to 208)

In the same manner as in the above-mentioned working examples, a disk-shaped glass substrate (glass disk) made of aluminosilicate glass and having a diameter of 66 mmφ was obtained from molten glass by direct pressing
10 using upper, lower, and drum molds. Next, a lapping step was performed on the glass substrate to improve the dimensional accuracy and shape accuracy.

Next, a cylindrical grindstone was used to make a hole in the central portion of the glass substrate, and the rough grinding processing was performed on the outer circumferential edge surface according to a processing method
15 using a formed grindstone as shown in FIG. 1 above. Subsequently, the precision grinding processing was performed according to a method described below.

An electrodeposition bond grindstone in which diamond abrasive particles were fixed with an electrodeposition bond was used in the
20 above-mentioned rough grinding processing. Moreover, a resin bond grindstone including diamond abrasive particles having an average particle diameter of 5 μm and a phenol resin as a binder was used in the above-mentioned precision grinding processing. Five types of resin bond grindstones that were composed of the same component materials but differed
25 in the hardness of the binder portion were prepared. The hardness of the binder portion of the grindstone was measured by the above-mentioned nano-indentation testing.

[0071]

Then, each of the five types of grindstones was used to perform the precision grinding processing on the outer circumferential edge surface of the substrate. The following four types of methods were performed as the precision grinding processing method.

5 A first method was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 1 (indicated as "external (FIG. 1)" in Table 4.

 A second method was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 7,
10 and the inclination angle of the grindstone with respect to the glass substrate was set to 0 degrees (i.e., no inclination) (indicated as "internal" in Table 4).

 A third method was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 2, and the inclination angle α of the grindstone with respect to the glass substrate
15 was set to 10 degrees (indicated as "external and inclined (FIG. 2)" in Table 4).

 A fourth method was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 7, and the inclination angle α of the grindstone with respect to the glass substrate was set to 10 degrees (indicated as "internal and inclined (FIG. 7)" in Table 4).

20 It should be noted that the circumferential speeds, rotation directions, and processing pressures of the glass substrate and the grindstone were set as appropriate.

[0072]

 The precision grinding processing was performed on the outer
25 circumferential edge surface of the substrate in this manner with the five types of grindstones and the four types of processing methods used in combination, and one hundred glass substrates were manufactured in each processing.

 The accuracy of the shape and dimensions of the side wall surfaces and

the chamfered surfaces of the outer circumferential edge surfaces of the obtained one hundred glass substrates was evaluated in the same manner as in the above-mentioned working examples, and the results are shown in Table 4. Also, the results from the surface roughness Ra of the chamfered surfaces and

5 the grinding speed are shown in Table 4.

[0073]

[Table 4]

Table 4	Processing method	Grindstone hardness (GPa)	Edge surface roughness Ra (μm)	Accuracy of shape and dimensions of edge portion	Grinding speed (μm/sec)
Comparative. Example. 201	External (FIG. 1)	0.24	0.15	Poor	0.31
Comparative Example 202	Internal	0.24	0.13	Poor	0.29
Comparative Example 203	External and inclined (FIG. 2)	0.24	0.13	Poor	0.31
Comparative Example 204	Internal and inclined (FIG. 7)	0.24	0.12	Poor	0.28
Working Example 201	External (FIG. 1)	0.41	0.10	Good	0.60
Working Example 202	Internal	0.41	0.08	Good	0.59
Working Example 203	External and inclined (FIG. 2)	0.41	0.08	Good	0.61
Working Example 204	Internal and inclined (FIG. 7)	0.41	0.07	Good	0.58
Working Example 205	External (FIG. 1)	1.2	0.06	Excellent	1.10
Working Example 206	Internal	1.2	0.05	Excellent	1.08
Working Example 207	External and inclined (FIG. 2)	1.2	0.04	Excellent	1.11
Working Example 208	Internal and inclined (FIG. 7)	1.2	0.03	Excellent	1.08
Working Example 209	External (FIG. 1)	1.7	0.08	Good	1.05
Working Example 210	Internal	1.7	0.08	Good	1.04
Working Example 211	External and inclined (FIG. 2)	1.7	0.07	Good	1.05
Working Example 212	Internal and inclined (FIG. 7)	1.7	0.06	Good	1.03
Comparative Example 205	External (FIG. 1)	1.82	0.16	Poor	0.41
Comparative Example 206	Internal	1.82	0.14	Poor	0.40
Comparative Example 207	External and inclined (FIG. 2)	1.82	0.13	Poor	0.39
Comparative Example 208	Internal and inclined (FIG. 7)	1.82	0.11	Poor	0.39

As is clear from the results shown in Table 4, when the precision grinding was performed on the outer circumferential edge surface of the substrate using the grindstones having a hardness in a range from 0.4 to 1.7 GPa, measured by the nano-indentation testing, favorable results were obtained for the roughness of the edge surface and the accuracy of the shape and dimensions of the edge portion in each processing method. It should be noted that the grinding speeds were also favorable.

In particular, as for the roughness of the edge surface, more favorable results were obtained when the processing was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 7 (internal, but not inclined) rather than when the processing was performed with the above-mentioned positional relationship between the glass substrate and the grindstone shown in FIG. 1 (external). Moreover, when the processing was performed in a state in which the grindstone was inclined with respect to the glass substrate as shown in FIG. 2 and FIG. 7, more favorable results were obtained.

In contrast, when the grindstones having a hardness of smaller than 0.4 GPa or greater than 1.7 GPa, measured by the nano-indentation testing, were used, favorable results were not obtained for both the quality of the edge surface and the grinding speed when using any processing method.

Description of Reference Numerals

[0075]

- | | | |
|----|------|--|
| | 1 | Magnetic-disk glass substrate |
| 25 | 2, 7 | Grindstone for outer circumferential side edge surface |
| | 3, 8 | Grindstone for inner circumferential side edge surface |
| | 6 | Groove |
| | 1a | Main surface of glass substrate |

- 1b Side wall surface
- 1c Chamfered surface

CLAIMS

1. A grindstone for grinding an edge surface of a disk-shaped glass substrate having a circular hole in a central portion, the grindstone comprising:
abrasive particles; and
5 a binder for binding the abrasive particles,
wherein a binder portion on a surface of the grindstone has a hardness in a range from 0.4 to 1.7 GPa, measured by nano-indentation testing using a Berkovich indenter under a condition that an indentation load of 250 mN is applied.
- 10 2. The grindstone according to claim 1,
wherein the abrasive particles have an average particle diameter in a range from 2 to 15 μm .
3. The grindstone according to claim 1 or 2, which is a rotary grindstone to be used in processing in which the grindstone is brought into
15 contact with the edge surface of the glass substrate in a state in which a rotation axis of the grindstone is inclined with respect to an axis orthogonal to a main surface of the glass substrate and grinds the edge surface of the glass substrate.
4. A method for manufacturing a magnetic-disk glass substrate
20 comprising performing grinding processing on the edge surface of the glass substrate using the grindstone according to any of claims 1 to 3.
5. A method for manufacturing a magnetic-disk glass substrate comprising grinding processing for grinding an edge surface of a disk-shaped glass substrate having a circular hole in a central portion using a grindstone,
25 wherein the grindstone includes abrasive particles and a binder for binding the abrasive particles,
a correlation is determined in advance between hardness of a binder portion on a surface of the grindstone, measured by nano-indentation testing

using a Berkovich indenter under a condition that an indentation load of 250 mN is applied, and a grinding speed when the grindstone is used to grind the edge surface of the glass substrate, and

a grindstone that has a hardness with which a desired grinding speed is
5 obtained is selected based on the determined correlation, and the grinding processing is performed using the selected grindstone.

6. The method for manufacturing a magnetic-disk glass substrate according to claim 5,

wherein in the grindstone, the binder is made of a resin material, and
10 hardness measured by the nano-indentation testing is in a range from 0.4 to 1.7 GPa.

7. The method for manufacturing a magnetic-disk glass substrate according to claim 5 or 6,

wherein the selected grindstone is used in processing in which the
15 grindstone is brought into contact with the edge surface of the glass substrate in a state in which a rotation axis of the grindstone is inclined with respect to an axis orthogonal to a main surface of the glass substrate, and grinds the edge surface of the glass substrate.

8. The method for manufacturing a magnetic-disk glass substrate
20 according to any of claims 4 to 7,

wherein the edge surface of the glass substrate is ground so as to have a surface roughness Ra of 0.1 μm or less.

9. A method for manufacturing a magnetic disk comprising forming at least a magnetic recording layer on the magnetic-disk glass substrate
25 manufactured by the method for manufacturing a magnetic-disk glass substrate according to any of claims 4 to 8.