

## DESCRIPTION

Title of the Invention:

METHOD FOR PRODUCING GLASS SUBSTRATE FOR MAGNETIC DISK  
5 AND METHOD FOR PRODUCING MAGNETIC DISK

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]

As described above, it is essential for a magnetic disk to have a highly smooth surface to achieve the low flying height that is necessary for achieving a high recording density. In order to attain a highly smooth magnetic disk surface, a highly smooth substrate surface is ultimately required, and thus it is necessary to precisely polish the surface of the glass substrate. In order to produce such a glass substrate, a highly smooth main surface has been achieved by performing grinding (lapping) to adjust the thickness and to improve the flatness (planeness), and by then further performing polishing to reduce surface roughness and minute waviness.

10 [0004]

Incidentally, a grinding method with fixed abrasive particles that uses a diamond pad in a grinding (lapping) step (Patent Literature 1, for example) in which loose abrasive particles were used conventionally has been proposed (Patent Literature 2, for example). A diamond pad is a sheet to which are stuck pellets formed by using a supporting material such as a resin (e.g., acrylic resin) to fix diamond particles or aggregates consisting of some diamond particles held together with a binder such as glass, ceramic, a metal or a resin. Alternatively, a diamond pad may also be obtained by forming a resin layer containing diamond particles on a sheet and then forming grooves in the resin layer to form projections. It should be noted that although the term "diamond pad" used here is not necessarily in common usage, "diamond pad" will be used herein for the sake of convenience.

[0005]

With conventional loose abrasive particles, abrasive particles with uneven shapes are present non-uniformly between the surface plate and the glass sheet, and thus the load applied to the abrasive particles is not uniform. If the load is concentrated in certain areas, deep cracks form in the glass sheet because the elasticity of the surface of the cast-iron surface plate is poor.

Accordingly, deeper layers are affected and the roughness of the processed glass surface increases, requiring large amounts of glass to be removed in the subsequent mirror-polishing step, and thus making it difficult to reduce processing costs. In contrast, in grinding with fixed abrasive particles using a diamond pad, the abrasive particles are uniformly present on the sheet surface, and thus the load is not concentrated in certain areas. In addition, the abrasive particles are fixed to the sheet using a resin, and therefore, even when a load is applied to the abrasive particles, cracks in the processed surface are shallow (shallow layers are affected) due to the highly elastic nature of the resin that fixes the abrasive particles. Thus, the roughness of the processed surface can be reduced, the load (e.g., machining allowance) on subsequent steps is reduced, and processing cost can be reduced.

After this grinding (lapping) step, mirror-polishing is performed to obtain a high precision flat surface.

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Prior Art Literature

Patent Literature

[0006]

Patent Literature 1: JP 2001-6161 A

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Patent Literature 2: JP 2012-209010 A

Summary of the Invention

Problem to be Solved by the Invention

[0007]

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As described above, in the grinding method with fixed abrasive particles using a diamond pad, the roughness of the processed surface can be reduced, the load on the subsequent mirror-polishing step is reduced, and the processing cost of glass substrates can be reduced. However, investigations conducted

by the inventors revealed the following problems.

That is, in the case where a glass substrate obtained by cutting a sheet of plate glass manufactured by a float method into a predetermined shape directly underwent simultaneous double-side grinding with fixed abrasive particles using a conventional diamond pad as disclosed in Patent Literature 2 above, flatness after the processing was deteriorated, and thus sufficient smoothness sometimes could not be achieved when manufacturing magnetic disks.

[0008]

It should be noted that although mirror-polishing is performed after the above-described grinding, machining allowance in this mirror-polishing is extremely small, and thus it is difficult to improve the flatness deteriorated by the grinding. Accordingly, it is necessary to sufficiently improve the flatness of the glass substrate by the grinding.

[0009]

The present invention was made in order to solve the foregoing conventional problems, and an object of the present invention is to provide a method for manufacturing a magnetic-disk glass substrate that can manufacture a high-quality glass substrate having a favorable flatness after processing, and a method for manufacturing a magnetic disk using the glass substrate obtained by the above method.

Means to Solve the Problem

[0010]

As a result of investigations by the inventors into the causes of the deterioration of flatness after processing in the case where simultaneous double-side grinding with fixed abrasive particles using a conventional diamond pad was performed, it was found that the main surface of the glass substrate

having a surface portion containing tin in a large amount had a larger roughness than the main surface on a side opposite thereto after the processing. That is, it is thought that in the case where both main surfaces of the glass substrate had different surface roughness due to the grinding, a difference in residual stress  
5 would arise due to the Twyman's effect, thus causing the substrate to be warped.

[0011]

It should be noted that a sheet of plate glass manufactured by a float method has a surface portion containing tin in a large amount on one main  
10 surface side due to the manufacturing method. In this specification, hereinafter, this main surface of the glass substrate having a surface portion containing tin in a large amount is referred to merely as a "tin surface" for the sake of convenience, and the main surface on the side opposite thereto that contains tin in a very small amount is referred to merely as a "non-tin surface".

15 [0012]

As a result of further investigations by the inventors, it was revealed that in the case where the glass substrate using plate glass manufactured by a float method was used, the tin surface was processed at a higher processing speed than the non-tin surface in the grinding with fixed abrasive particles. Moreover,  
20 in the simultaneous double-side grinding in which a pair of an upper surface plate and a lower surface plate having a grinding surface provided with fixed abrasive particles such as diamond particles is used and both main surfaces of the glass substrate are sandwiched between and ground with the pair of upper and lower surface plates while supplying a lubricant between the surface plates  
25 and the glass substrate, when the processing speed is increased, the surface roughness of the processed surface is generally increased. It is inferred that in the case where the tin surface side of the glass substrate, which is processed at a high processing speed, is processed using a surface plate with a high

processing speed (e.g., upper surface plate), the difference in the surface roughness between the main surfaces of the glass substrate is increased by the synergistic effect of increasing the processing speed, as a result of which the substrate is warped.

5 [0013]

The present invention was made based on the above findings obtained through the investigations of the inventors and furthermore as a result of their intensive research.

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

(Aspect 1)

An aspect of the present invention is a method for manufacturing a magnetic-disk glass substrate including grinding processing for using a lubricant and a pair of an upper surface plate and a lower surface plate having a grinding  
15 surface provided with fixed abrasive particles including diamond particles, and sandwiching and grinding both main surfaces of the glass substrate with the pair of upper and lower surface plates while supplying the lubricant between the grinding surfaces and the glass substrate, wherein the glass substrate is obtained by cutting a sheet of plate glass manufactured by a float method into a  
20 predetermined shape, and one main surface side has a surface portion containing tin in a larger amount than that of the other main surface side, the grinding processing is performed such that the upper surface plate side and the lower surface plate side are different in a processing speed, and the main surface of the glass substrate having the surface portion containing tin in a large  
25 amount is set on the surface plate side with the lower processing speed and ground.

[0014]

(Aspect 2)

In the method for manufacturing a magnetic-disk glass substrate according to aspect 1, the substrate after being ground has a flatness of 2.5  $\mu\text{m}$  or less.

(Aspect 3)

- 5            In the method for manufacturing a magnetic-disk glass substrate according to aspect 1 or 2, grinding is performed such that a difference in surface roughness between both of the main surfaces of the ground substrate is 0.01  $\mu\text{m}$  or less in Ra.

[0015]

- 10           (Aspect 4)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 3, both of the main surfaces of the ground substrate have a roughness of 0.130  $\mu\text{m}$  or less in Ra.

(Aspect 5)

- 15           In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 4, when simultaneously grinding a plurality of glass substrates, the main surfaces having the surface portion containing tin in a large amount are all set so as to face in the same direction.

[0016]

- 20           (Aspect 6)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 5, an amount of projection of the fixed abrasive particles on the surface plate side with the relatively higher processing speed is relatively greater compared with the surface plate side with the lower processing  
25 speed.

(Aspect 7)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 6, the grinding processing includes a first stage

in which the main surfaces of the glass substrate are roughened with a higher load than a load applied in grinding and a second stage, after the first stage, in which the surface of the glass substrate is ground with a lower load than the load applied in the first stage.

5 [0017]

(Aspect 8)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 7, a processing speed in the grinding processing is 3.0 to 9.0  $\mu\text{m}/\text{minute}$ .

10 (Aspect 9)

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 8.

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Effects of the Invention

[0018]

With the present invention, it is possible to suppress a deterioration of flatness of a substrate in a grinding process using conventional fixed abrasive particles. This makes it possible to manufacture a high-quality glass substrate. Furthermore, it is possible to obtain a highly reliable magnetic disk using the glass substrate obtained by the present invention.

20

Brief Description of Drawings

25 [0019]

FIG. 1 is a schematic cross-sectional view showing a configuration of a diamond pad that is used in the present invention.

FIG. 2 is a schematic view illustrating a state during grinding.

FIG. 3 is a diagram showing an example of a sequence of applied loads in grinding processing of the present invention.

#### Mode for Embodying the Invention

5 [0020]

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

As described in aspect 1 above, the present invention is a method for manufacturing a magnetic-disk glass substrate including grinding processing for using a lubricant and a pair of an upper surface plate and a lower surface plate having a grinding surface provided with fixed abrasive particles including diamond particles, and sandwiching and grinding both main surfaces of the glass substrate with the pair of upper and lower surface plates while supplying the lubricant between the surface plates and the glass substrate, wherein the glass substrate is obtained by cutting a sheet of plate glass manufactured by a float method into a predetermined shape, and one main surface side has a surface portion containing tin in a larger amount than that of the other main surface side, the grinding processing is performed such that the upper surface plate side and the lower surface plate side are different in a processing speed, and the main surface of the glass substrate having the surface portion containing tin in a large amount is set on the surface plate side with the lower processing speed and ground. Moreover, as described in aspect 2 above, it is preferable that the substrate after being ground has a flatness of 2.5  $\mu\text{m}$  or less.

[0021]

25 The magnetic-disk glass substrate is generally manufactured through a rough grinding step (rough lapping step), a shape processing step, a precision grinding step (precision lapping step), an edge surface polishing step, a main surface polishing step, a chemical strengthening step, and the like.

In a method for manufacturing a magnetic-disk glass substrate according to the present invention, a glass substrate is used that is obtained by cutting a sheet of plate glass manufactured by a float method into a glass substrate having a predetermined size. As described above, a sheet of plate glass manufactured by a float method has a surface portion containing tin in a large amount on one main surface side due to the manufacturing method. With the present invention, problems are solved that are specific to the case where a glass substrate obtained from a sheet of plate glass manufactured by a float method is used.

10 [0022]

Next, grinding (lapping) for enhancing the dimensional accuracy and shape accuracy is performed on this glass substrate. In this grinding, a double-side lapping device is generally used to grind the main surfaces of the glass 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.

[0023]

The present invention relates to an improvement of this grinding. The grinding processing in the present invention is grinding that uses fixed abrasive particles containing diamond particles, and for example, in a double-side lapping device, a glass substrate that is held by a carrier is tightly placed between an upper surface plate and a lower surface plate to which diamond pads are attached, then the glass substrate and the upper and lower surface plates are moved relative to each other while the glass substrate is pressed by the upper and lower surface plates at a predetermined pressure, and thus both main surfaces of the glass substrate are ground simultaneously. At this time, a lubricant (coolant) is supplied in order to cool the processing work surfaces and

promote processing.

[0024]

FIG. 1 shows an outline of the configuration of a diamond pad 1 serving as a grinding tool (grindstone with fixed abrasive particles) used in the present invention. The diamond pad 1 is obtained by sticking, to a sheet 2, pellets 4 to which aggregates 3 consisting of some diamond particles 5 (see FIG. 2) held together with a binder such as glass, ceramic, a metal or a resin are fixed by using a supporting material such as a resin (e.g., acrylic resin). It should be understood that the configuration shown in FIG. 1 is merely an example, and the present invention is not to be construed as being limited thereto. For example, a diamond pad obtained by forming a resin layer containing diamonds on a sheet and then forming grooves in the resin layer to form projections may also be used. Each diamond particle contained in the aggregates preferably has a size of 1 to 5  $\mu\text{m}$  in terms of average particle diameter.

15 [0025]

It is possible to manufacture diamond pads with different particle diameters (average particle diameters) of the above-described aggregates and different densities of the abrasive particles in the resin. It should be noted that in this embodiment, a case where the above-described aggregates are used as diamond fixed abrasive particles is described. Accordingly, in the present invention, unless otherwise stated, "diamond fixed abrasive particles" means the above-described aggregates, and the terms "average particle diameter of diamond abrasive particles" and "density of abrasive particles" respectively mean the average particle diameter of the above-described aggregates and the density of the aggregates in the pellet.

However, the present invention is not limited to the case where the above-described aggregates are used as diamond fixed abrasive particles. It is also possible to use a diamond pad in which each of diamond fixed abrasive

particles is not an aggregate but a single diamond particle.

[0026]

As described above, the grinding processing of the present invention is performed such that in the simultaneous double-side grinding, a difference in  
5 process speed is created between an upper surface plate side and a lower surface plate side, and a tin surface of the glass substrate having a surface portion containing tin in a large amount is set and ground on the surface plate side with the lower processing speed.

With the present invention, it is possible to perform processing such that  
10 the flatness is improved compared with the case where the tin surface of the glass substrate is set to a side of the surface plate whose processing speed is high, for example. It is possible to perform grinding such that the substrate that has undergone the grinding has a flatness of 2.5  $\mu\text{m}$  or less.

[0027]

As described above, in the case where the glass substrate using plate  
15 glass manufactured by a float method is used, the tin surface is processed at a higher processing speed than the non-tin surface in the grinding with fixed abrasive particles, and has a larger surface roughness after the grinding. Therefore, in the present invention, by setting the tin surface of the glass  
20 substrate on the surface plate side with the lower processing speed and grinding the tin surface, it is possible to perform processing such that both main surfaces of the substrate have the surface roughness after grinding at the same level. As a result, it is possible to prevent the substrate from being warped after the grinding, and thus to obtain a glass substrate having a favorable flatness.

25 [0028]

For example, in the case where the processing speed on the lower surface plate side of the upper and lower surface plates is made lower than that of the upper surface plate, it is preferable to set the tin surface of the glass

substrate on the lower surface plate side. In contrast, if the processing speed on the upper surface plate side is made slower than that of the lower surface plate, it is preferable to set the tin surface of the glass substrate on the upper surface plate side.

5 [0029]

In the grinding processing of the present invention, the simultaneous double-side grinding with fixed abrasive particles needs to be set such that the upper surface plate side and the lower surface plate side are made different in a processing speed. If the processing speed on the upper surface plate side and  
10 the processing speed on the lower surface plate side are at the same level, the main surfaces have different surface roughness due to the difference in the processing speed between the tin surface and the non-tin surface of the glass substrate, and therefore, it is not possible to prevent the substrate from being warped.

15 [0030]

It is preferable to set the difference in the processing speed between the upper surface plate side and the lower surface plate side so as to cancel out, as much as possible, the difference between the processing speeds at which the tin surface and the non-tin surface of the glass substrate are processed. In the  
20 case where the glass substrate using plate glass manufactured by a float method is used, the tin surface is processed at a processing speed higher by about 10 to 20% than the non-tin surface, and therefore, it is preferable to set the difference in the processing speed between the upper surface plate side and the lower surface plate side so as to substantially cancel out the difference in the  
25 surface roughness between the main surfaces of the substrate due to the difference between the processing speeds at which the tin surface and the non-tin surface are processed. That is, it is preferable that the processing speed of the surface plate with which the tin surface is processed is lower by 10

to 20% than that of the surface plate on the opposite side.

[0031]

The processing speeds on the upper and lower surface plate sides can be adjusted by the rotation speeds of the upper and lower surface plates, and rotation, revolution, and the like of a work carrier determined by the rotation speed of a sun gear and the rotation speed of an internal gear. Accordingly, by adjusting these respectively on the upper and lower surface plate sides, it is possible to set the processing speeds on the upper surface plate side and the lower surface plate side such that the desired difference in processing speed occurs.

[0032]

In the present invention, it is preferable to perform grinding such that the substrate that has undergone the grinding has a flatness of 2.5  $\mu\text{m}$  or less in order to obtain a glass substrate having a favorable flatness. It is more preferable to perform grinding such that the substrate has a flatness of 2.0  $\mu\text{m}$  or less. If the substrate that has undergone the grinding has a flatness of more than 2.5  $\mu\text{m}$ , it is difficult to improve the flatness by subsequent polishing. It should be noted that the flatness of the substrate can be measured by a method described later in examples.

[0033]

In the grinding processing of the present invention, it is desirable to set the tin surface of the glass substrate on the surface plate side with the lower processing speed as described above, and to grind the main surfaces such that a difference in surface roughness  $R_a$  ( $\Delta R_a$ ) between the main surfaces of the substrate that has undergone the grinding is 0.01  $\mu\text{m}$  or less. This makes it possible to cause the substrate that has undergone the grinding to have a flatness of 2.5  $\mu\text{m}$  or less. It is more preferable to grind the main surfaces such that a difference in surface roughness  $R_a$  ( $\Delta R_a$ ) between the main surfaces of

the substrate that has undergone the grinding is 0.005  $\mu\text{m}$  or less. This makes it possible for the substrate that has undergone the grinding to have a more favorable flatness of 2.0  $\mu\text{m}$  or less. It should be noted that the surface roughness of the substrate can be measured by a method described later in examples.

[0034]

In the present invention, it is preferable for both main surfaces of the glass substrate that has undergone the above-described grinding to have a roughness of 0.130  $\mu\text{m}$  or less in Ra. The roughness finished by the above-described grinding is suppressed to a low level in this manner, thus making it possible to reduce the processing load on a subsequent polishing step.

[0035]

Generally, in the manufacture of magnetic-disk glass substrates, a plurality of glass substrates (about one hundred substrates per batch) are simultaneously ground, and it is preferable to set the glass substrates on the surface plate side with the lower processing speed such that all the tin surfaces thereof face in the same direction and to perform processing. This makes it possible to finish all the processed glass substrate so as to have a favorable flatness.

[0036]

Incidentally, in the case where a substrate having a mirror glass surface, such as plate glass manufactured by a float method is directly ground with fixed abrasive particles using a diamond pad, the diamond abrasive particles have difficulty engaging the substrate surface and tend to slide over the surface due to the substrate surface being a mirror surface at an early stage of the processing, and thus there is likely to be a period of time during which no grinding is performed.

[0037]

In the present invention, it is preferable to relatively increase the amount of projection of fixed abrasive particles on the surface plate side with a relatively higher processing speed compared with the surface plate side with a lower processing speed. That is, it is preferable to relatively increase the amount of projection of fixed abrasive particles on the surface plate side with a relatively higher processing speed compared with the surface plate side with a lower processing speed, and to process the non-tin surface on that surface plate side.

In the present invention, sludge is likely to accumulate on the surface of the grindstone with fixed abrasive particles due to the main surface of the substrate that is processed being a mirror surface. The inventors found that it is preferable to control the amount of projection of fixed abrasive particles in the upper and lower surface plates in the case where a large number of substrates is processed using the same grindstone with fixed abrasive particles in order to increase the productivity.

That is, by relatively increasing the amount of projection of fixed abrasive particles on the surface plate side with a relatively higher processing speed compared with the surface plate side with a lower processing speed, it is possible to suppress the variation in flatness among the substrates in the case where a large number of substrates are processed. It is thought that this is because engaging properties of fixed abrasive particles at an early stage of the grinding are improved on the non-tin surface side that is difficult to grind, and thus the abrasive particles engage the non-tin surface at the same timing.

[0038]

The above-described amount of projection of fixed abrasive particles can be measured as follows.

In grindstones (generally formed in a disk shape) of the upper and lower surface plates before performing the grinding, six samples (pad pieces) in total that each have a size of 2.5 mm×2.5 mm are cut out at positions 10%, 50% and

90% away from the inner circumference when the distance between the inner circumference and the outer circumference is given as 100%. In each of the six samples, five arbitrary abrasive particles are selected from an observation image obtained using a laser microscope, for example, the differences in height  
5 between the selected abrasive particles and resin portions around the abrasive particles are measured, and the amount of projection of the abrasive particles in the grindstone is defined as the average value of the differences in height of all of the selected abrasive particles.

[0039]

10 The amount of projection of the abrasive particles can be adjusted by dressing, for example. Specifically, the double-side grinding device used in grinding is also used in dressing, for example, and dressing can be performed in a state in which grindstones that are controlled so as to have appropriate thickness variation are brought into contact with the surfaces of a grindstone  
15 such as a diamond pad provided on the upper and lower surface plates, and the upper and lower surface plates of the double-side grinding device are rotated. Although there is no particular restriction on the material of a grindstone used in dressing, it is preferable to use an alumina grindstone, for example. In this case, a plurality of grindstones having different thickness variations may also be  
20 used to perform dressing in a gradual manner.

It is preferable that a difference in the amount of projection of fixed abrasive particles between the upper and lower surface plates is 0.1  $\mu\text{m}$  or more in order to obtain a stable effect. If the difference in the amount of projection of fixed abrasive particles is more than 10  $\mu\text{m}$ , there is a risk that scratches will  
25 occur on a side in which the amount of projection is large, and therefore, it is preferable that the difference in the amount of projection of fixed abrasive particles is set to 10  $\mu\text{m}$  or less.

[0040]

Moreover, in the grinding processing of the present invention, it is also preferable to perform grinding through a first stage in which the surface of the glass substrate is roughened with a higher load than a load applied in grinding and a second stage, after the first stage, in which the surface of the glass  
5 substrate is ground with a lower load than the load applied in the first stage.

In order to directly grind the mirror glass surface using a diamond pad, first, it is necessary to apply a higher load to the glass surface than that in ordinary grinding for the purpose of causing the diamond abrasive particles to engage the surface of the glass substrate. A high load enables the roughness  
10 of the glass surface to be increased (roughened) because the cuts made by the abrasive particles are deeper. The above-described first stage is a stage for causing the diamond abrasive particles to engage a mirror glass surface to roughen the surface in this manner.

[0041]

15 After the glass surface is roughened in the first stage during such processing, a high load is no longer necessary in the grinding. The load is thus reduced, and original grinding (main processing) is performed under conditions that cause the cuts made by the abrasive particles to be shallower. The above-described second stage is a stage for performing this main processing.  
20 FIG. 2 is a diagram illustrating a state during grinding, and shows a state in which the diamond abrasive particles 3 are engaging a glass substrate 10 and grind the glass substrate 10 (image).

[0042]

By performing the grinding process having the first stage and the second  
25 stage described above, it is possible to perform the grinding without reducing the processing speed. Furthermore, by adjusting detailed conditions of the grinding, the roughness of the finished surface can also be suppressed to a low level.

FIG. 3 is a diagram showing an example of a sequence of applied loads in this grinding processing.

In FIG. 3, the horizontal axis indicates time, and the vertical axis indicates load. The load is gradually increased from the start to a point of time when the load reaches P1 (point A), and is then maintained for a given fixed time period (t1). This is the above-described first stage in which the glass surface is roughened.

It should be noted that the application of load reaching point A may be divided into multiple steps. That is, the load may be increased in a stepwise manner (in a stepped manner in the sequence).

The load is gradually reduced from point B to a point of time when the load reaches an ordinary grinding load P2 (point C), and is then maintained for a given fixed time period (t2). The grinding is finished at point D. The stage between point C and point D is the above-described second stage in which the main processing is performed.

[0043]

It is preferable that the load P1 in the above-described first stage is in a range of 130 to 200 g/cm<sup>2</sup>. If the load P1 is smaller than 130 g/cm<sup>2</sup>, the period of time during which no grinding is performed cannot be reduced sufficiently, and the processing speed will decrease. On the other hand, if the load P1 is larger than 200 g/cm<sup>2</sup>, cuts made by the abrasive particles are formed too deeply, and thus a large number of scratches occur. Therefore, it is necessary to increase machining allowance in the main processing and the subsequent polishing step, and there is a risk that the processing time will be extended.

It is preferable that the load P2 in the above-described second stage is in a range of 50 to 120 g/cm<sup>2</sup>. By adjusting the conditions of the grinding, the roughness of the processed surface can also be suppressed to a low level.

Furthermore, it is preferable that P1/P2 is 3.0 or less. This makes it

possible to improve the processing speed as well as achieve a low roughness after the grinding.

[0044]

It is preferable that the load application speed (slope  $k$ ) in the first stage  
 5 between the start of processing and point A above (load  $P1$ ) is 0.5 to 15  
 $\text{g}/(\text{cm}^2 \cdot \text{sec})$ . The slope  $k$  is preferably not smaller than  $0.5 \text{ g}/(\text{cm}^2 \cdot \text{sec})$  (that is,  
 the application speed is low) because the abrasive particles slide rather than  
 engaging due to the low load and are instead abraded, such that the grinding  
 capacity is deteriorated. On the other hand, in the case where the slope  $k$  is  
 10 greater than  $15 \text{ g}/(\text{cm}^2 \cdot \text{sec})$  (that is, the application speed is high), a sudden load  
 is applied to the glass substrate, and therefore, the grinding capacity may be  
 deteriorated due to the abrasive particles being crushed or the glass substrate  
 may break.

[0045]

It is preferable that the time period  $t1$  for roughening the surface with the  
 15 load  $P1$  in the above-described first stage is in a range of 10 to 600 seconds. If  
 $t1$  is shorter than 10 seconds, there is a risk that the abrasive particles will  
 insufficiently engage the glass main surface and the processing speed will  
 decrease. On the other hand, if  $t1$  is longer than 600 seconds, deep scratches  
 20 are likely to occur, and there is a risk that the finished main surface will become  
 rough.

It is preferable that a period of time between point B and point C during  
 which the load is gradually reduced from the load  $P1$  to the ordinary grinding  
 load  $P2$  is in a range of 10 to 90 seconds, for example. If the period of time  
 25 between points B and C is shorter than 10 seconds, there is a risk that the  
 flatness will be deteriorated due to the abrupt change of load. On the other  
 hand, if the period of time between points B and C is longer than 90 seconds,  
 there are risks that it will become difficult to control the thickness because of the

glass substrate being excessively ground while the load changes from P1 (first stage) to P2 (second stage), and that deep scratches will occur to increase the roughness of the finished main surface.

[0046]

5           It is preferable that the time period  $t_2$  during which the grinding is performed with the load P2 in the above-described second stage is 30 seconds or more. If a certain amount of grinding is not performed with the load P2, there is a risk that grooves formed with the load P1 will not be completely removed and will remain as scratches. The upper limit of  $t_2$  is determined as appropriate  
10 considering finish quality to be achieved by the grinding processing, and the like. It should be noted that it is preferable that  $t_1 < t_2$  because the finished roughness can be reduced.

[0047]

Moreover, in the present invention, the processing speed of the overall  
15 grinding processing is in a range of about 3.0 to 9.0  $\mu\text{m}/\text{minute}$ , and the grinding can be performed without reducing the processing speed. It should be noted that the processing speed of the overall grinding processing refers to a value obtained by dividing the total ground thickness by the total processing time (including the first stage and the second stage).

20 [0048]

In the present invention, it is preferable that the average particle diameter of the above-described diamond fixed abrasive particles is 20 to 40  $\mu\text{m}$ . Furthermore, it is preferable that the particle diameter of each diamond fixed abrasive particle is 10 to 50  $\mu\text{m}$ . If the average particle diameter of the  
25 above-described diamond abrasive particles or the particle diameter of each diamond abrasive particle is smaller than the above-described values, shallow cuts are made in the mirror glass substrate, and the abrasive particles do not engage the glass substrate. On the other hand, if the average particle diameter

of the above-described diamond abrasive particles or the particle diameter of each diamond abrasive particle is larger than the above-described values, the finished roughness increases, and, therefore, the machining allowance load in subsequent steps increases.

5           It should be noted that as described above, "diamond fixed abrasive particles" here means the above-described aggregates.

Moreover, it is preferable that each diamond particle contained in the aggregates has a size of 1 to 5  $\mu\text{m}$  in average particle diameter.

[0049]

10           It should be noted that in the present invention, the above-described average particle diameter 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  
15 (50% diameter)" hereinafter). In the present invention, specifically, the cumulative average particle diameter is a value obtained by measuring the particle diameter using, for example, a particle diameter/particle size distribution measurement device.

[0050]

20           In the present invention, the main surface of the glass substrate subjected to the grinding processing generally has a roughness of 0.001 to 0.01  $\mu\text{m}$  in Ra. Moreover, in the present invention, the surface roughness of the glass substrate after the above-described first stage is in a range of about 0.100 to 0.150  $\mu\text{m}$  in Ra. By roughening the surface such that the surface roughness  
25 is in this range, the grinding in the subsequent second stage is favorably performed.

Furthermore, the surface roughness of the glass substrate after the above-described second stage, that is, the polishing, is as described above.

[0051]

As described above, by performing the grinding processing of the present invention with a first stage in which the surface of the glass substrate is roughened with a higher load and a second stage in which the surface of the glass substrate is ground with a lower load than the load applied in the first stage, it is possible to suppress a reduction of productivity caused by the above-described period of time during which no grinding is performed, and the grinding processing having the first stage and the second stage can be continuously performed using the same device, thus making it possible to increase the productivity. Moreover, it is possible to suppress the roughness of a processed surface to a low level without reducing the processing speed, and to reduce the processing load in subsequent steps.

[0052]

Moreover, in the case where the grinding processing of the present invention is performed through the first stage and the second stage as described above, it is necessary to set the conditions such that the processing speeds on the upper surface plate side and the lower surface plate side are different from each other, and to process the tin surface side of the glass substrate on the surface plate side with the lower processing speed.

Furthermore, in the case where the grinding is performed through two stages, it is preferable to remove the tin surface of the glass substrate in the second stage (a final phase of the second stage is more preferable). The reason for this is described as follows. In the present invention, the processing speeds of the upper and lower surface plates are different. Therefore, if the entire tin surface of the glass substrate is removed at the early stage of the processing such as the first stage, machining allowance is increased on only one of the main surfaces, and thus the main surfaces may be different in roughness after the grinding processing.

[0053]

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  $\text{SiO}_2$  as a main component and  $\text{Al}_2\text{O}_3$  in an amount of 20 wt% or less. Furthermore, glass that contains  $\text{SiO}_2$  as a main component and  $\text{Al}_2\text{O}_3$  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  $\text{SiO}_2$  in an amount of 62 wt% or more to 75 wt% or less,  $\text{Al}_2\text{O}_3$  in an amount of 5 wt% or more to 15 wt% or less,  $\text{Li}_2\text{O}$  in an amount of 4 wt% or more to 10 wt% or less,  $\text{Na}_2\text{O}$  in an amount of 4 wt% or more to 12 wt% or less, and  $\text{ZrO}_2$  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.

[0054]

As heat resistant glass, it is preferable to use, for example, glass that contains  $\text{SiO}_2$  in an amount of 50 to 75 mol%,  $\text{Al}_2\text{O}_3$  in an amount of 0 to 5 mol%,  $\text{BaO}$  in an amount of 0 to 2 mol%,  $\text{Li}_2\text{O}$  in an amount of 0 to 3 mol%,  $\text{ZnO}$  in an amount of 0 to 5 mol%;  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  in a total amount of 3 to 15 mol%,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{SrO}$  and  $\text{BaO}$  in a total amount of 14 to 35 mol%, and  $\text{ZrO}_2$ ,  $\text{TiO}_2$ ,  $\text{La}_2\text{O}_3$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{Yb}_2\text{O}_3$ ,  $\text{Ta}_2\text{O}_5$ ,  $\text{Nb}_2\text{O}_5$  and  $\text{HfO}_2$  in a total amount of 2 to 9 mol%, and that 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  $\text{SiO}_2$  in an amount of 56 to 75 mol%,  $\text{Al}_2\text{O}_3$  in an amount of 1 to 9 mol%, alkali metal oxide(s) selected from the group consisting of  $\text{Li}_2\text{O}$ ,  $\text{Na}_2\text{O}$ , and  $\text{K}_2\text{O}$  in a total amount of 6 to 15 mol%, alkaline

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<sub>2</sub>, TiO<sub>2</sub>, Y<sub>2</sub>O<sub>3</sub>, La<sub>2</sub>O<sub>3</sub>, Gd<sub>2</sub>O<sub>3</sub>, Nb<sub>2</sub>O<sub>5</sub>, and Ta<sub>2</sub>O<sub>5</sub> in a total amount of more than 0 and 10 mol% or less.

5            In the present invention, it is preferable that the Al<sub>2</sub>O<sub>3</sub> content in the glass composition is 15 wt% or less. Furthermore, it is more preferable that the Al<sub>2</sub>O<sub>3</sub> content is 5 mol% or less.

[0055]

          After the grinding processing of the present invention, mirror-polishing is  
10    performed to obtain a high precision flat surface. In the present invention, a substrate having a favorable flatness can be obtained and the roughness of the processed surface can also be reduced in this grinding by applying the grinding processing according to the present invention, and therefore, the amount of glass to be removed in the subsequent mirror-polishing step is small, the  
15    processing load is reduced, and the processing cost can be reduced.

[0056]

          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  
20    a metal oxide such as cerium oxide or colloidal silica. A highly smooth glass 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.

25    [0057]

          In the present invention, the surface of the glass substrate after the mirror-polishing processing is preferably a mirror surface having an arithmetic average roughness Ra of 0.2 nm or less, and more preferably a mirror surface

having an arithmetic average roughness Ra of 0.13 nm or less. It should be noted that Ra and Rmax 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 (maximum roughness Rmax and arithmetic average roughness Ra, for example) in the present invention is preferably the surface roughness of a surface shape that is measured using an atomic force microscope (AFM). It should be noted that an area of 5  $\mu\text{m}$ ×5  $\mu\text{m}$  is measured using an AFM.

[0058]

10 In the present invention, it is preferable to perform chemical strengthening after the first polishing and before the second polishing. As a method for the chemical strengthening, it is preferable to use, for example, a low-temperature ion-exchange method that performs ion exchange in a temperature range not exceeding the glass transition point. The chemical

15 strengthening is processing in which the glass substrate is brought in contact with a molten 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

20 atomic radius permeates through the surface layer of the glass substrate, and 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

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

It should be noted that it is preferable that substantially the entire surface portion containing tin in a large amount on the tin surface side of the glass

substrate is removed at a point of time when the glass substrate is subjected to the above-described chemical strengthening. This is because there is a problem in that the substrate is warped by the chemical strengthening if the surface portion containing tin in a large amount remains before the chemical strengthening.

[0059]

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 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 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 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 sputtering method in the same manner as the magnetic layer.

[0060]

It is preferable to form a protective layer and a lubricant layer in this

order on the magnetic layer. An amorphous hydrogenated carbon-based protecting 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  
5 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.

Use of the magnetic disk glass substrate obtained according to the  
10 present invention makes it possible to obtain a highly reliable magnetic disk.

## Examples

### [0061]

Hereinafter, the embodiment of the present invention will be described in  
15 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 step, (3) an  
20 edge surface polishing step, (4) main surface grinding processing, (5) a main surface polishing step (first polishing step), (6) a chemical strengthening step, and (7) a main surface polishing step (second polishing step) as described below.

### [0062]

25 (1) Substrate preparation step

A large sheet of plate glass constituted by aluminosilicate glass having a thickness of 1 mm manufactured by a float method was prepared, and was cut into small square pieces using a diamond cutter. Next, each of the glass pieces

was processed into a disk shape that had an outer diameter of 65 mm and a circular hole having an inner diameter of 20 mm in the center portion using a diamond cutter. As this aluminosilicate glass, glass for chemical strengthening was used that had a composition of  $\text{SiO}_2$  in an amount of 58 to 66 wt%,  $\text{Al}_2\text{O}_3$  in an amount of 13 to 19 wt%,  $\text{Li}_2\text{O}$  in an amount of 3 to 4.5 wt%,  $\text{Na}_2\text{O}$  in an amount of 6 to 13 wt%,  $\text{K}_2\text{O}$  in an amount of 0 to 5 wt%,  $\text{R}_2\text{O}$  (where  $\text{R}_2\text{O}=\text{Li}_2\text{O}+\text{Na}_2\text{O}+\text{K}_2\text{O}$ ) in an amount of 10 to 18 wt%,  $\text{MgO}$  in an amount of 0 to 3.5 wt%,  $\text{CaO}$  in an amount of 1 to 7 wt%,  $\text{SrO}$  in an amount of 0 to 2 wt%,  $\text{BaO}$  in an amount of 0 to 2 wt%,  $\text{RO}$  (where  $\text{RO}=\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO}$ ) in an amount of 2 to 10 wt%,  $\text{TiO}_2$  in an amount of 0 to 2 wt%,  $\text{CeO}_2$  in an amount of 0 to 2 wt%,  $\text{Fe}_2\text{O}_3$  in an amount of 0 to 2 wt%, and  $\text{MnO}$  in an amount of 0 to 1 wt% (where  $\text{TiO}_2+\text{CeO}_2+\text{Fe}_2\text{O}_3+\text{MnO}=0.01$  to 3 wt%).

[0063]

#### (2) Shape processing step

Next, a diamond grindstone was used to create a hole in the central portion of the glass substrate, and predetermined chamfering was performed on an outer circumferential edge surface and an inner circumferential edge surface. It should be noted that a magnetic disk having an outer diameter of 65 mm is generally used in a 2.5-inch HDD (hard disk drive).

[0064]

#### (3) Edge surface polishing step

Next, the edge surfaces (inner and outer circumferential edge surfaces) of the glass substrate were polished by a known brushing method while the glass substrate was rotated.

[0065]

#### (4) Main surface grinding processing

This main surface grinding processing 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. A grindstone with fixed abrasive particles was used as the diamond pads, the fixed abrasive particles being obtained by fixing, using a resin, aggregates in which a plurality of diamond particles were bound by being vitrified with glass. Here, the average particle diameter of the aggregates was set to about 25  $\mu\text{m}$ , and the average particle diameter (D50) of each diamond particle in the aggregates was set to 2.5  $\mu\text{m}$ . This processing was performed using a lubricant. It should be noted that the main surface of the glass substrate before the grinding processing was a mirror surface. The roughness of the main surface measured using a stylus type roughness tester was 5 nm in Ra.

[0066]

Specifically, the rotation rate of the surface plates was selected as appropriate in a range of 10 to 100 rpm, and a load was applied to the glass substrate in accordance with the sequence shown in FIG. 3. In this example, the load (P1) in the first stage (roughening) was set to 150  $\text{g}/\text{cm}^2$ . In addition, the load (P2) in the second stage (main processing) was set to 100  $\text{g}/\text{cm}^2$ . The rotation rate of the upper surface plate was set to 20 rpm, and the rotation rate of the lower surface plate was set to 30 rpm. Furthermore, the rotation rate of the sun gear was set to 8 rpm, and the rotation rate of the internal gear was set to 3 rpm. Under these conditions, the relative speed of the upper surface plate to the substrate is higher by 10 to 20% than the relative speed of the lower surface plate to the substrate, as a result of which the processing speed on the upper surface plate side is higher than the processing speed on the lower surface plate side. The glass substrate was set such that the tin surface of the glass substrate faced the lower surface plate side with a lower processing speed, and both sides of the glass substrate accommodated in a carrier were simultaneously ground.

It should be noted that in FIG. 3, the slope  $k$  was set to 10  $\text{g}/(\text{cm}^2 \cdot \text{sec})$ ,  $t_1$

was set to 60 seconds, the period of time between points B and C was set to 15 seconds, and  $t_2$  was set to 200 seconds, which was longer than  $t_1$ .

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

[0067]

In this grinding processing, one hundred glass substrates per batch were processed in total. The flatness of each glass substrate after the processing  
 10 was measured using a slanting incidence interference method flatness tester. The surface roughness ( $R_a$ ) of the main surfaces of each glass substrate after the processing was measured using a stylus type surface roughness tester. Table 1 shows the measurement results for the flatness of each glass substrate after the processing and the difference in the surface roughness ( $\Delta R_a$ ) between  
 15 the main surfaces. It should be noted that numerical values shown in Table 1 are average values of measurement values of the one hundred substrates. Moreover, the average value of the flatness of the glass substrates just before the grinding processing was  $2.5\ \mu\text{m}$ .

[0068]

20 (5) Main surface polishing step (first polishing step)

Next, a first polishing step to remove blemishes and distortion remaining after the above-described 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  
 25 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 load was set to 100 g/cm<sup>2</sup>. The glass substrate that had undergone the first polishing step was cleaned and dried.

[0069]

#### (6) 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.

[0070]

#### (7) 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 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 load was set to 100 g/cm<sup>2</sup>. The glass substrate that had undergone the second polishing step was cleaned and dried.

[0071]

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. An area of 5  $\mu\text{m}$ ×5  $\mu\text{m}$  was measured using an AFM. 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.

[0072]

(Comparative example 1)

In the grinding processing in example 1, the glass substrate was set such that the tin surface of the glass substrate faced the upper surface plate side with a higher processing speed, and the glass substrate was ground. A magnetic-disk glass substrate was obtained by performing the steps other than the grinding processing in the same manner as in example 1.

[0073]

(Comparative example 2)

In the grinding processing in example 1, the conditions were set such that the processing speeds of the upper and lower surface plates were substantially the same, the glass substrate was set such that the tin surface of the glass substrate faced the upper surface plate side, and the glass substrate was ground. A magnetic-disk glass substrate was obtained by performing the steps other than the grinding processing in the same manner as in example 1.

[0074]

(Examples 2 to 5)

In the grinding processing in example 1, the processing speed of the

upper surface plate side was set to be lower by 5, 10, 20 and 30%, respectively, the glass substrate was set such that the tin surface of the glass substrate faced the upper surface plate side, and the glass substrate was ground. A magnetic-disk glass substrate was obtained by performing the steps other than the grinding processing in the same manner as in example 1.

Table 1 shows the measurement results for flatness and the difference in the surface roughness ( $\Delta Ra$ ) between the main surfaces regarding the glass substrates of the above-described examples and comparative examples that had been ground.

[0075]

[Table 1]

| Table 1               | Direction of tin surface of glass substrate                                                 | Flatness ( $\mu\text{m}$ ) | $\Delta Ra$ ( $\mu\text{m}$ ) |
|-----------------------|---------------------------------------------------------------------------------------------|----------------------------|-------------------------------|
| Example 1             | Lower surface plate side (with lower processing speed than upper surface plate side)        | 2.3                        | 0.009                         |
| Comparative Example 1 | Upper surface plate side (with higher processing speed than lower surface plate side)       | 3.4                        | 0.021                         |
| Comparative Example 2 | Upper surface plate side (with the same processing speed as lower surface plate side)       | 2.8                        | 0.015                         |
| Example 2             | Upper surface plate side (with lower processing speed by 5% than lower surface plate side)  | 2.2                        | 0.008                         |
| Example 3             | Upper surface plate side (with lower processing speed by 10% than lower surface plate side) | 2.0                        | 0.005                         |
| Example 4             | Upper surface plate side (with lower processing speed by 20% than lower surface plate side) | 1.9                        | 0.005                         |
| Example 5             | Upper surface plate side (with lower processing speed by 30% than lower surface plate side) | 2.1                        | 0.006                         |

[0076]

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

above.

1. In example 1 in which the tin surface of the glass substrate was set on the lower surface plate side with the lower processing speed and ground, the processed substrate had a favorable flatness. The difference in the surface roughness between the main surfaces of the substrate was small, and the substrate was processed such that both the main surfaces had substantially the same substrate roughness after the grinding. Furthermore, it was found from the comparison of example 1 and examples 2 to 5 that when the processing speed of the upper surface plate was reduced and the tin surface was set on the upper surface plate side, the processed substrate had a more favorable flatness. It was thought that this was because relatively large amount of sludge was likely to be generated due to the grinding with fixed abrasive particles, and the sludge was likely to accumulate on the lower surface plate side. That is, it was thought that since the sludge tended to attach to the surface of the polishing pad on the lower surface plate side and cause the polishing rate to be reduced, the processing was stably performed by increasing the processing speed on the lower surface plate side, thus improving the flatness and the difference in the surface roughness. Furthermore, it was found that the most favorable results were obtained by setting the difference in the processing speed to 10 to 20%.

2. In contrast, in comparative example 1 in which the tin surface of the glass substrate, which was processed at a high processing speed, was set on the upper surface plate side with the higher processing speed and ground, the flatness of the processed substrate was deteriorated, and the substrate was warped. In addition, the difference in the surface roughness between the main surfaces of the substrate was large, which was a factor in deteriorating the flatness.

Also in comparative example 2 in which the processing speeds of the upper and lower surface plates were set to be substantially the same, the

flatness of the processed substrate was deteriorated, and the substrate was warped. In addition, the difference in the surface roughness between the main surfaces of the substrate was larger than that in example 1, which was a factor in deteriorating the flatness. It was thought that in comparative example 2, the  
5 difference between the processing speeds at which the tin surface and the non-tin surface of the glass substrate were processed caused the difference in the surface roughness between the main surfaces.

[0077]

(Examples 6 to 9)

10 Next, substrates were manufactured with different amounts of projection of the diamond fixed abrasive particles (aggregates) on a diamond pad set for the upper and lower surface plates. The average amount of projection on the upper surface plate side was fixed to 5  $\mu\text{m}$ , and the average amount of projection of diamond fixed abrasive particles on the lower surface plate side  
15 was changed as shown in Table 2. The amount of projection was changed by changing the number of times dressing was performed on the upper and lower surface plates.

The grinding processing was performed in the same manner as in example 4 other than the above point. The flatness of each of one hundred  
20 glass substrates obtained was measured, and the difference between the maximum value and the minimum value was determined as the variation in flatness. Magnitude of the variation in flatness of each example was shown as a relative value when the value for example 4 (in which the upper and lower surface plates had the same average amount of projection of fixed abrasive  
25 particles) was given as 1.00 (100%).

[0078]

[Table 2]

| Table 2   | Difference in average amount of projection between upper and lower surface plate       | Variation in flatness (Max-Min) |
|-----------|----------------------------------------------------------------------------------------|---------------------------------|
| Example 6 | Lower surface plate side is smaller by 0.5 $\mu\text{m}$ than upper surface plate side | 1.05                            |
| Example 4 | Lower surface plate side is the same as upper surface plate side                       | 1.00 (reference)                |
| Example 7 | Lower surface plate side is larger by 0.5 $\mu\text{m}$ than upper surface plate side  | 0.96                            |
| Example 8 | Lower surface plate side is larger by 1 $\mu\text{m}$ than upper surface plate side    | 0.92                            |
| Example 9 | Lower surface plate side is larger by 2 $\mu\text{m}$ than upper surface plate side    | 0.89                            |

[0079]

5           It was found from Table 2 that by making the amount of projection of fixed abrasive particles on the surface plate side with a relatively high processing speed (lower surface plate side here) larger than that on the upper surface plate side, the variation in flatness was suppressed. It was thought that this was because engaging properties of fixed abrasive particles at the early stage of the grinding were improved the non-tin surface side that was difficult to grind, and thus the abrasive particles engaged the non-tin surface at the same timing. That is, it was thought that a slightly higher pressure was applied to a substrate engaged by the fixed abrasive particles after delay from the polishing pad than to other substrates, and the processing rate was correspondingly increased just after the fixed abrasive particles engaged the substrate. It was thought that variation in a ground state during the processing also affected the flatness.

          It was found from the above results and discussions that it was preferable to relatively increase the amount of projection of fixed abrasive particles on the surface plate side with a relatively higher processing speed compared with the surface plate side with a lower processing speed, and to process the non-tin surface on that surface plate side.

[0080]

(Example 10)

A magnetic disk for perpendicular magnetic recording was manufactured by performing the following film forming step on the magnetic-disk glass

5 substrates obtained in example 1 described above.

Specifically, an adherent layer consisting of a Ti-based alloy thin film, a 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  
10 on the glass substrate. The protective layer is to prevent degradation of the magnetic recording layer caused by contact with the magnetic head. The protective layer was composed of hydrogenated carbon and yielded wear resistance. The lubricant layer was formed by a dipping method using an alcohol-modified perfluoropolyether liquid lubricant.

15 The resulting magnetic disk was incorporated into an HDD equipped with a DFH head, and then subjected to load/unload durability testing for one 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.

20

Description of Reference Numerals

[0081]

|    |    |                  |
|----|----|------------------|
|    | 1  | Diamond pad      |
|    | 2  | Sheet            |
| 25 | 3  | Aggregate        |
|    | 4  | Pellet           |
|    | 5  | Diamond particle |
|    | 10 | Glass substrate  |

**[Claim 1]**

A method for manufacturing a magnetic-disk glass substrate comprising grinding processing for using a lubricant and a pair of an upper surface plate and a lower surface plate having a grinding surface provided with fixed abrasive particles including diamond particles, and sandwiching and grinding both main surfaces of the glass substrate with the pair of upper and lower surface plates while supplying the lubricant between the grinding surfaces and the glass substrate,

wherein the glass substrate is obtained by cutting a sheet of plate glass manufactured by a float method into a predetermined shape, and one main surface side has a surface portion containing tin in a larger amount than that of the other main surface side,

the grinding processing is performed such that the upper surface plate side and the lower surface plate side are different in a processing speed, and

the main surface of the glass substrate having the surface portion containing tin in a large amount is set on the surface plate side with the lower processing speed and ground.

**[Claim 2]**

The method for manufacturing a magnetic-disk glass substrate according to claim 1, wherein the substrate after being ground has a flatness of 2.5  $\mu\text{m}$  or less.

**[Claim 3]**

The method for manufacturing a magnetic-disk glass substrate according to claim 1 or 2, wherein grinding is performed such that a difference in surface roughness between both of the main surfaces of the ground substrate is 0.01  $\mu\text{m}$  or less in Ra.

[Claim 4]

The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 3, wherein both of the main surfaces of the ground substrate have a roughness of 0.130  $\mu\text{m}$  or less in Ra.

[Claim 5]

The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 4, wherein, when simultaneously grinding a plurality of glass substrates, the main surfaces having the surface portion containing tin in a large amount are all set so as to face in the same direction.

[Claim 6]

The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 5, wherein an amount of projection of the fixed abrasive particles on the surface plate side with the relatively higher processing speed is relatively greater compared with the surface plate side with the lower processing speed.

[Claim 7]

The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 6, wherein the grinding processing includes a first stage in which the main surfaces of the glass substrate are roughened with a higher load than a load applied in grinding and a second stage, after the first stage, in which the surface of the glass substrate is ground with a lower load than the load applied in the first stage.

[Claim 8]

The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 7, wherein a processing speed in the grinding processing is 3.0 to 9.0  $\mu\text{m}/\text{minute}$ .