

## DESCRIPTION

## Title of the Invention

METHOD FOR MANUFACTURING MAGNETIC-DISK GLASS SUBSTRATE,  
5 METHOD FOR MANUFACTURING MAGNETIC DISK, AND POLISHING PAD

## Technical Field

[0001]

The present invention relates to a method for manufacturing a  
10 magnetic-disk glass substrate to be used in a magnetic disk that is provided in a  
magnetic recording device such as a hard disk drive (simply referred to as  
"HDD" hereinafter).

## Background Art

15 [0002]

Magnetic disks are one type of information recording media provided in  
magnetic recording devices such as 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  
20 response to the pursuit of high recording density, glass 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 polished with high precision such that the flying height of the magnetic  
head can be lowered as much as possible to achieve a high recording density.  
25 In recent years, the demand for HDDs with a larger storage 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,  
 5 a highly smooth substrate surface is ultimately required, and thus it is necessary to polish the surface of the glass substrate with high precision.

A conventional method for polishing a glass substrate involves polishing 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 of a  
 10 metal oxide such as cerium oxide or colloidal silica. A highly smooth glass substrate can be obtained by additionally performing final-polishing (mirror-polishing) using colloidal silica abrasive particles after performing polishing using a cerium oxide-based abrasive, for example.

15 Prior Art Literature

Patent Literature

[0004]

Patent Literature 1: JP 2008-112572 A

Patent Literature 2: JP 2012-130988 A

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Summary of the Invention

Problem to be Solved by the Invention

[0005]

Although currently available HDDs can store about 320 gigabytes of  
 25 information per 2.5-inch (diameter of 65 mm) magnetic disk, for example, there is demand for a further increase in recording density, such as the realization of 750 gigabytes, or even 1 terabyte. Following such demand for HDDs with a larger storage capacity in recent years, the need for improvement in the surface

quality of a substrate is greater than ever. Next-generation substrates for magnetic disks of 750 gigabytes, for example, such as described above will greatly influence the reliability of HDDs, and thus a further improvement from currently available HDDs is required, not only in terms of the surface roughness of substrates, but also with regard to the absence of surface defects such as waviness and scratches (marks) on the substrate surface.

[0006]

Next-generation substrates will greatly influence the reliability of HDDs for reasons such as the follows.

10 A significant reduction is achieved in the flying height (the gap between the magnetic head and the surface of the medium (magnetic disk)) of a magnetic head (lower flying height). This reduces the distance between the magnetic head and the magnetic layer of the medium, which makes it possible to write signals to a smaller region and pick up signals of smaller magnetic particles, and  
15 hence a high recording density is achieved. In recent years, magnetic heads have been provided with a function called DFH (Dynamic Flying Height) control. This function causes only the recording and reproduction element portion of the magnetic head to protrude toward (approach) the medium surface by utilizing thermal expansion of a heating unit such as a heater incorporated in the vicinity  
20 of the recording and reproduction element portion, instead of lowering the flying height of a slider. Under such circumstances, in order to realize a lower flying height of the magnetic head, it is necessary to not only achieve high smoothness of the glass substrate surface but also a reduction in surface defects such as waviness and scratches on the glass substrate surface that are inhibiting factors.

25 [0007]

Incidentally, conventionally a method in which a polishing pad whose surface roughness (Rz) is set to a specific value is used (Patent Literature 1) is known as a method for reducing the waviness on the glass substrate surface

described above, for example. According to Patent Literature 1, a reduction in waviness having a shape wavelength of 2  $\mu\text{m}$  to 4 mm on the glass substrate surface can be achieved.

On the other hand, Patent Literature 2 discloses that by using a specific  
5 pad dresser that adjusts the surface of a polishing pad, a reduction in waviness having a shape wavelength of 60 to 160 nm can be achieved.

[0008]

However, when attempts were made to manufacture a magnetic disk having a higher recording density than previously available, such as a recording  
10 density exceeding 750 gigabytes, for example, it was also necessary to reduce microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$ , for example, but according to studies conducted by the inventor of the present invention, it was found that there is a limit to how much this microwaviness can be reduced simply by reducing the roughness of the polishing pad surface described above, and  
15 that it is thus difficult to achieve a reduction in microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$ . In particular, when the inventors performed the method disclosed in Patent Literature 2, microwaviness having a shape wavelength of 50  $\mu\text{m}$  to 150  $\mu\text{m}$  could not be reduced at all with this method.

[0009]

20 In addition, when attempts were made to manufacture the above-described magnetic disk having a high recording density exceeding 750 gigabytes, it was necessary to achieve a reduction in not only waviness on the glass substrate surface but also surface defects such as scratches, but according to studies conducted by the inventor, it was found that even if the  
25 above-described method of Patent Literature 1 or Patent Literature 2 is applied, it is difficult to achieve a reduction in surface defects such as scratches on the glass substrate surface.

[0010]

In view of this, the present invention was made in order to resolve such conventional issues, and a first object thereof is to provide a method for manufacturing a magnetic-disk glass substrate that is also capable of reducing microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$ .

5 In addition, a second object of the present invention is to provide a method for manufacturing a magnetic-disk glass substrate that is capable of further reducing surface defects such as the extremely minute scratches described above compared with the conventional method.

Also, a third object of the present invention is to provide a method for  
10 manufacturing a magnetic disk in which the magnetic-disk glass substrate obtained by the present invention is used.

Moreover, a fourth object of the present invention is to provide a polishing pad to be used to polish a magnetic-disk glass substrate.

## 15 Means to Solve the Problem

[0011]

In view of this, in order to obtain a glass substrate in which microwaviness is reduced, the inventor studied use of a polishing pad having a pad surface having a small amount of elastic variation or hardness variation for  
20 uniformizing the load on abrasive particles in order to reduce an uneven portion of the glass substrate surface after polishing. As a result of these studies, the inventor measured a depression amount at a plurality of locations on the polishing pad that occurred when a cylindrical indenter having a diameter of 50  $\mu\text{m}$  was pushed into the surface of the polishing pad at a load of 2.5 mN, and  
25 found that the value of the standard deviation of the obtained depression amounts was optimal as an index for evaluating the variation in elasticity distribution or the variation in hardness on the polishing pad surface. Also, the inventor also found that the value of the standard deviation of the depression

amounts of this polishing pad has a correlation with microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$ .

[0012]

In addition, the inventor studied prescribing the hardness in a minute  
5 region of the polishing pad in order to reduce mark defects such as minute scratches on the glass substrate surface after polishing. As a result of these studies, the inventor measured a depression amount at a plurality of locations on the polishing pad that occurred when a cylindrical indenter having a diameter of 50  $\mu\text{m}$  was pushed into the surface of the polishing pad at a load of 2.5 mN, and  
10 found that an arithmetic mean value of the plurality of the obtained depression amounts was optimal as an index for evaluating the hardness in a minute region of the polishing pad surface. Also, the inventor found that the arithmetic mean value of the depression amounts of this polishing pad has a correlation with the number of mark defects such as minute scratches.

15 In view of this, the inventor found that according to the invention having the following aspects, the above-described issues can be resolved based on the above-described findings, and thereby accomplished the present invention.

[0013]

That is, in order to achieve the above-described object, the present  
20 invention has the following aspects.

(Aspect 1)

A method for manufacturing a magnetic-disk glass substrate including polishing processing for supplying a polishing liquid containing polishing abrasive particles to a surface of a glass substrate and polishing the glass  
25 substrate surface by pressing a polishing pad having a resin foam layer against the glass substrate surface, in which as the polishing pad, a polishing pad is used that has a standard deviation of 0.15  $\mu\text{m}$  or less obtained when a depression amount of the polishing pad that occurs when a circular portion of a

cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, and the depression amount is successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, from data on ten depression amounts  
 5 excluding a maximum value and a minimum value of the obtained depression amounts.

(Aspect 2)

In the method for manufacturing a magnetic-disk glass substrate according to aspect 1, an arithmetic mean value of the ten depression amounts  
 10 in the polishing pad is 5  $\mu\text{m}$  or more.

[0014]

(Aspect 3)

A method for manufacturing a magnetic-disk glass substrate including polishing processing for supplying a polishing liquid containing polishing  
 15 abrasive particles between a main surface of a glass substrate and a polishing pad having a resin foam layer, and polishing the main surface of the glass substrate, in which as the polishing pad, a polishing pad is used that has an arithmetic mean value of 5  $\mu\text{m}$  or more obtained when a depression amount of the polishing pad that occurs when a circular portion of a cylindrical indenter  
 20 having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, and the depression amount is successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, from data on ten depression amounts excluding a maximum value and a minimum value of the obtained depression amounts.

25 (Aspect 4)

In the method for manufacturing a magnetic-disk glass substrate according to aspect 3, the arithmetic mean value of the ten depression amounts in the polishing pad is 10  $\mu\text{m}$  or more.

[0015]

(Aspect 5)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 4, a glass substrate before the polishing  
5 processing is performed has a surface roughness (Ra) of 3 nm or less.

[0016]

(Aspect 6)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 5, when both main surfaces of the glass  
10 substrate are polished at the same time using a planetary polishing device in which the polishing pad is attached to a surface plate, the polishing processing is performed such that a pressing force of the polishing pad applied to the glass substrate is in a range of 75 to 150 gf/cm<sup>2</sup>.

(Aspect 7)

15 In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 6, the polishing abrasive particles contain colloidal silica.

[0017]

(Aspect 8)

20 In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 7, the magnetic-disk glass substrate is a glass substrate to be used in a magnetic disk to be provided in a hard disk drive provided with a DFH-type magnetic head.

(Aspect 9)

25 A method for manufacturing a magnetic disk, in which at least a magnetic layer is formed on a magnetic-disk glass substrate obtained by the manufacturing method according to any of aspects 1 to 8.

(Aspect 10)

A polishing pad to be used in polishing processing for polishing a main surface of a magnetic-disk glass substrate, in which when a depression amount of the polishing pad that occurs when a circular portion of a cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, the depression amount is successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, and a standard deviation is obtained from data on ten depression amounts excluding a maximum value and a minimum value of the obtained depression amounts, the standard deviation is 0.15  $\mu\text{m}$  or less.

10 (Aspect 11)

A polishing pad to be used in polishing processing for polishing a main surface of a magnetic-disk glass substrate, in which when a depression amount of the polishing pad that occurs when a circular portion of a cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, the depression amount is successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, and an arithmetic mean value is obtained from data on ten depression amounts excluding a maximum value and a minimum value of the obtained depression amounts, the arithmetic mean value is 5  $\mu\text{m}$  or more.

20

Effect of the Invention

[0018]

With the above-described configuration of the present invention, it is possible to manufacture a high-quality glass substrate in which waviness on a glass substrate surface, and, in particular, microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$ , that is a factor inhibiting the realization of a lower flying height of a magnetic head can be reduced.

25

Also, with the above-described configuration of the present invention, it

is possible to manufacture a high-quality glass substrate in which minute mark defects on the glass substrate surface that are a factor inhibiting the realization of a further lowering of the flying height of the magnetic head can be reduced.

Also, with the above-described aspects of the present invention, it is  
5 possible to manufacture a high-quality glass substrate that is favorable for manufacturing a magnetic disk having a higher recording density than previously available, such as a recording density exceeding 750 gigabytes, for example.

In addition, the polishing pad of the present invention is favorable for polishing processing for polishing a magnetic-disk glass substrate.

10

#### Brief Description of Drawings

[0019]

FIG. 1 is a diagram illustrating a method for measuring the depression amount of a polishing pad in the present invention.

15

FIG. 2 is a longitudinal cross-sectional view showing a schematic configuration of a double-side polishing device.

#### Mode for Embodiment the Invention

[0020]

20

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

#### [First Embodiment]

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

This magnetic-disk glass substrate is manufactured by first molding a

disk-shaped glass substrate (glass disk) from molten glass by direct pressing. It should be noted that, other than using such direct pressing, a glass substrate may be obtained by cutting plate glass manufactured by a down draw method or a float method into a predetermined size. Next, grinding (lapping) for

5 enhancing the dimensional accuracy and shape accuracy is performed on the main surfaces of this molded glass substrate. In this grinding step, 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

10 substrate is processed so as to have a predetermined substrate thickness and flatness and to attain a predetermined surface roughness.

[0021]

After this grinding step ends, the shape processing step and the edge surface polishing step are performed, and the mirror-polishing processing for

15 obtaining a high precision flat surface is then performed. It is preferable to perform a method for mirror-polishing a glass substrate using a polishing pad made of polyurethane foam or the like while supplying a slurry (polishing liquid) containing an abrasive that is made of a metal oxide such cerium oxide or colloidal silica.

20 [0022]

As described in aspect 1 above, a first embodiment of the present invention is a method for manufacturing a magnetic-disk glass substrate including polishing processing for supplying a polishing liquid containing polishing abrasive particles to a surface of a glass substrate and polishing the

25 glass substrate surface by pressing a polishing pad having a resin foam layer against the glass substrate surface, in which as the polishing pad, a polishing pad is used that has a standard deviation of 0.15  $\mu\text{m}$  or less obtained when a depression amount of the polishing pad that occurs when a circular portion of a

cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, and the depression amount is successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, from data on ten depression amounts  
5 excluding a maximum value and a minimum value of the obtained depression amounts.

[0023]

As described above, the inventor found that when attempts were made to manufacture a magnetic disk having a higher recording density than  
10 previously available, such as a recording density exceeding 750 gigabytes, for example, it was necessary to reduce microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$ , for example, that can be an factor inhibiting the realization of a further lowering of the flying height by adoption of a magnetic head provided with the above-described DFH control function, for example, and in order to achieve  
15 this, it is important to suppress variation in elasticity or hardness distribution in a minute region of a polishing pad that is used in polishing processing.

[0024]

The reason for this can be inferred as follows.

That is, in polishing processing, the abrasive particles that receive the  
20 load from the polishing pad come into contact with the glass surface and cause the glass surface to brittle fracture, and when the load applied to the abrasive particles at this time is non-uniform, the brittle fractures on the glass surface are also non-uniform, resulting in a difference in grinding amount and thus waviness on the glass surface.

25 Specifically, a polishing pad that is used to polish a magnetic-disk glass substrate usually includes a base material such as nonwoven fabric or a PET resin and a nap layer constituted by a resin foam layer formed on the base material. In this manner, the actual polishing pad internally has void portions

called pores, and there is variation in the elasticity distribution of the polishing pad surface. Because the polishing pad surface having void portions resulting from pores has a high elasticity, abrasive particles sink into the polishing pad when a load is applied thereto and a grinding amount decreases due to a

5 reduction in the amount of brittle fractures in the glass, as a result of which the glass surface protrudes in this portion. On the other hand, because the polishing pad surface of a wall portion that has no pores has a low elasticity, the abrasive particles do not sink into the polishing pad when a load is applied thereto and a grinding amount increases due to an increase in the amount of

10 brittle fractures in the glass, as a result of which the glass surface is recessed in this portion. As a result, an uneven portion is formed on the glass substrate surface due to variation in the grinding amount, resulting in waviness.

[0025]

In view of this, in order to obtain a glass substrate in which

15 microwaviness is reduced, as a result of studying use of a polishing pad having a small amount of elastic variation or hardness variation in a minute region of the pad surface to apply a uniform load to abrasive particles in polishing processing, the inventor measured a depression amount at a plurality of locations on the polishing pad that occurred when a cylindrical indenter having a diameter of 50

20  $\mu\text{m}$  was pushed into the surface of the polishing pad at a load of 2.5 mN, and found that the value of the standard deviation of the obtained depression amounts was optimal as an index for evaluating the variation in elasticity distribution or the variation in hardness of the polishing pad surface. Also, the inventor found a correlation between the value of the standard deviation of the

25 depression amounts of the polishing pad obtained by an indenter being pushed into the surface of the polishing pad in this manner and microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$ .

[0026]

In addition, in the present invention, it is preferable that polishing performed using the above-described polishing pad is precision polishing. Specifically, it is preferable that the above-described polishing processing is performed on a glass substrate having a surface roughness of 3 nm or less.

- 5 Also, it is preferable that the polishing is performed on a glass substrate in which the arithmetic mean roughness of microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$  is 3  $\text{\AA}$  or less.

FIG. 1 is a diagram illustrating a method for measuring the depression amount of a polishing pad in the present invention.

- 10 As shown in FIG. 1, a polishing pad 7 used in polishing processing has a base material 7A made of nonwoven fabric or a PET resin and a nap layer 7B constituted by a resin foam layer formed on the base material 7A.

- The resin foam layer internally has void portions called pores 8 and wall portions 9 other than the pores. It should be noted that, for convenience of illustration, an internal cross-sectional structure (nap layer, in particular) of the polishing pad is depicted merely as an image in FIG. 1, and the actual internal structure is not necessarily depicted accurately.

[0027]

- It is preferable that a soft polisher polishing pad (suede pad) is used as the polishing pad for the finishing mirror-polishing, in particular. It is preferable that the surface of the polishing pad that abuts against the glass substrate is made of resin foam in which foam pores are formed, with polyurethane foam being particularly preferable. When polished in this manner, the glass substrate can be polished so as to have a smooth mirror surface.

25 [0028]

The above-described nap layer 7B of the polishing pad 7 usually has pores having the largest pore diameter (100 to 200  $\mu\text{m}$ , for example) on the

substrate 7A side, and has pores having the smallest pore diameter (3 to 20  $\mu\text{m}$ , for example) on the outermost layer side (the glass substrate abutting side).

[0029]

Next, a method for measuring the depression amount of the polishing  
5 pad resulting from an indenter being pushed into the surface of the polishing pad in the present invention will be specifically described.

(1) As shown in FIG. 1, a depression amount of the polishing pad 7 is measured when a circular portion of a cylindrical indenter 10 having a diameter of 50  $\mu\text{m}$  is pushed into the surface of the polishing pad 7 that serves as the  
10 polishing surface, at a load of 2.5 mN.

Here, as described in examples, which will be described later, the reason why the diameter of the cylindrical indenter 10 was set to 50  $\mu\text{m}$  and a pushing load was set to 2.5 mN is that the value of the standard deviation of depression amounts of the polishing pad measured under these conditions has  
15 a correlation with microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$ .

[0030]

(2) Next, this depression amount is successively obtained twelve times on the surface of the polishing pad 7 at an interval of 50  $\mu\text{m}$ . That is, a depression amount of the polishing pad is measured when the indenter 10 is  
20 moved by 50  $\mu\text{m}$  along the surface of the polishing pad 7 and pushed into the surface, and depression amounts of the polishing pad are measured at 12 locations in total while repeating this measurement. It should be noted that because the diameter of the indenter 10 is 50  $\mu\text{m}$ , movement of this indenter by 50  $\mu\text{m}$  each time indicates that the indenter 10 is moved without leaving a space  
25 therebetween. At this time, the indenter is moved linearly.

[0031]

(3) A standard deviation is obtained from data on ten depression amounts excluding the maximum value and the minimum value of the twelve

depression amounts obtained in the manner described above. Here, the reason why the maximum value and the minimum value are excluded is to eliminate the factor of variation resulting from measurement errors.

In addition, by performing polishing processing on the glass substrate  
5 using the polishing pad in which this standard deviation is 0.15  $\mu\text{m}$  or less, it is possible to achieve a reduction in microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$  in particular and to manufacture a high-quality glass substrate. Therefore, in the case of manufacturing a magnetic disk having a higher recording density than previously available, such as a recording density  
10 exceeding 750 gigabytes, for example, it is possible to manufacture a high-quality glass substrate that is favorable for the realization of a further lowering of the flying height to a lower flying height than previously available.  
[0032]

Also, in the present embodiment, when the above-described standard  
15 deviation of the polishing pad is obtained in the case where the glass substrate is polished using a planetary polishing device, it is preferable that a difference between the standard deviation obtained in the case where the movement direction of the indenter is the circumferential direction of the polishing pad and the standard deviation obtained in the case where the movement direction  
20 thereof is the radial direction of the polishing pad is 0.01  $\mu\text{m}$  or less.

In addition, in the present embodiment, it is more preferable that variation (maximum value – minimum value) in the standard deviation measured at a plurality of positions of the polishing pad is 0.01  $\mu\text{m}$  or less. By setting the standard deviation to the above-described value, it is possible to achieve a  
25 reduction in variation between the above-described microwaviness of a plurality of magnetic-disk glass substrates that are polished using this polishing pad in a batch (among the plurality of magnetic-disk glass substrates polished per batch using a polishing device).

[0033]

Also, the above-described polishing liquid applied in the mirror-polishing contains an abrasive and water, which is a solvent, in combination, and also contains a pH adjusting agent for adjusting the pH of the polishing liquid and  
5 other additive agents as required.

[0034]

Also, a polishing liquid that is adjusted to be acidic is favorably used as the above-described polishing liquid that is applied to the mirror-polishing processing of the present embodiment. For example, if a polishing liquid that is  
10 adjusted by adding acid to a polishing liquid to be acidic (in a range of pH from 1 to 4) is used to mirror-polish a glass substrate, a polishing rate can be increased and cleanliness can be improved. It is preferable that the pH is in a range of 1 to 4, for example. Accordingly, it is preferable that the above-described polishing liquid is adjusted in order to prevent occurrence of foreign matter in at  
15 least an acidic environment. It should be noted that in the present invention, polishing may be performed after adjusting a pH, which indicates the acidity or alkalinity of the polishing liquid to alkaline ( $7 < \text{pH} \leq 10$ , for example).

[0035]

From the point of view of polishing efficiency, it is preferable to use  
20 colloidal silica polishing abrasive particles that are included in the polishing liquid and that have an average particle diameter of 10 to 50 nm. In particular, in order to achieve a further reduction in surface roughness, it is preferable to use polishing abrasive particles that are included in the polishing liquid used in a final mirror-polishing step (second polishing step provided downstream) and have an  
25 average particle diameter of 10 nm or more to less than 30 nm, and more preferably have an average particle diameter from 10 to 20 nm.

[0036]

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

[0037]

Also, there is no particular limitation on the concentration of abrasive particles in the polishing liquid, and from the point of view of the surface quality after polishing and the polishing rate, the concentration of abrasive particles can be set in a range of 10 to 30 wt%. A range of 10 to 20 wt% is particularly favorable.

[0038]

Although there is no particular limitation on the polishing method in the polishing processing of the present invention, it is sufficient that the surface of the glass substrate is polished to be a mirror surface by bringing the glass substrate and the polishing pad into contact with each other, and moving the polishing pad and the glass substrate relative to each other while supplying the polishing liquid containing polishing abrasive particles.

For example, FIG. 2 is a longitudinal cross-sectional view showing a schematic configuration of a planetary double-side polishing device that can be used in the step of mirror-polishing a glass substrate. The double-side polishing device shown in FIG. 2 includes a sun gear 2, an internal gear 3 arranged concentrically on the outside of the sun gear 2, a carrier 4 that is engaged with the sun gear 2 and the internal gear 3 and revolves and rotates in response to the rotation of the sun gear 2 or the internal gear 3, an upper surface

plate 5 and a lower surface plate 6 to which a polishing pad 7 that is capable of holding a product 1 to be polished that is held by the carrier 4 is respectively attached, and a polishing liquid supplying portion (not shown) that supplies the polishing liquid between the upper surface plate 5 and the lower surface plate 6.

5 [0039]

At the time of polishing processing, by using such a double-side polishing device, the product 1 to be polished, that is, the glass substrate, held by the carrier 4 is held between the upper surface plate 5 and the lower surface plate 6, and then both of the upper and lower surfaces of the product 1 to be polished are polished while the polishing liquid is supplied between each of the polishing pads 7 of the upper and lower surface plates 5 and 6 and the product 1 to be polished and the carrier 4 revolves and rotates in response to the rotation of the sun gear 2 and the internal gear 3.

It should be noted that it is preferable to apply the load (processing surface pressure) in a range of 75 gf/cm<sup>2</sup> or more to 150 gf/cm<sup>2</sup> or less. The lower limit is more preferably 95 gf/cm<sup>2</sup> or more. In addition, the upper limit is more preferably 135 gf/cm<sup>2</sup> or less.

A load of less than 75 gf/cm<sup>2</sup> is not preferable because the processability (polishing rate) of the glass substrate is reduced. Also, a load of more than 150 gf/cm<sup>2</sup> is not preferable because there are cases in which marks such as scratches occur on the glass substrate surface. In addition, by using the polishing pad according to the present embodiment and polishing a main surface of a glass substrate at the processing surface pressure in the above-described range, it is possible to achieve a further reduction in microwaviness having a shape wavelength of 50 to 150 μm and surface defects such as scratches.

[0040]

In general, as described above, the mirror-polishing step is performed over two stages, namely the first polishing step for removing marks and

distortion remaining in the lapping step and the second polishing step for finishing the surface roughness of the glass substrate main surface into a smooth mirror surface while maintaining a flat surface obtained in this first polishing step (it should be noted that there are cases in which multi-stage polishing having three or more stages may be performed). In this case, it is preferable to apply the polishing pad in which the standard deviation of depression amounts described above is 0.15  $\mu\text{m}$  or less in at least the second polishing step provided downstream.

[0041]

10 [Second Embodiment]

As described in aspect 3 above, a second embodiment of the present invention is a method for manufacturing a magnetic-disk glass substrate including polishing processing for supplying a polishing liquid containing polishing abrasive particles between a main surface of a glass substrate and a polishing pad having a resin foam layer, and polishing the main surface of the glass substrate, in which as the polishing pad, a polishing pad is used that has an arithmetic mean value of 5  $\mu\text{m}$  or more obtained when a depression amount of the polishing pad that occurs when a circular portion of a cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, and the depression amount is successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, from data on ten depression amounts excluding a maximum value and a minimum value of the obtained depression amounts.

[0042]

25 As described above, the inventor found that when attempts were made to manufacture magnetic disks having a higher recording density than previously available, such as a recording density exceeding 750 gigabytes, for example, it was necessary to also achieve a reduction in mark defects such as extremely

minute scratches having a length of about 50 nm or less and a depth of about 5 nm or less that can be a factor inhibiting the realization of a further lowering of the flying height by adopting a magnetic head provided with the above-described DFH control function, for example, and in order to achieve this, it is important to  
5 prescribe the hardness in a minute region of the polishing pad used in the polishing processing.

[0043]

The reason for this can be inferred as follows. That is, in polishing processing, the abrasive particles that receive the load from the polishing pad  
10 come into contact with the glass surface and cause the glass surface to brittle fracture, and when the load applied to the abrasive particles at this time is non-uniform, the brittle fractures on the glass surface are also non-uniform, resulting in a difference in grinding amount.

Specifically, a polishing pad that is used to polish a magnetic-disk glass  
15 substrate usually includes a base material such as nonwoven fabric or a PET resin and a nap layer constituted by a resin foam layer formed on the base material. In this manner, the actual polishing pad internally has void portions called pores, and there is variation in the elasticity distribution of the polishing pad surface. Because the polishing pad surface having void portions resulting  
20 from pores has a high elasticity, abrasive particles sink into the polishing pad when a load is applied thereto and a grinding amount decreases due to a reduction in the amount of brittle fractures in the glass. On the other hand, because the polishing pad surface of a wall portion that has no pores has a low elasticity, the abrasive particles do not sink into the polishing pad when a load is  
25 applied thereto and a grinding amount increases due to an increase in the amount of brittle fractures in the glass. As a result, an uneven portion is formed on the glass substrate surface due to variation in the grinding amount, resulting in mark defects such as scratches in a minute region.

[0044]

The inventor inferred that there was a high possibility that the hardness (or elasticity) in a minute region of the polishing pad surface, which had not been studied in the past, influenced the cause of such extremely minute scratches.

- 5 That is, it is thought that a difference in the grinding amount resulting from the hardness (or elasticity) in a minute region of the polishing pad surface caused marks such as the above-described extremely minute scratches.

[0045]

- 10 In view of this, in order to achieve a reduction in mark defects such as minute scratches on the glass substrate surface after polishing, as a result of studies on prescribing of the hardness in a minute region of the polishing pad, the inventor measured depression amounts at a plurality of locations on the polishing pad that occurred when a cylindrical indenter having a diameter of 50  $\mu\text{m}$  was pushed into the surface of the polishing pad at a load of 2.5 mN, and
- 15 found that the arithmetic mean value of a plurality of the obtained depression amounts was optimal as an index for evaluating the hardness in a minute region of the polishing pad surface. Also, the inventor found that the arithmetic mean value of the depression amounts of this polishing pad had a correlation with the number of mark defects such as minute scratches.

20 [0046]

- In addition, in the present invention, it is preferable that polishing performed using the above-described polishing pad is precision polishing. Specifically, it is preferable to perform the above-described polishing processing on a glass substrate having a surface roughness of 3 nm or less. Also, it is
- 25 preferable that the polishing is performed on the glass substrate in which the arithmetic mean roughness of microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$  is 3  $\text{\AA}$  or less.

[0047]

Next, a method for measuring the depression amount of a polishing pad resulting from an indenter being pushed into the surface of the polishing pad according to the present embodiment will be specifically described.

(1) Similarly to the case of the above-described first embodiment, as shown in FIG. 1, the cylindrical portion of the cylindrical indenter 10 having a diameter of 50  $\mu\text{m}$  is pushed into the surface of the polishing pad 7 that serves as a polishing surface at a load of 2.5 mN, and a depression amount of the polishing pad 7 at that time is measured.

Here, as described in examples, which will be described later, the reason why the diameter of the cylindrical indenter 10 was set to 50  $\mu\text{m}$  and the pushing load was set to 2.5 mN is that the arithmetic mean value of depression amounts of the polishing pad measured under these conditions has a correlation with the number of mark defects such as minute scratches.

[0048]

(2) Next, the depression amount is successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the surface of the polishing pad 7. That is, a depression amount of the polishing pad is measured when the indenter 10 is moved by 50  $\mu\text{m}$  along the surface of the polishing pad 7 and pushed into the surface, and depression amounts of the polishing pad are measured at 12 locations in total while repeating this measurement. It should be noted that because the diameter of the indenter 10 is 50  $\mu\text{m}$ , movement of this indenter by 50  $\mu\text{m}$  each time indicates that the indenter 10 is moved without leaving a space therebetween. At this time, the indenter is moved linearly.

[0049]

(3) An arithmetic mean value is obtained from data on ten depression amounts excluding the maximum value and the minimum value of the twelve depression amounts obtained in the manner described above. Here, the

reason why the maximum value and the minimum value are excluded is to eliminate the factor of variation resulting from measurement errors.

In addition, by performing polishing processing on the glass substrate using a polishing pad in which this arithmetic mean value is 5  $\mu\text{m}$  or more, it is possible to achieve a reduction in mark defects such as extremely minute scratches having a length of about 50 nm or less and a depth of about 5 nm or less and to manufacture a high-quality glass substrate. Therefore, when attempts are made to manufacture a magnetic disk having a higher recording density than previously available, such as a recording density exceeding 750 gigabytes, for example, it is possible to manufacture a high-quality glass substrate that is favorable for the realization of a further lowering of the flying height to a lower flying height than previously available.

Also, by performing the polishing processing on a glass substrate using a polishing pad in which the above-described arithmetic mean value is 10  $\mu\text{m}$  or more, it is possible to achieve a further reduction in mark defects such as the above-described minute scratches.

[0050]

Also, in the present embodiment, variation (maximum value – minimum value) in arithmetic mean values measured at a plurality of positions of the polishing pad is preferably 3  $\mu\text{m}$  or less, more preferably 2  $\mu\text{m}$  or less, and even preferably 1  $\mu\text{m}$  or less. By setting the variation to the above-described value, it is possible to achieve a reduction in variation between the above-described surface defects of a plurality of magnetic-disk glass substrates that are polished using this polishing pad in a batch (among the plurality of magnetic-disk glass substrates polished per batch using a polishing device).

[0051]

Also, a polishing liquid that is adjusted to be acidic is favorably used for the above-described polishing liquid that is applicable to the mirror-polishing

processing of the present embodiment. For example, if a polishing liquid that is adjusted by adding acid to a polishing liquid to be acidic (in a range of pH from 1 to 4) is used to mirror-polish a glass substrate, the polishing rate can be increased and cleanliness can be improved. It is preferable that the pH is in a range of 1 to 4, for example. Accordingly, it is preferable that the above-described polishing liquid is adjusted in order to prevent occurrence of foreign matter in at least an acidic environment. It should be noted that in the present invention, polishing may be performed after adjusting the pH, which indicates the acidity or alkalinity of the polishing liquid, to alkaline ( $7 < \text{pH} \leq 10$ , for example).

[0052]

From the point of view of polishing efficiency, it is preferable to use colloidal silica polishing abrasive particles that are included in the polishing liquid and that have an average particle diameter of 10 to 50 nm. In particular, in order to achieve a further reduction in surface roughness, it is preferable to use polishing abrasive particles that are included in the polishing liquid used in a final mirror-polishing step (second polishing step provided downstream) and have an average particle diameter of 10 nm or more to less than 30 nm, and more preferably have an average particle diameter from 10 to 20 nm.

[0053]

Also, there is no particular limitation on the concentration of abrasive particles in the polishing liquid, and from the point of view of the surface quality after polishing and the polishing rate, the concentration of abrasive particles can be set in a range of 10 to 30 wt%. A range of 10 to 20 wt% is particularly favorable.

Also, as described above, the mirror-polishing step is usually performed over two stages, namely the first polishing step for removing marks and distortion remaining in the lapping step and the second polishing step for

finishing the surface roughness of the glass substrate main surface into a smooth mirror surface while maintaining a flat surface obtained in this first polishing step (it should be noted that there are cases in which multi-stage polishing having three or more stages may be performed). In this case, it is preferable to apply the polishing pad in which the arithmetic mean value of depression amounts described above is 5  $\mu\text{m}$  or more in at least the second polishing step provided downstream.

It should be noted that because the polishing method in the polishing processing, the load applied (processing surface pressure), and the like of the present embodiment are similarly to those in the above-described first embodiment, redundant description thereof is omitted here.

[0054]

Also, in the present invention, it is preferable that the (type of) glass constituting the glass substrate is aluminosilicate glass containing  $\text{SiO}_2$  as a main component and alumina. Mirror-polishing the surface of the glass substrate in which such glass is used can yield a smooth mirror-finished surface, and the post-processing strength is favorable. Also, the strength can be further increased by performing chemical strengthening.

Also, the above-described glass may be crystallized glass or amorphous glass. By using amorphous glass, when the amorphous glass is made into a glass substrate, a further reduction in the surface roughness of the main surface can be achieved.

Aluminosilicate glass containing  $\text{SiO}_2$  in an amount of 58 wt% or more to 75 wt% or less,  $\text{Al}_2\text{O}_3$  in an amount of 5 wt% or more to 23 wt% or less,  $\text{Li}_2\text{O}$  in an amount of 3 wt% or more to 10 wt% or less, and  $\text{Na}_2\text{O}$  in an amount of 4 wt% or more to 13 wt% or less as main components (it should be noted that aluminosilicate glass that does not contain phosphorus oxide) can be used as such aluminosilicate glass. Furthermore, it is possible to use phosphorus

oxide-free amorphous aluminosilicate glass that contains an oxide of an alkaline earth metal in an amount of 5 wt% or more and, as main components, SiO<sub>2</sub> in an amount of 62 wt% or more to 75 wt% or less, Al<sub>2</sub>O<sub>3</sub> in an amount of 5 wt% or more to 15 wt% or less, Li<sub>2</sub>O in an amount of 4 wt% or more to 10 wt% or less, Na<sub>2</sub>O in an amount of 4 wt% or more to 12 wt% or less, and ZrO<sub>2</sub> in an amount of 5.5 wt% or more to 15 wt% or less, and has an Na<sub>2</sub>O/ZrO<sub>2</sub> weight ratio of 0.5 or more to 2.0 or less and an Al<sub>2</sub>O<sub>3</sub>/ZrO<sub>2</sub> weight ratio of 0.4 or more to 2.5 or less, for example.

[0055]

In addition, there are cases in which heat resistance is required as a characteristic of a next-generation substrate (substrate that is used in a magnetic disk applicable to a thermally assisted magnetic recording method, for example). As heat resistant glass in this case, it is preferable to use, for example, glass that contains an oxide of an alkaline earth metal in an amount of 5 wt% or more and SiO<sub>2</sub> in an amount of 50 to 75 mol%, Al<sub>2</sub>O<sub>3</sub> in an amount of 0 to 6 mol%, BaO in an amount of 0 to 2 mol%, Li<sub>2</sub>O in an amount of 0 to 3 mol%, ZnO in an amount of 0 to 5 mol%, Na<sub>2</sub>O and K<sub>2</sub>O in a total amount of 3 to 15 mol%, MgO, CaO, SrO and BaO in a total amount of 14 to 35 mol%, and ZrO<sub>2</sub>, TiO<sub>2</sub>, La<sub>2</sub>O<sub>3</sub>, Y<sub>2</sub>O<sub>3</sub>, Yb<sub>2</sub>O<sub>3</sub>, Ta<sub>2</sub>O<sub>5</sub>, Nb<sub>2</sub>O<sub>5</sub> and HfO<sub>2</sub> in a total amount of 2 to 9 mol%, and that has a molar ratio [(MgO+CaO)/(MgO+CaO+SrO+BaO)] in a range of 0.85 to 1 and a molar ratio [Al<sub>2</sub>O<sub>3</sub>/(MgO+CaO)] in a range of 0 to 0.30.

[0056]

In the present invention, the surface of the glass substrate after the mirror-polishing described above is preferably a mirror surface having an arithmetic mean roughness Ra of 0.20 nm or less, and in particular a mirror surface having an arithmetic mean roughness Ra of 0.15 nm or less. It is further preferable that the surface of the glass substrate is a mirror surface having a maximum roughness Rmax of 2.0 nm or less. It should be noted that

Ra and Rmax of the present invention refer to roughness calculated in conformity with Japanese Industrial Standard (JIS) B0601.

From a practical viewpoint, the surface roughness (maximum roughness Rmax and arithmetic mean roughness Ra, for example) in the present invention  
5 is preferably the surface roughness of a surface shape that is measured using an atomic force microscope (AFM) in a range of  $1\ \mu\text{m} \times 1\ \mu\text{m}$  at a resolution of  $256 \times 256$  pixels.

[0057]

In the present invention, it is preferable to perform chemical  
10 strengthening before or after the mirror-polishing processing step. 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, at a temperature from  $300^\circ\text{C}$  or more to  $400^\circ\text{C}$  or less. The chemical strengthening is  
15 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.

[0058]

A rinsing treatment may be performed in which main surfaces of the glass substrate are cleaned after the second polishing step for finishing the surface roughness of the main surfaces of the glass substrate into smooth mirror surfaces while maintaining the flat surface obtained in the first polishing step, by  
5 supplying, between the glass substrate and the polishing pad, a treatment liquid (rinsing liquid) containing no abrasive particles or containing abrasive particles in a low concentration compared with the second polishing step, using the same polishing device as used in the second polishing step. By performing this rinsing treatment, it is possible to reduce the number of abrasive particles  
10 (colloidal silica abrasive particles) that attach to the main surfaces and remain after the second polishing step, and to ultimately enhance the quality of a magnetic-disk glass substrate.

[0059]

The treatment liquid contains no abrasive particles or contains abrasive  
15 particles such as colloidal silica in a concentration of 3 wt% or less, and preferably in a concentration of 1 wt% or less. In the case where the treatment liquid contains abrasive particles, it is preferable to use abrasive particles having an average particle diameter of 10 nm or more to less than 30 nm. It is more preferable to use abrasive particles having an average particle diameter of about  
20 10 to 20 nm.

[0060]

As described above, the magnetic-disk glass substrate that is manufactured by the present invention is favorable for a glass substrate that is used in a magnetic disk that is provided in a HDD provided with a DFH magnetic  
25 head that can realize an extremely low flying height.

[0061]

In addition, the present invention provides a method for manufacturing a magnetic disk using the above-described magnetic-disk glass substrate will be

described. 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.

- 5 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
- 10 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, a longitudinal magnetic recording type magnetic disk 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
- 15 the magnetic layer along the normal of the plane of the magnetic disk. In this case, a perpendicular magnetic recording type magnetic disk is manufactured. The base layer can be formed by a sputtering method in the same manner as the magnetic layer.

[0062]

- 20 It is preferable to form a protective layer and a lubricant layer in this order on the magnetic layer. An amorphous hydrogenated carbon-based protective layer is preferable as the protective layer. The protective layer can be formed by a plasma CVD method, for example. As the lubricant layer, a lubricant that has a functional group at the terminal of the main chain of a
- 25 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 present invention makes it possible to obtain a highly reliable magnetic disk in which problems such as recording and reproduction errors and head crash do not occur even when recording and reproduction are performed using a DFH  
5 head. Therefore, the present invention is favorable for manufacturing a magnetic disk having a higher recording density than previously available, such as a recording density exceeding 500 gigabytes, for example.

#### Examples

10 [0063]

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

The following examples 1 to 11 are examples corresponding to the  
15 above-described first embodiment.

(Examples 1 to 4 and Comparative Examples 1 to 3)

A magnetic-disk glass substrate was manufactured through (1) a rough lapping step (rough grinding step), (2) a shape processing step, (3) a precision lapping step (precision grinding step), (4) an edge surface polishing step, (5) a  
20 main surface polishing step (first polishing step), (6) a chemical strengthening step, and (7) a main surface polishing step (second polishing step) that will be described below.

[0064]

(1) Rough lapping step

25 First, a disk-shaped glass substrate made of aluminosilicate glass and having a diameter of 66 mm $\phi$  and a thickness of 1.0 mm was obtained from molten glass by direct pressing using upper, lower, and drum molds. It should be noted that, other than using direct pressing, a glass substrate may be

obtained by cutting plate glass manufactured by a down draw method or a float method into a predetermined size.

[0065]

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

#### (2) Shape processing step

Next, a cylindrical grindstone was used to create a hole in the central portion of the glass substrate and an outer circumferential edge surface was ground to have a diameter of 65 mm $\phi$ , and predetermined chamfering was then performed on the outer circumferential edge surface and an inner circumferential edge surface.

#### (3) Precision lapping step

This precision lapping step was performed using a double-side lapping device.

[0066]

#### (4) Edge surface polishing step

Next, the edge surfaces (inner and outer circumferential edge surfaces) of the glass substrate were polished by brushing while the glass substrate was rotated. The surface of the glass substrate that had undergone the above-described edge surface polishing was then cleaned.

[0067]

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

Next, the first polishing step was performed using a double-side polishing device. In the double-side polishing device, the glass substrate that was held by a carrier was tightly placed between the upper and lower surface plates to which polishing pads were attached, the carrier was engaged with the sun gear and the internal gear, and the glass substrate was pressed between

the upper and lower surface plates. Then, a polishing liquid was supplied between the polishing pads and the glass substrate surfaces to be polished, the upper and lower surface plates were rotated, and thus the glass substrate revolved while rotating on the surface plates so that both main surfaces of the glass substrate were polished at the same time. Specifically, the first polishing step was performed using a hard polisher (hard urethane foam) as a polisher. A liquid in which cerium oxide was dispersed as an abrasive was used as the polishing liquid. The glass substrate that had undergone the first polishing step was cleaned and dried.

10 [0068]

#### (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 potassium nitrate and sodium nitrate, heating this chemical strengthening liquid to 380°C, and immersing the glass substrate that was cleaned and dried in the heated chemical strengthening liquid for approximately 4 hours.

[0069]

#### (7) Main surface polishing step (second polishing step)

20 Next, the second polishing step was performed using the same double-side polishing device as used in the above-described first polishing step, and polishing pads (polyurethane foam having an Asker C hardness of 75) with a soft polisher (suede) were used instead as the polisher. This second polishing step is mirror-polishing processing to finish the main surfaces of the glass substrate into smooth mirror surfaces having a surface roughness Ra of about 0.2 nm or less, for example, while maintaining the flat surfaces obtained in the first polishing step described above. A liquid in which colloidal silica was dispersed in water was adjusted to be acidic and used as the polishing liquid.

The glass substrate that had undergone the second polishing step was cleaned and dried.

[0070]

It should be noted that seven types of polishing pads were used as the  
5 above-described polishing pad. All of these seven types of polishing pads had  
the largest pore diameter (100 to 200  $\mu\text{m}$ ) on the base material side and the  
smallest pore diameter (3 to 20  $\mu\text{m}$ ) on the outermost layer side. With regard to  
each polishing pad, depression amounts obtained when a cylindrical indenter  
10 was pushed into the surface of the polishing pad were measured and the  
standard deviation thereof was derived in accordance with the above-described  
method. The results are shown in Table 1.

[0071]

When surface roughnesses of main surfaces of glass substrates  
(Examples 1 to 4 and Comparative Examples 1 to 3) that were obtained through  
15 the above-described steps (the seven types of polishing pads were respectively  
used in the above-described second polishing step) were measured by an  
atomic force microscope (AFM), glass substrates having an extremely smooth  
surface with a  $R_{\text{max}}$  of 1.43 nm and a  $R_{\text{a}}$  of 0.13 nm were obtained in the  
examples and comparative examples.

20 Also, an arithmetic mean roughness of microwaviness having a shape  
wavelength of 50 to 150  $\mu\text{m}$  on the glass substrate surface was measured by an  
optical surface inspection device (laser surface shape measurement device),  
and the results are shown in Table 1.

Also, the outer diameter, inner diameter, and substrate thickness of the  
25 obtained glass substrate were respectively 65 mm, 20 mm, and 0.635 mm.

[0072]

Table 1

| Table 1                  | standard deviation<br>( $\mu\text{m}$ ) | arithmetic mean roughness of<br>microwaviness ( $\text{\AA}$ ) |
|--------------------------|-----------------------------------------|----------------------------------------------------------------|
| Example 1                | 0.07                                    | 0.60                                                           |
| Example 2                | 0.10                                    | 0.61                                                           |
| Example 3                | 0.12                                    | 0.61                                                           |
| Example 4                | 0.15                                    | 0.65                                                           |
| Comparative<br>Example 1 | 0.16                                    | 0.72                                                           |
| Comparative<br>Example 2 | 0.21                                    | 0.86                                                           |
| Comparative<br>Example 3 | 0.24                                    | 0.88                                                           |

[0073]

As can be understood from the results of Table 1 above, by performing  
 5 mirror-polishing processing using a polishing pad in which the standard deviation  
 of depression amounts resulting from an indenter being pushed into the surface  
 of the polishing pad is 0.15  $\mu\text{m}$  or less, it is possible to achieve a reduction in  
 microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$  (0.65  $\text{\AA}$  or less).

[0074]

10 Next, a relationship between the standard deviation and microwaviness  
 obtained when the diameter of an indenter was varied was studied. The results  
 are shown in Table 2. At this time, the load applied to the indenter was 2.5 mN.

15

20

[0075]

| Table 2                                                                     |                                          |                                          |                                           |                                                                   |
|-----------------------------------------------------------------------------|------------------------------------------|------------------------------------------|-------------------------------------------|-------------------------------------------------------------------|
| standard deviation<br>when indenter diameter is varied<br>( $\mu\text{m}$ ) |                                          |                                          |                                           |                                                                   |
| Table 2                                                                     | indenter<br>diameter<br>50 $\mu\text{m}$ | indenter<br>diameter<br>20 $\mu\text{m}$ | indenter<br>diameter<br>100 $\mu\text{m}$ | arithmetic mean<br>roughness of<br>microwaviness ( $\text{\AA}$ ) |
| Example 1                                                                   | 0.07                                     | 0.34                                     | 0.07                                      | 0.60                                                              |
| Example 2                                                                   | 0.10                                     | 0.25                                     | 0.06                                      | 0.61                                                              |
| Example 3                                                                   | 0.12                                     | 0.28                                     | 0.07                                      | 0.61                                                              |
| Example 4                                                                   | 0.15                                     | 0.31                                     | 0.05                                      | 0.65                                                              |
| Comparative<br>Example 1                                                    | 0.16                                     | 0.22                                     | 0.04                                      | 0.72                                                              |
| Comparative<br>Example 2                                                    | 0.21                                     | 0.25                                     | 0.05                                      | 0.86                                                              |
| Comparative<br>Example 3                                                    | 0.24                                     | 0.30                                     | 0.03                                      | 0.88                                                              |

[0076]

In the case where conditions were set such that the pushing load of the

5 indenter was 2.5 mN and the diameter of the indenter was 20  $\mu\text{m}$  or 100  $\mu\text{m}$  in measurement of depression amounts, as can be understood from the result of Table 2 above, a correlation between the standard deviation of depression amounts and microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$  was not found. The reason for that can be conjectured to be that in the case where

10 the diameter of the indenter was 20  $\mu\text{m}$ , a tip portion of the indenter passes through a minute pore present on the polishing pad surface, and thus accurate variation in elasticity cannot be measured. Also, it is conjectured that in the case where the diameter of the indenter is 100  $\mu\text{m}$ , the diameter of the indenter is larger than the pore diameter inside the pad, and thus the variation in elasticity

15 in a pore portion and a wall portion cannot be measured.

[0077]

Next, a relationship between microwaviness and the standard deviation obtained in the case where conditions were set such that the diameter of an

indenter was 50  $\mu\text{m}$  and a pushing load was 0.25 mN or 25.0 mN was studied.

The results are shown in Table 3.

[0078]

Table 3

| Table 3               | standard deviation when load applied to indenter is varied ( $\mu\text{m}$ ) |              |              | arithmetic mean roughness of microwaviness ( $\text{\AA}$ ) |
|-----------------------|------------------------------------------------------------------------------|--------------|--------------|-------------------------------------------------------------|
|                       | load 2.5 mN                                                                  | load 0.25 mN | load 25.0 mN |                                                             |
| Example 1             | 0.07                                                                         | 0.08         | 1.67         | 0.60                                                        |
| Example 2             | 0.10                                                                         | 0.04         | 1.13         | 0.61                                                        |
| Example 3             | 0.12                                                                         | 0.05         | 2.18         | 0.61                                                        |
| Example 4             | 0.15                                                                         | 0.03         | 1.87         | 0.65                                                        |
| Comparative Example 1 | 0.16                                                                         | 0.08         | 1.56         | 0.72                                                        |
| Comparative Example 2 | 0.21                                                                         | 0.07         | 1.96         | 0.86                                                        |
| Comparative Example 3 | 0.24                                                                         | 0.10         | 2.32         | 0.88                                                        |

5 [0079]

As can be understood from the results of Table 3, a correlation between the standard deviation of depression amounts and microwaviness having a shape wavelength of 50 to 150  $\mu\text{m}$  was not found.

Therefore, based on the above-described reason, as indenter pushing  
 10 conditions when a depression amount of the polishing pad is measured, the diameter of the indenter is optimally set to 50  $\mu\text{m}$  and the pushing load is optimally set to 2.5 mN.

[0080]

(Examples 5 to 11)

15 Similarly to Example 1 described above, glass substrates were produced in accordance with the above-described method except that twelve depression amounts that occurred when a cylindrical indenter was pushed into the surface of the polishing pad were measured, an arithmetic mean value of ten depression amounts excluding the maximum value and the minimum value of  
 20 the twelve depression amounts was derived, seven types of polishing pads

having different derived arithmetic mean values were prepared, and each of these polishing pads was used to perform the above-described second polishing step. It should be noted that the above-described seven types of polishing pads had a standard deviation of the ten depression amount in a range of 0.13 to 0.14  $\mu\text{m}$ .

With regard to the obtained glass substrates (Examples 5 to 11), the surfaces of the glass substrates were visually observed and measured by an optical surface analyzer, defects that were found were analyzed by a SEM and an AFM, and the number of surface defects such as marks (minute scratches having a length of about 50 nm or less and a depth of about 5 nm or less) was counted. The results are shown in Table 4.

[0081]

Table 4

| Table 4    | arithmetic mean value of depression amount of polishing pad ( $\mu\text{m}$ ) | number of mark defects |
|------------|-------------------------------------------------------------------------------|------------------------|
| Example 5  | 6.9                                                                           | 7                      |
| Example 6  | 3.0                                                                           | 23                     |
| Example 7  | 5.6                                                                           | 8                      |
| Example 8  | 5.7                                                                           | 8                      |
| Example 9  | 7.3                                                                           | 6                      |
| Example 10 | 10.1                                                                          | 4                      |
| Example 11 | 12.3                                                                          | 3                      |

[0082]

As is clear from the result of Table 4 above, it can be understood that in the case where polishing pads in which the standard deviation of depression amounts was 0.15  $\mu\text{m}$  or less were used and, in particular, where the arithmetic mean value of depression amounts thereof was 5  $\mu\text{m}$  or more, the effect of

reducing mark defects (ten defects or less) can be obtained in addition to the effect of reducing microwaviness described above.

[0083]

Examples 12 to 17 below are examples corresponding to the  
5 above-described second embodiment.

(Examples 12 to 17 and Comparative Example 4)

Magnetic-disk glass substrate were manufactured through (1) a rough lapping step (rough grinding step), (2) a shape processing step, (3) a precision lapping step (precision grinding step), (4) an edge surface polishing step, (5) a  
10 main surface polishing step (first polishing step), (6) a chemical strengthening step, and (7) a main surface polishing step (second polishing step) described below.

[0084]

(1) Rough lapping step

15 First, a disk-shaped glass substrate made of aluminosilicate glass and having a diameter of 66 mm $\phi$  and a thickness of 1.0 mm was obtained from molten glass by direct pressing using upper, lower, and drum molds. It should be noted that, other than using direct pressing, a glass substrate may be obtained by cutting plate glass manufactured by a down draw method or a float  
20 method into a predetermined size.

[0085]

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

25 (2) Shape processing step

Next, a cylindrical grindstone was used to create a hole in the central portion of the glass substrate and an outer circumferential edge surface was ground to have a diameter of 65 mm $\phi$ , and predetermined chamfering was then

performed on the outer circumferential edge surface and an inner circumferential edge surface.

(3) Precision lapping step

A double-side lapping device was used to perform this precision lapping  
 5 step.  
 [0086]

(4) Edge surface polishing step

Next, the edge surfaces (inner and outer circumferential edge surfaces)  
 of the glass substrate were polished by brushing while the glass substrate was  
 10 rotated. The surface of the glass substrate that had undergone the  
 above-described edge surface polishing was then cleaned.  
 [0087]

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

Next, a first polishing step was performed using a double-side polishing  
 15 device. With the double-side polishing device, a glass substrate held by a  
 carrier was in close contact between an upper polishing surface plate and a  
 lower polishing surface plate to which polishing pads were respectively attached,  
 this carrier was engaged with a sun gear and an internal gear, and the glass  
 substrate was pressed by the upper and lower surface plates. Thereafter, by  
 20 supplying the polishing liquid between the polishing pads and the polishing  
 surfaces of the glass substrate and rotating the polishing pads, the glass  
 substrate revolved while rotating on the surface plates so that both surfaces  
 were polished at the same time. Specifically, the first polishing step was  
 performed using a hard polisher (hard urethane foam) as a polisher. A  
 25 polishing liquid in which cerium oxide was dispersed as an abrasive was used as  
 the polishing liquid. The glass substrate that had undergone the  
 above-described first polishing step was cleaned and dried.  
 [0088]

## (6) Chemical strengthening step

Next, the glass substrate that had undergone the cleaning was chemically strengthened. Chemical strengthening was performed by preparing a chemical strengthening liquid obtained by mixing potassium nitrate and sodium nitrate, heating the chemical strengthening liquid to 380°C, and immersing the glass substrate that had undergone the above-described cleaning and drying in the chemical strengthening liquid for approximately four hours.

[0089]

## (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, and polishing pads (polyurethane foam) with a soft polisher (suede) were used instead as the polisher. This second polishing step is mirror-polishing processing to finish the main surfaces of the glass substrate into smooth mirror surfaces having a surface roughness Ra of about 0.2 nm or less, for example, while maintaining the flat surfaces obtained in the first polishing step described above. A polishing liquid in which colloidal silica was dispersed in water and that was adjusted to be acidic was used as the polishing liquid. The glass substrate that had undergone the above-described second polishing step was cleaned and dried.

[0090]

It should be noted that the seven types of polishing pads were used as the above-described polishing pad. All of these seven types of polishing pads had the largest pore diameter (100 to 200  $\mu\text{m}$ ) on the base material side and the smallest pore diameter (3 to 20  $\mu\text{m}$ ) on the outermost layer side. With regard to each polishing pad, depression amounts that occurred when a cylindrical indenter was pushed into the surface of the polishing pad were measured and

the arithmetic mean value thereof was derived in accordance with the above-described method. The results are shown in Table 5.

[0091]

When surface roughnesses of main surfaces of glass substrates  
5 (Examples 12 to 17 and Comparative Example 4) that were obtained through the above-described steps (the seven types of polishing pads were respectively used in the above-described second polishing step) were measured by an atomic force microscope (AFM), glass substrates having an extremely smooth surface having a Rmax of 1.43 nm and a Ra of 0.13 nm were obtained in the  
10 examples and comparative example.

With regard to the obtained glass substrates, the surfaces of the glass substrates were visually observed and measured by an optical surface analyzer, defects that were found were analyzed by a SEM and an AFM, and the number of surface defects such as marks (minute scratches having a length of about 50  
15 nm or less and a depth of about 5 nm or less) was counted. The results are shown in Table 5.

Also, the outer diameter, inner diameter, and substrate thickness of the obtained glass substrate were respectively 65 mm, 20 mm, and 0.635 mm.

20

25

[0092]

Table 5

| Table 5                  | arithmetic mean value<br>( $\mu\text{m}$ ) | number of<br>minute mark defects |
|--------------------------|--------------------------------------------|----------------------------------|
| Example 12               | 6.9                                        | 7                                |
| Example 13               | 5.6                                        | 8                                |
| Example 14               | 5.7                                        | 8                                |
| Example 15               | 7.3                                        | 6                                |
| Example 16               | 10.1                                       | 4                                |
| Example 17               | 12.3                                       | 3                                |
| Comparative<br>Example 4 | 3.0                                        | 23                               |

[0093]

As can be understood from the result of Table 5 above, by performing

5 mirror-polishing using a polishing pad in which the arithmetic mean value of depression amounts resulting from the indenter being pushed into the surface of the polishing pad is 5  $\mu\text{m}$  or more, it is possible to achieve a reduction in the above-described minute mark defects (six to ten defects per substrate). In particular, by performing mirror-polishing processing using a polishing pad in

10 which the arithmetic mean value of depression amounts is 10  $\mu\text{m}$  or more, it is possible to achieve a further reduction in the above-described minute mark defects (five or less defects per substrate).

[0094]

Next, a relationship between the arithmetic mean value and the number

15 of minute mark defects obtained when the diameter of an indenter was varied was studied. The results are shown in Table 6. At this time, the load applied to the indenter was 2.5 mN.

[0095]

| Table 6                                                                  |                                    |                                    |                                     |                               |
|--------------------------------------------------------------------------|------------------------------------|------------------------------------|-------------------------------------|-------------------------------|
| arithmetic mean value when indenter diameter is varied ( $\mu\text{m}$ ) |                                    |                                    |                                     |                               |
| Table 6                                                                  | indenter diameter 50 $\mu\text{m}$ | indenter diameter 20 $\mu\text{m}$ | indenter diameter 100 $\mu\text{m}$ | number of minute mark defects |
| Example 12                                                               | 6.9                                | 13.5                               | 3.9                                 | 7                             |
| Example 13                                                               | 5.6                                | 25.0                               | 3.0                                 | 8                             |
| Example 14                                                               | 5.7                                | 11.1                               | 2.8                                 | 8                             |
| Example 15                                                               | 7.3                                | 12.3                               | 4.9                                 | 6                             |
| Example 16                                                               | 10.1                               | 26.2                               | 4.8                                 | 4                             |
| Example 17                                                               | 12.3                               | 30.3                               | 6.2                                 | 3                             |
| Comparative Example 4                                                    | 3.0                                | 28.3                               | 2.9                                 | 23                            |

[0096]

In the case where conditions were set such that the pushing load of the indenter was 2.5 mN and the diameter of the indenter was 20  $\mu\text{m}$  or 100  $\mu\text{m}$  in measurement of depression amounts, as can be understood from the result of Table 6 above, a correlation between the arithmetic mean value of depression amounts and the number of minute mark defects was not found. The reason for that can be conjectured to be that in the case where the diameter of the indenter was 20  $\mu\text{m}$ , a tip portion of the indenter passes through a minute pore present on the polishing pad surface, and thus accurate variation in hardness cannot be measured. Also, it is conjectured that in the case where the diameter of the indenter is 100  $\mu\text{m}$ , the diameter of the indenter is larger than the pore diameter inside the pad, and thus the hardnesses in a pore portion and a wall portion cannot be measured.

[0097]

Next, a relationship between the arithmetic mean value and the number of minute mark defects obtained in the case where conditions were set such that the diameter of an indenter was 50  $\mu\text{m}$  and the pushing load was 0.25 mN or 25.0 mN was studied. The results are shown in Table 7.

[0098]

| Table 7                                                                         |             |              |              |                              |
|---------------------------------------------------------------------------------|-------------|--------------|--------------|------------------------------|
| arithmetic mean value when load applied to indenter is varied ( $\mu\text{m}$ ) |             |              |              |                              |
| Table 7                                                                         | load 2.5 mN | load 0.25 mN | load 25.0 mN | number of minute mark defect |
| Example 12                                                                      | 6.9         | 0.7          | 51.6         | 7                            |
| Example 13                                                                      | 5.6         | 0.6          | 38.8         | 8                            |
| Example 14                                                                      | 5.7         | 0.6          | 56.2         | 8                            |
| Example 15                                                                      | 7.3         | 0.7          | 41.7         | 6                            |
| Example 16                                                                      | 10.1        | 0.8          | 62.8         | 4                            |
| Example 17                                                                      | 12.3        | 0.9          | 70.1         | 3                            |
| Comparative Example 4                                                           | 3.0         | 0.6          | 28.3         | 23                           |

[0099]

As can be understood from the result of Table 7, a correlation between the arithmetic mean value of depression amounts and the number of minute mark defects was not found.

Therefore, based on the above-described reason, as indenter pushing conditions when a depression amount of the polishing pad is measured, the diameter of the indenter is optimally set to 50  $\mu\text{m}$  and the pushing load is optimally set to 2.5 mN.

[0100]

(Manufacture of magnetic disk)

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

Specifically, an adherent layer constituted by a Ti-based alloy thin film, a soft magnetic layer constituted by a CoTaZr alloy thin film, a base layer constituted by a Ru thin film, a perpendicular magnetic recording layer made of a

CoCrPt alloy, a carbon protective layer, and a lubricant layer were sequentially formed on the glass substrate. The protective layer is to prevent degradation of the magnetic recording layer caused by contact with the magnetic head. The protective layer was composed of hydrogenated carbon and yielded wear  
 5 resistance. The lubricant layer was formed by a dipping method using an alcohol-modified perfluoropolyether liquid lubricant.

[0101]

With regard to the obtained magnetic disks, as a result of testing glide properties using a DFH head, head crash did not occur and favorable results  
 10 were obtained.

Also, by performing the above-described film forming step on the magnetic-disk glass substrates obtained in Example 12 described above, a magnetic disk for perpendicular magnetic recording was obtained.

With regard to the obtained magnetic disks, a predetermined test on  
 15 overwrite properties was performed using a DFH head, and favorable results were obtained without overwrite failure occurring.

#### Descriptions of Reference Numerals

[0102]

|    |    |                      |
|----|----|----------------------|
| 20 | 1  | Glass substrate      |
|    | 2  | Sun gear             |
|    | 3  | Internal gear        |
|    | 4  | Carrier              |
|    | 5  | Upper surface plate  |
| 25 | 6  | Lower surface plate  |
|    | 7  | Polishing pad        |
|    | 10 | Cylindrical indenter |

## CLAIMS

1. A method for manufacturing a magnetic-disk glass substrate comprising polishing processing for supplying a polishing liquid containing  
5 polishing abrasive particles between a main surface of a glass substrate and a polishing pad having a resin foam layer, and polishing the main surface of the glass substrate, wherein  
as the polishing pad, a polishing pad is used that has a standard deviation of 0.15  $\mu\text{m}$  or less obtained when a depression amount of the polishing  
10 pad that occurs when a circular portion of a cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, and the depression amount is successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, from data on ten depression amounts excluding a maximum value and  
15 a minimum value of the obtained depression amounts.
2. The method for manufacturing a magnetic-disk glass substrate according to claim 1, wherein an arithmetic mean value of the ten depression amounts in the polishing pad is 5  $\mu\text{m}$  or more.
3. A method for manufacturing a magnetic-disk glass substrate  
20 comprising polishing processing for supplying a polishing liquid containing polishing abrasive particles between a main surface of a glass substrate and a polishing pad having a resin foam layer, and polishing the main surface of the glass substrate, wherein  
as the polishing pad, a polishing pad is used that has an arithmetic mean  
25 value of 5  $\mu\text{m}$  or more obtained when a depression amount of the polishing pad that occurs when a circular portion of a cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, and the depression amount is

successively obtained twelve times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, from data on ten depression amounts excluding a maximum value and a minimum value of the obtained depression amounts.

4. The method for manufacturing a magnetic-disk glass substrate  
5 according to claim 3, wherein the arithmetic mean value of the ten depression amounts in the polishing pad is 10  $\mu\text{m}$  or more.

5. The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 4, wherein a glass substrate before the polishing processing is performed has a surface roughness (Ra) of 3 nm or less.

10 6. The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 5, wherein when both main surfaces of the glass substrate are polished at the same time using a planetary polishing device in which the polishing pad is attached to a surface plate, the polishing processing is performed such that a pressing force of the polishing pad applied to the glass  
15 substrate is in a range of 75 to 150  $\text{gf}/\text{cm}^2$ .

7. The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 6, wherein the polishing abrasive particles contain colloidal silica.

8. The method for manufacturing a magnetic-disk glass substrate  
20 according to any of claims 1 to 7, wherein the magnetic-disk glass substrate is a glass substrate to be used in a magnetic disk to be provided in a hard disk drive provided with a DFH-type magnetic head.

9. A method for manufacturing a magnetic disk, in which at least a magnetic layer is formed on a magnetic-disk glass substrate obtained by the  
25 manufacturing method according to any of claims 1 to 8.

10. A polishing pad to be used in polishing processing for polishing a main surface of a magnetic-disk glass substrate, wherein

when a depression amount of the polishing pad that occurs when a circular portion of a cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, the depression amount is successively obtained twelve  
 5 times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, and a standard deviation is obtained from data on ten depression amounts excluding a maximum value and a minimum value of the obtained depression amounts, the standard deviation is 0.15  $\mu\text{m}$  or less.

11. A polishing pad to be used in polishing processing for polishing a  
 10 main surface of a magnetic-disk glass substrate, wherein

when a depression amount of the polishing pad that occurs when a circular portion of a cylindrical indenter having a diameter of 50  $\mu\text{m}$  is pushed into a surface of the polishing pad that serves as a polishing surface at a load of 2.5 mN is measured, the depression amount is successively obtained twelve  
 15 times at an interval of 50  $\mu\text{m}$  on the polishing pad surface, and an arithmetic mean value is obtained from data on ten depression amounts excluding a maximum value and a minimum value of the obtained depression amounts, the arithmetic mean value is 5  $\mu\text{m}$  or more.