

DESCRIPTION

Title of the Invention

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

Technical Field

[0001]

10 The present invention relates to a 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) and a method for
manufacturing the same.

15 Background Art

[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
20 an aluminum substrate has been used as the substrate. However, recently, in
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 precisely polished such that the flying height of the magnetic head can
25 be lowered as much as possible to achieve a high recording density. 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, a highly smooth substrate surface is ultimately required, and thus it is necessary to precisely polish the surface of the glass substrate.

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 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.

[0004]

Here, for example, Patent Literature 1 describes a magnetic-disk glass substrate that is capable of suppressing problems in a HDD provided with a magnetic head having an extremely small flying height by managing the shape and number of defects on the surface of the substrate.

20 Prior Art Literature

Patent Literature

[0005]

Patent Literature 1: WO 2010/001843

25 Summary of the Invention

Problem to be Solved by the Invention

[0006]

Although currently available HDDs can store about 320 gigabytes of 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, for example. 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 the substrate, but also with regard to the absence of surface defects such as defects caused by foreign matter or the like.

[0007]

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

A significant reduction is achieved in the flying height (the gap between the magnetic head and the surface of 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 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 of the recording and reproduction element portion, instead of lowering the flying height of a slider. In the future, it is expected that the DFH function will greatly reduce the gap between the element portion of the magnetic head and the medium surface to less than 2 nm. Under such circumstances, even if the

average roughness of the substrate surface is reduced to an extremely low level, if there are surface defects such as defects resulting from foreign matter, which were conventionally not a problem, the protruding recording and reproduction element portion of the magnetic head collides with the foreign matter defects, and frequent collision between the magnetic head and the foreign matter defect influences driving of the magnetic head, which can cause a reading failure which is a serious malfunction resulting from deterioration of the element.

[0008]

Incidentally, Patent Literature 1 describes protruding foreign matter defects having a broad protruding region as defects that are considered to have an influence on a magnetic head having an extremely small flying height such as a magnetic head provided with the DFH function (simply referred to as "DFH head" hereinafter). Such defects having a broad protruding region have a relatively large area that comes into contact with the magnetic head and apply considerable collision energy to the magnetic head compared with defects having a sharp protruding region, as a result of which the magnetic head may crash.

[0009]

In recent years, technology using a DFH head equipped with a HDI (head disk interface) sensor has been proposed as technology that can prevent the DFH head from crashing due to the presence of defects having a broad protruding region as described in Patent Literature 1.

This HDI sensor is a so-called contact detection sensor, and detects protruding defects (protrusions) on the surface of a magnetic disk. The HDI sensor is configured by a MR (magnetoresistive) element, for example, and performs detection utilizing a thermal asperity phenomenon.

[0010]

It is thought that contact between protruding defects present on the magnetic disk surface and writing/reading elements of the DFH head that is scanning the magnetic disk surface can be avoided by detecting the state of the magnetic disk surface using the DFH head equipped with this HDI sensor and
5 controlling the protruding amount of at least one of the writing element and the reading element. In other words, because the state of the magnetic disk surface can be detected by using the HDI sensor, it is thought that even if there is a defect having a broad protruding region as described in Patent Literature 1, contact between these elements and the defect can be avoided by controlling
10 the protruding amount of the writing and reading elements before the DFH head passes over this defect.

[0011]

However, according to studies conducted by the inventor, when attempts were made to manufacture a magnetic disk having a higher recording
15 density than previously available such as a recording density exceeding 750 gigabytes, for example, there were cases in which head crash occurred unexpectedly, even when the above-described HDI sensor was used.

The inventor studied the cause of this and found that there was a high possibility that the frequency of reading errors of the head increased and thus
20 that the above-described head crash problem was caused due to a specific defect that had not been detected in the past.

[0012]

In view of this, the present invention was made to resolve such conventional issues, and an object thereof is to provide a method for
25 manufacturing a magnetic-disk glass substrate, a magnetic-disk glass substrate, and a method for manufacturing a magnetic disk that are capable of reducing foreign matter defects that can unexpectedly cause head crash even in the case where a HDI sensor is used.

Means to Solve the Problem

[0013]

The inventor further studied the causes of foreign matter defects that
5 could cause the above-described head crash and found that there was foreign
matter on the surface of the glass substrate, which was the substrate of the
magnetic disk. It was also found that this foreign matter was present even in
the case where magnetic substrates were manufactured in accordance with the
manufacturing method disclosed in Patent Literature 1 described above, for
10 example. In other words, these defects are conceivably foreign matter defects
that are caused by different factors from the defects having a broad protruding
region such as described as an issue in Patent Literature 1 described above.

In view of this, the inventor further studied the causes of these foreign
matter defects and found that a polishing liquid that was used to polish the glass
15 substrate contained foreign matter that caused the above-described defects.
Accordingly, the inventor found that there was a possibility that since the
polishing liquid was in contact with the glass substrate even after the glass
substrate surface has been polished, the foreign matter that was included in the
polishing liquid adhered to the glass substrate surface, and was present on the
20 glass substrate surface without being removed by cleaning processing or the like
performed thereafter.

[0014]

In view of this, based on the above-described findings, the inventor
found that the above-described issues could be resolved by adjusting the
25 polishing liquid so as to not contain the foreign matter that caused the
above-described defects, or selecting a polishing liquid that did not contain such
foreign matter as the polishing liquid, thus accomplishing the invention.

[0015]

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

(Aspect 1)

A method for manufacturing a magnetic-disk glass substrate to be applied to a magnetic disk compatible with a DFH head that is equipped with a HDI sensor and is capable of controlling a protruding amount of at least one of a recording element and a reproduction element based on a signal from the HDI sensor, the method including polishing processing for supplying a polishing liquid containing colloidal silica between a main surface of a glass substrate and a polishing pad, bringing the glass substrate and the polishing pad into contact with each other, and mirror-polishing the main surface of the glass substrate, and the polishing liquid being adjusted in order to prevent occurrence of foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) at least in an acidic environment.

15 [0016]

(Aspect 2)

A method for manufacturing a magnetic-disk glass substrate to be applied to a magnetic disk compatible with a DFH head that is equipped with a HDI sensor and is capable of controlling a protruding amount of at least one of a recording element and a reproduction element based on a signal from the HDI sensor, the method including polishing processing for supplying a polishing liquid containing colloidal silica between a main surface of a glass substrate and a polishing pad, bringing the glass substrate and the polishing pad into contact with each other, and mirror-polishing the main surface of the glass substrate, a polishing liquid that does not contain foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) that can inhibit recording or reproduction when the glass substrate is made into a magnetic disk and undergoes recording or reproduction with a magnetic head being selected as the

polishing liquid, and the polishing processing being performed using the selected polishing liquid.

[0017]

(Aspect 3)

5 In the method for manufacturing a magnetic-disk glass substrate according to aspect 1 or 2, the foreign matter is a layered compound.

(Aspect 4)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 3, the colloidal silica is manufactured by an ion
10 exchange method.

[0018]

(Aspect 5)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 4, a content of aluminum (Al) in the colloidal
15 silica is 5 $\mu\text{g/g}$ or less.

(Aspect 6)

In the method for manufacturing a magnetic-disk glass substrate according to any of aspects 1 to 5, cleaning processing is performed on a glass substrate after the polishing processing, under a condition that a difference in a
20 surface roughness R_q of the glass substrate before cleaning and after cleaning is 0.05 nm or less.

[0019]

(Aspect 7)

In the method for manufacturing a magnetic-disk glass substrate
25 according to any of aspects 1 to 6, the magnetic-disk glass substrate is a glass substrate to be used in a magnetic disk to be provided in a hard disk drive for a server.

[0020]

(Aspect 8)

A method for manufacturing a magnetic-disk glass substrate to be applied to a magnetic disk compatible with a DFH head that is equipped with a HDI sensor and is capable of controlling a protruding amount of at least one of a recording element and a reproduction element based on a signal from the HDI sensor, the method including polishing processing for supplying a polishing liquid containing colloidal silica between a main surface of a glass substrate and a polishing pad, bringing the glass substrate and the polishing pad into contact with each other, and mirror-polishing the main surface of the glass substrate, the polishing liquid being adjusted in order to prevent occurrence of foreign matter that can inhibit recording or reproduction when the glass substrate is made into a magnetic disk and undergoes recording or reproduction with the DFH head.

(Aspect 9)

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

(Aspect 10)

A magnetic-disk glass substrate having a main surface, in which an arithmetic mean roughness R_a obtained when a measurement region of $1\ \mu\text{m} \times 1\ \mu\text{m}$ square of the main surface of the substrate is measured using an atomic force microscope at a resolution of 256×256 pixels is $0.15\ \text{nm}$ or less and an arithmetic mean roughness R_a having a wavelength bandwidth of 30 to $200\ \text{nm}$ is $0.06\ \text{nm}$ or less, and when the main surface of the substrate is irradiated with laser light having a wavelength of $405\ \text{nm}$ and a power of $80\ \text{mW}$ at a spot diameter of $6\ \mu\text{m}$ and foreign matter is detected using scattered light from the main surface of the substrate, a number of defects having a size of 30 to $200\ \text{nm}$ in an in-plane direction per main surface is 30 or less and the detected defects

do not include a layered compound.

Effect of the Invention

[0021]

5 With the above-described aspects of the present invention, it is possible to manufacture a high-quality magnetic-disk glass substrate in which foreign matter defects that can cause head crash, even in the case where a HDI sensor is used, can be reduced.

 Also, with the above-described aspects of the present invention, a
10 high-quality magnetic-disk 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, can be manufactured.

Brief Description of Drawings

15 [0022]

 FIG. 1 is a plan view (a) showing an example of the shape of foreign matter relating to the present invention and a diagram (b) showing a cross-sectional shape of the foreign matter.

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

Mode for Embodying the Invention

[0023]

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

 The magnetic-disk glass substrate is generally manufactured through a rough grinding step (rough lapping step), a shape processing step, a precision grinding step (precision lapping step), an edge surface polishing step, a main

surface polishing step (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.

5 It should be noted that a glass substrate may be obtained by cutting plate glass manufactured by a down draw method or a float method other than using direct pressing into a predetermined size. Next, grinding (lapping) for 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
10 is generally used to grind the main surfaces of the glass substrate with hard abrasive particles such as diamond particles. By grinding the main surfaces of the glass substrate in this manner, the glass substrate is processed so as to have a predetermined substrate thickness and flatness and to attain a predetermined surface roughness.

15 [0024]

After this grinding step ends, the shape processing step and the edge surface polishing step are performed, and the mirror-polishing processing for 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
20 made of polyurethane or the like while supplying a slurry (polishing liquid) containing an abrasive that is made of a metal oxide such as cerium oxide or colloidal silica.

[0025]

Here, a first embodiment according to the present invention will be
25 described.

As described in Aspect 1 above, the first embodiment of the present invention is a method for manufacturing a magnetic-disk glass substrate including polishing processing for mirror-polishing a surface of a glass substrate

by bringing a polishing liquid containing colloidal silica and a polishing pad into contact with the surface of the glass substrate, and the polishing liquid is adjusted to prevent occurrence of foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) at least in an acidic environment.

5 [0026]

As described above, according to the studies conducted by the inventor, when attempts were made to manufacture a magnetic disk having a higher recording density than previously available, such as recording density exceeding 750 gigabytes, for example, it was found that there were cases in which head
10 crash occurred unexpectedly, even if a clearance between the magnetic disk and the recording and reproduction elements of a head was controlled with high precision using a HDI sensor.

The inventor found that there was a high possibility that the above-described head crash occurred due to the presence of defects having a
15 specific shape or the like that had not been detected previously, and having further studied the cause of foreign matter defects that could cause the above-described head crash, found that foreign matter was present on the surface of the glass substrate, which is the substrate of a magnetic disk. In addition, it was found that there were cases in which this foreign matter was
20 present even in the case where a magnetic disk was manufactured in accordance with the manufacturing method disclosed in Patent Literature 1, and these defects are conceivably foreign matter defects that are caused by different factors from the defects having a broad protruding region such as described as an issue in Patent Literature 1 described above.

25 [0027]

FIG. 1 shows an example of the shape of foreign matter that is the problem addressed in the present invention, with (a) being a plan view and (b) being a diagram showing the cross-sectional shape of the foreign matter.

In the present invention, foreign matter that is addressed as a problem, that can cause the above-described head crash problem and is present on the surface of the glass substrate contains elements of aluminum (Al), silicon (Si), and oxygen (O).

5 Also, the foreign matter has a small thickness and is relatively flat, as shown in FIG. 1, for example. X and Y sizes (see FIG. 1(a)) of the foreign matter in a plane (X-Y plane) are respectively in a range of about 30 to 200 nm. Also, the size (see FIG. 1(b)) of a thickness H of the foreign matter is in a range of about 1 to 20 nm. A ratio (Y/H) of the Y size to the size of the thickness H of
10 the foreign matter in the plane is in a range of about 5 to 200, for example.

In addition, the shape of the foreign matter (plan view) is not limited to an indeterminate shape that is shown in FIG. 1(a) as an example, and can have various shapes such as a polygonal shape (i.e. a square shape, a rectangular shape, or a hexagonal shape).

15 Also, when the cross-section of the foreign matter is observed by a cross-section TEM, a layered structure in which multiple thin layers are laminated in the thickness direction is observed and an edge portion rises relatively steeply.

[0028]

20 As a result of analyzing the structure and composition of such foreign matter, the inventor found that the foreign matter was crystalline layered foreign matter and, specifically, layered clay mineral (layered silicate) foreign matter (montmorillonite, saponite, kaolinite, for example) or the like.

In a magnetic disk produced using a glass substrate of which foreign
25 matter having such a specific shape is present on the surface, when recording or reproduction is performed with a DFH head, there are cases in which an element deteriorates even if a clearance between the magnetic disk and recording and reproduction elements of the head is precisely controlled using a HDI sensor,

and it is suggested that the reason for this is that the tip of the sensor collides with the defects due to delay in the tracking of the HDI sensor due to this shape.

Although such foreign matter defects were not a problem with the conventional DFH head or were not detected, when the DFH head is equipped with a HDI sensor, the gap between the disk surface and DFH head is reduced to 1 nm or less, as a result of which such foreign matter is recognized as issues (abrasion of protruding element portion) for the first time.

The HDI sensor can obtain a temperature change resulting from a change in the distance between the DFH element portion and the disk surface, and is capable of controlling a DFH protruding amount in approximately real time by feeding back the obtained signal into an electric current value that controls the DFH protruding amount, and therefore the gap between the head and the disk surface can be reduced to 1 nm or less. However, it is suggested that the foreign matter that is addressed as a problem in the present invention has a specific shape as described above, and a signal of the HDI sensor rises steeply, and thus feeding back of the signal to the DFH element portion is not timing, as a result of which the DFH element portion comes into contact with foreign matter and is worn away.

[0029]

The inventor further studied the causes of foreign matter defects on the glass substrate surface and found that a polishing liquid that was used to polish the glass substrate contained foreign matter that causes the above-described defects. In other words, it is thought that there is a possibility that since the polishing liquid is in contact with the glass substrate even after the glass substrate surface has been polished, foreign matter that is included in the polishing liquid adheres to the glass substrate surface and is present on the glass substrate surface without being removed by cleaning or the like performed thereafter.

Because foreign matter made of a layered compound is extremely flat, the lower roughness the glass substrate surface has, the more likely the foreign matter is to closely stick thereto with a strong force, in the case of adhering thereto. Also, because the foreign matter made of a layered compound is
5 extremely small, it is extremely difficult to completely eliminate the foreign matter by filtering.

Therefore, it is very important to prevent the foreign matter from adhering thereto during polishing or after polishing.

[0030]

10 In view of this, based on the above-described findings, the inventor found that by adjusting the polishing liquid so as to not contain foreign matter that causes the above-described defects the above-described issues can be resolved. That is, in the first embodiment of the present invention, as in Aspect 1 described above, a polishing liquid that is used in the polishing is adjusted in
15 order to prevent occurrence of foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) at least in an acidic environment.

[0031]

In this embodiment, in order to prevent occurrence of foreign matter that contains elements of aluminum (Al), silicon (Si), and oxygen (O), and that
20 causes the above-described defects, in a method for adjusting the polishing liquid that is used in the polishing processing so as to not contain the foreign matter, silica abrasive particles obtained by dissolving silica abrasive particles serving as polishing abrasive particles to be included in the polishing liquid so that the content of aluminum included in the dissolved silica abrasive particles is
25 5 $\mu\text{g/g}$ or less and more preferably 3 $\mu\text{g/g}$ or less may be used as the polishing abrasive particles, for example. Also, in another method, a polishing liquid in which the amount of aluminum included in a solid obtained by evaporating and drying a slurry, which is the polishing liquid, is 5 $\mu\text{g/g}$ or less is used, for example.

By mirror-polishing a main surface of a glass substrate using such silica abrasive particles or such a polishing liquid, the number of the foreign matter adhering to the surface of the glass substrate after polishing can be reduced.

[0032]

5 Also, it is preferable that polishing abrasive particles are produced using a highly-pure silica sol that does not include impurities such as Al or include an extremely small amount of impurities that are obtained by the following manufacturing method, for example, and a polishing liquid of the present invention is adjusted.

10 Specifically, highly-pure silica sol that does not include impurities such as Al can be manufactured by a first step in which a raw material silica (silica gel) containing impurities such as Al and the like in an amount of 5 µg/g or less is dissolved in a quaternary ammonium hydroxide aqueous solution, a second step in which the quaternary ammonium hydroxide is removed by an ion exchange
15 method to prepare an active silicic acid solution, and a third step in which the active silicic acid solution is heated under the presence of an alkaline catalyst so that silica grows to have a predetermined particle diameter.

[0033]

20 The raw material silica that is used in the above-described first step is obtained by a reaction between sodium silicate and mineral acid. A commercially available sodium silicate solution (water glass) can be used as sodium silicate. Also, hydrochloric acid, nitric acid, sulfuric acid, or the like can be used as the mineral acid. In addition, at the time of the reaction between sodium silicate and mineral acid, as a result of coexisting of a chelating agent
25 such as dicarboxylic acids like oxalic acid, malonic acid, and succinic acid, polycarboxylic acids, oxycarboxylic acids like citric acid, and hydrogen peroxide, impurities can be eliminated to a predetermined amount or less. It should be

noted that the content of impurities such as Al can be measured using inductively coupled plasma atomic emission spectroscopy (ICP-AES).

[0034]

Incidentally, it was found that in the case where a raw material silica was
5 obtained from a commercially available sodium silicate solution (water glass), even if a plurality of instances of the above-described mineral acid processing were performed, it was difficult to reduce the content of Al element to 5 ppm ($\mu\text{g/g}$) or less. This is because Al elements are taken into the particles of the raw material silica at the time of a condensation reaction by the mineral acid
10 processing. The Al elements taken into the particles cannot be removed by repeatedly performing processing with mineral acid thereafter. In view of this, the Al elements are further removed after the following crushing processing is performed.

[0035]

15 A raw material silica (referred to as "crude silica" hereinafter) obtained by first mineral acid processing usually has a size of 50 nm or more. In the case of crushing this, dry crushing may or wet crushing may be performed. Crude silica can be crushed by a ball mill, a bead mill, a jet mill, or ultrasonic waves, for example.

20 Next, the crushed crude silica is cleaned using an aqueous solution of a strong acid to remove impurities of metal such as Al. A mineral acid of hydrochloric acid, nitric acid, sulfuric acid, or the like can be used as the strong acid. The pH of the strong acid is preferably 1 or more, and more preferably 2 to 4.

25 Also, an oxidizing agent that does not contain a metal element may be added to the strong acid aqueous solution. Metal impurities are positively ionized by the oxidizing agent, and thus the metal impurities can be efficiently

removed. Hydrogen peroxide or the like can be used as such an oxidizing agent, for example.

[0036]

Furthermore, a chelating agent in which a metal ion that is positively ionized by a strong acid or an oxidizing agent forms a chelate complex may be added to the strong acid aqueous solution. The chelating agent can prevent a metal ion from re-adhering to silica and reliably remove the metal impurities.

N'-(2-hydroxyethyl)ethylenediamine-N,N,N'-triacetic acid (HEDTA),

1-hydroxyethane-1,1-diphosphonic acid (HEDP), nitrilotriacetic acid (NTA),

N,N-di(2-hydroxyethyl)glycine (DHEG), ethylenediamine tetraacetic acid (EDTA), N-(2-hydroxyethyl)iminodiacetic acid (HIDA), diethylenetriaminepentaacetic acid (DTPA), oxalic acid, malic acid, tartaric acid, fumaric acid, succinic acid, citric acid, gluconic acid, or the like can be used as such a chelating agent, for example.

[0037]

Thereafter, pure silica containing Al elements in an amount of 5 ppm or less can be obtained by removing the strong acid aqueous solution by filtration and washing with water.

It should be noted that in the case where the content of metal impurities in the obtained pure silica is greater than 5 ppm, the above-described crushing and processing for removing metal elements are repeatedly performed until the content of Al elements reaches 5 ppm or less. Also, the above-described crushing and removing processing may be performed at the same time, by wet crushing the strong acid aqueous solution containing crude silica.

By crushing crude silica containing metal impurities in an amount of more than 5 ppm and then cleaning the crushed crude silica with a strongly acidic aqueous solution in this manner, metal impurities of Al elements and the like that are taken into the crude silica can be precisely removed, and pure silica

that is purified until the content of the metal impurities reaches 5 ppm or less can be obtained. This pure silica is then used as a raw material silica, and thereby occurrence of crystalline layered foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) can be suppressed in the subsequent
 5 step.

[0038]

In the above-described first step, thus obtained silica gel containing impurities such as Al in an amount of 5 $\mu\text{g/g}$ or less is dissolved in an aqueous solution of quaternary ammonium hydroxide such as tetramethylammonium
 10 hydroxide or tetrabutylammonium hydroxide.

[0039]

In the above-described second step, the above-described quaternary ammonium hydroxide is removed by an ion exchange method to prepare an active silicic acid solution. In other words, silica sol is manufactured from a
 15 solution of silica. The ion exchange method that can be performed with a simple operation and has no risk of intrusion of impurities is favorably used to remove quaternary ammonium hydroxide.

[0040]

In the above-described third step, the active silicic acid solution obtained
 20 in the above-described second step is heated under the presence of an alkaline catalyst, and silicic acid is polymerized so that particles grow, as a result of which silica grows to have a predetermined particle diameter. Here, ammonia, amine, or the like is used as the alkaline catalyst. Also, it is sufficient to set a heating temperature in a range of about 60°C to 250°C as appropriate.

25 Although the particle diameter of grown silica is arbitrary depending on intended use, silica sol having a particle diameter of 3 to 300 nm is obtained, for example.

The silica sol obtained by the above-described steps can be concentrated by evaporation or filtration. Also, by removing the

above-described alkaline catalyst by the ion exchange method, silica sol that does not substantially contain components other than silica can be obtained.

[0041]

By preparing a polishing liquid of the present invention using highly pure
5 silica sol that is obtained in this manner and does not contain impurities such as Al, it is possible to prevent occurrence of foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) that causes foreign matter defects on the glass substrate surface described above.

[0042]

10 In the present embodiment, in order to make up a polishing liquid containing colloidal silica abrasive particles, it is preferable to use pure water, that is, RO water, for example. Here, RO water refers to pure water that was subjected to RO (reverse osmosis membrane) processing. It is particularly preferable to use RO-DI water that was subjected to RO processing and DI
15 processing (deionization processing). This is because RO water or RO-DI water contains extremely small amount of impurities, or in other words, contains an extremely small amount of alkali metal, for example, and a small amount of ions.

[0043]

20 Also, a polishing liquid that is adjusted to be acidic is favorably used for 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 adjusted by adding acid to a polishing liquid to be acidic (in a range of a pH from 1 to 4) is used to mirror-polish a glass substrate, a polishing rate can be
25 increased and cleanliness can be improved. It is preferable that 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 the above-described foreign matter at least in an acidic environment. It should be

noted that in the present invention, polishing may be performed after adjusting pH, which indicates the acidity or alkalinity of the polishing liquid, to alkaline ($7 < \text{pH} \leq 10$, for example).

[0044]

5 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
10 mirror-polishing step (second polishing step provided in a later stage) 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.

 It should be noted that in the present invention, the above-described average particle diameter denotes a particle diameter at which a cumulative
15 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
20 measuring the particle diameter using a particle diameter/particle size distribution measurement device.

[0045]

 Also, in the present invention, it is particularly preferable to use a colloidal silica manufactured by the ion exchange method as the
25 above-described colloidal silica. The colloidal silica manufactured by the ion exchange method has a higher hardness due to a higher density than that manufactured by another method (sol-gel method, for example) and has an excellent polishing rate, and thus is particularly preferable. In addition, the

colloidal silica manufactured by the ion exchange method has a small abrasion amount in polishing and the polishing rate is unlikely to deteriorate even if the colloidal silica is used for a long time, and thus is preferable. Also, the colloidal silica manufactured by the ion exchange method has high dispersiveness, and thus minute scratches are unlikely to be formed on the surface to be polished. Conversely, the colloidal silica manufactured by the sol-gel method is likely to relatively aggregate, and thus minute scratches are likely to be formed. Therefore, in order to highly efficiently manufacture high-quality magnetic-disk glass substrates for super high recording density of about 750 gigabytes or more per 2.5-inch disk, it is preferable to use the colloidal silica manufactured by the ion exchange method.

It should be noted that a magnetic-disk glass substrate in which an arithmetic mean roughness Ra is 0.15 nm or less and an arithmetic mean roughness Ra having a wavelength bandwidth of 30 to 200 nm is 0.06 nm or less can be efficiently manufactured by using the above-described colloidal silica. [0046]

Also, there is no particular limitation on the concentration of abrasive particles in the polishing liquid, and from the point of view of surface quality after polishing and polishing rate, the concentration of abrasive particles can be set in a range of 10 to 30 wt%. In particular, a range of 10 to 20 wt% is favorable. [0047]

Also, a second embodiment of the present invention will be described. In the second embodiment, a polishing liquid that does not contain foreign matter as described above is selected as the polishing liquid.

Specifically, as described in Aspect 2 described above, the second embodiment of the present invention is a method for manufacturing a magnetic-disk glass substrate including polishing processing for bringing a surface of a glass substrate into contact with a polishing liquid containing

colloidal silica and a polishing pad, and mirror-polishing the glass substrate surface, and a polishing liquid that does not contain foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) that can inhibit recording or reproduction when the glass substrate is made into a magnetic disk and
5 undergoes recording or reproduction with a magnetic head, is selected as the polishing liquid, and the polishing is performed using the selected polishing liquid.

[0048]

For example, a polishing liquid that is adjusted using highly pure silica
10 sol that does not contain impurities such as Al, as described in the above-described first embodiment, can be selected. Of course, a polishing liquid that is adjusted using silica sol that is manufactured by another method other than the manufacturing method described in the above-described first embodiment and accordingly does not contain impurities such as Al may be
15 selected.

By applying the second embodiment described above, selecting a polishing liquid that does not contain foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) that can inhibit recording or reproduction when the glass substrate is made into a magnetic disk and
20 undergoes recording or reproduction with the magnetic head, and performing mirror-polishing using the selected polishing liquid, it is possible to prevent occurrence of defects due to the foreign matter on the glass substrate surface. In addition, in a magnetic disk that is manufactured using the glass substrate obtained by applying the second embodiment described above, when recording
25 or reproduction is performed using the DFH head provided with the HDI sensor, problems such as head crash can be reduced.

[0049]

Although there is no particular limitation on a polishing method in the polishing of the above-described embodiment, 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, moving the
 5 polishing pad and the glass substrate relative to each other while supplying the polishing liquid containing polishing abrasive particles, for example.

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
 10 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
 15 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.
 [0050]

At the time of polishing processing, by using such a double-side
 20 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
 25 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 to 150 gf/cm².

A load of less than 75 gf/cm² is not preferable because the processability (polishing rate) of the glass substrate is reduced. Also, a load of more than 150 gf/cm² is not preferable because there are cases in which scratches or the like occur on the glass substrate surface.

5 [0051]

It is particularly preferable that a soft polisher polishing pad (suede pad) is used as the polishing pad used for the finishing mirror-polishing. It is preferable that the hardness of the polishing pad is set to be 60 or more to 90 or less in an Asker C hardness. It is preferable that the surface of the polishing
10 pad that abuts against the glass substrate is made of resin foam in which foam pores are formed, particularly polyurethane foam. When polished in this manner, the glass substrate surface can be polished so as to be a smooth mirror surface.

[0052]

15 Also, in order to manufacture the magnetic-disk glass substrate, polishing is often performed a plurality of times. For example, the polishing is sometimes performed through two stages, namely, the first polishing step for removing scratches and distortion remaining in the lapping step, and the second polishing step (mirror polishing) for finishing the surface roughness of the glass
20 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 a multi-stage polishing having three or more stages may be performed). In this case, it is preferable to apply the polishing liquid according to the above-described first or second embodiment at least in second polishing
25 step provided in a later stage.

[0053]

Also, in the present invention, it is preferable that the (type of) glass constituting the glass substrate is aluminosilicate glass containing SiO₂ 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.

- 5 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 SiO_2 in an amount of 58 wt% or more to
10 75 wt% or less, Al_2O_3 in an amount of 5 wt% or more to 23 wt% or less, Li_2O in an amount of 3 wt% or more to 10 wt% or less, and Na_2O 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
15 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_2 in an amount of 62 wt% or more to 75 wt% or less, Al_2O_3 in an amount of 5 wt% or more to 15 wt% or less, Li_2O in an amount of 4 wt% or more to 10 wt% or less, Na_2O in an amount of 4 wt% or more to 12 wt% or less, and ZrO_2 in an amount
20 of 5.5 wt% or more to 15 wt% or less, and has an $\text{Na}_2\text{O}/\text{ZrO}_2$ weight ratio of 0.5 or more to 2.0 or less and an $\text{Al}_2\text{O}_3/\text{ZrO}_2$ weight ratio of 0.4 or more to 2.5 or less, for example.

[0054]

- In addition, there are cases in which heat resistance is required as a
25 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_2 in an amount of 50 to 75 mol%, Al_2O_3 in an amount of 0 to 6 mol%, BaO in an amount of 0 to 2 mol%, Li_2O in an amount of 0 to 3 mol%, ZnO in an amount of 0 to 5 mol%, Na_2O and K_2O in a total amount of 3 to 15 mol%, MgO , CaO , SrO and BaO in a total amount of 14 to 35 mol%, and ZrO_2 ,
 5 TiO_2 , La_2O_3 , Y_2O_3 , Yb_2O_3 , Ta_2O_5 , Nb_2O_5 and HfO_2 in a total amount of 2 to 9 mol%, and that has a molar ratio $[(\text{MgO}+\text{CaO})/(\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO})]$ in a range of 0.85 to 1 and a molar ratio $[\text{Al}_2\text{O}_3/(\text{MgO}+\text{CaO})]$ in a range of 0 to 0.30.
 [0055]

In the present invention, the surface of the glass substrate after the
 10 mirror-polishing processing described above is preferably a mirror surface having an arithmetic mean roughness R_a of 0.15 nm or less, and in particular a mirror surface having an arithmetic mean roughness R_a of 0.10 nm or less. It is further preferable that the surface of the glass substrate is a mirror surface having a maximum roughness R_{max} of 1.5 nm or less.

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

20 [0056]

Also, it is particularly preferable that the present embodiment is applied in the case where a glass substrate is cleaned after being mirror-polished under conditions that the difference in the surface roughness R_q (root mean square roughness) of the glass substrate before and after cleaning is 0.05 nm or less.

25 The cleaning performed under the above-described conditions is particularly effective in not increasing the roughness of the main surface of the glass substrate formed by mirror-polishing processing. However, on the other hand, because of having a weak cleansing power, it is more difficult to remove

foreign matter adhering thereto after the above-described mirror-polishing processing compared to conventional cleaning (cleaning that deteriorates the surface roughness of the substrate). Even if such cleaning is used, by performing mirror-polishing processing according to the present embodiment, occurrence of the above-described foreign matter can be inhibited and a reduction in the surface roughness of the glass substrate can be achieved.

In other words, in order to obtain a magnetic-disk glass substrate whose main surface has an arithmetic mean surface roughness (R_a) of 0.15 nm or less, it is more preferable to perform mirror-polishing using a polishing liquid according to the present invention, and to apply cleaning conditions in cleaning processing after the mirror-polishing such that the difference in the surface roughness R_q of the glass substrate before and after cleaning is 0.05 nm or less. [0057]

In the present invention, it is preferable to perform chemical 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°C or more to 400°C or less. The chemical strengthening is processing in which the glass substrate is brought into 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 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 as potassium nitrate or sodium nitrate can be preferably used as the chemical strengthening salt.

[0058]

- 5 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, by supplying, between the glass substrate and the polishing pad, a treatment liquid (rinsing liquid) containing no abrasive particles or containing
10 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 (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
15 magnetic-disk glass substrate.

[0059]

- The treatment liquid contains no abrasive particles or contains abrasive particles such as colloidal silica in a concentration of 3 wt% or less, preferably in a concentration of 1 wt% or less. In the case where the treatment liquid
20 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 10 to 20 nm. It should be noted that in the case where the treatment liquid contains abrasive particles, it is particularly preferable to use polishing abrasive
25 particles containing impurities such as Al included in the abrasive particles in an amount of 5 $\mu\text{g/g}$ or less, for example.

[0060]

In addition, the present invention also provides a magnetic-disk glass substrate. Specifically, the present invention provides a magnetic-disk glass substrate whose main surface is a mirror surface and that does not include foreign matter made of a layered compound.

5 Specifically, a magnetic-disk glass substrate of the present invention is a magnetic-disk glass substrate having a main surface, and an arithmetic mean roughness R_a obtained when a measurement region of $1\ \mu\text{m} \times 1\ \mu\text{m}$ square of the main surface of the substrate is measured using the atomic force microscope at a resolution of 256×256 pixels is $0.15\ \text{nm}$ or less and an arithmetic mean
10 roughness R_a having a wavelength bandwidth of 30 to $200\ \text{nm}$ is $0.06\ \text{nm}$ or less, and when the main surface of the substrate is irradiated with a laser light having a wavelength of $405\ \text{nm}$ and a power of $80\ \text{mW}$ at a spot diameter of $6\ \mu\text{m}$ and foreign matter is detected using scattered light from the main surface of the
15 substrate, the number of defects having a size of 30 to $200\ \text{nm}$ in an in-plane direction per main surface is 30 or less and the detected defects do not include a layered compound.

[0061]

The magnetic-disk glass substrate of the present invention has the main surface having an extremely high smoothness, R_a is $0.15\ \text{nm}$ or less, and an
20 arithmetic mean roughness R_a having a wavelength bandwidth of 30 to $200\ \text{nm}$ is $0.06\ \text{nm}$ or less, and thus naturally, once layered flat foreign matter included in the silica slurry attaches thereto, the layered foreign matter strongly attaches thereto, resulting in a state in which it cannot be easily removed by cleaning performed thereafter. However, the magnetic-disk glass substrate of the
25 present invention has a main surface having a small roughness and contains no layered foreign matter, and thus even if the gap between the DFH element portion and the magnetic disk surface is $1\ \text{nm}$ or less, a magnetic-disk glass substrate having a long-term reliability can be obtained. In order to obtain such

a magnetic-disk glass substrate of the present invention, it is preferable to use the method for manufacturing a magnetic-disk glass substrate according to the present invention as described above.

[0062]

5 It should be noted that it is preferable to measure a region (measurement region) of the substrate main surface that is irradiated with the laser light and has a radius of 15 to 31.5 mm (that is, approximately 24.09 cm²), for example.

 Also, it is possible to determine whether the detected foreign matter has
10 a layered shape using a cross-section TEM, for example. It is possible to specify the size of the detected foreign matter using a TEM, a SEM, an AFM, or the like after the position is specified by a laser-type defect inspection device, for example.

 In addition, the arithmetic mean roughness Ra of the main surface
15 having a wavelength bandwidth of 30 to 200 nm can be calculated as follows.

 First, the three-dimensional data on the surface properties is obtained by measuring a region of the main surface of a magnetic-disk glass substrate having a predetermined size in a minimum constant interval (a region of 1 μm×1 μm is sectioned into 512×512 sections, for example) using an AFM (atomic force
20 microscope). Next, two-dimensional Fourier transformation is performed on the measured three-dimensional data to obtain two-dimensional image. A wavelength component of 30 to 200 nm is extracted from the obtained two-dimensional image (that is, band-pass filtering is performed). Lastly, inverse Fourier transformation is performed on the two-dimensional image
25 having the extracted wavelength component to generate three-dimensional data (three-dimensional data having a wavelength component of 30 to 200 nm only), and an arithmetic mean roughness Ra is calculated from this three-dimensional data.

It should be noted that in order to study the wavelength bandwidth having a correlation with the likelihood of a layered foreign matter being absorbed, it was found that, having performed studies after changing the upper limit and the lower limit of the wavelength bandwidth, a wavelength of 30 to 200 nm showed the highest correlation. It should be noted that the minimum wavelength is two times the minimum measurement resolution (1000 (nm)/512), and thus is approximately 4 nm. It is conceivable that in the case where the roughness having a wavelength bandwidth of 30 to 200 nm is low, the size of layered foreign matter is equal to the size of the roughness, and thus the layered foreign matter is likely to be absorbed.

[0063]

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 head.

Also, the magnetic-disk glass substrate manufactured by the present invention is favorable for a glass substrate that is used in a magnetic disk that is provided in a HDD for a server that requires a high performance of high speed data transfer, high speed access, and the like, in addition to the high reliability for long-term sequential operation.

[0064]

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. It is preferable to form the magnetic layer on the glass substrate by a sputtering method such as

a DC magnetron sputtering method. Interposing a base layer between the glass substrate and the magnetic layer makes it possible to control the orientation direction and size of magnetic particles in the magnetic layer. For example, use of a cubic-system base layer made of Cr-based alloy or the like makes it possible to orient, for example, the direction of easy magnetization of the magnetic layer along the magnetic disk surface. In this case, the magnetic disk of a longitudinal magnetic recording type is manufactured. In addition, for example, use of a hexagonal-system base layer containing Ru and Ti makes it possible to orient, for example, the direction of easy magnetization of the magnetic layer along the normal of the plane of the magnetic disk. In this case, the magnetic disk of a perpendicular magnetic recording type is manufactured. The base layer can be formed by a sputtering method in the same manner as the magnetic layer.

[0065]

It is preferable to form a protective layer and a lubricant layer in this order on the magnetic layer. An amorphous hydrogenated carbon-based protective layer is preferable as the protective layer. The protective layer can be formed by a plasma CVD method, for example. As the lubricant layer, a lubricant that has a functional group at the terminal of the main chain of a perfluoropolyether compound can be used. In particular, it is preferable that the lubricant contains, as a main component, a perfluoropolyether compound that has a hydroxyl group as a polar functional group at the terminal. The lubricant layer can be coated and formed by a dipping method.

Use of the glass substrate obtained according to the present invention makes it possible to obtain a highly reliable magnetic disk that does not cause problems such as head crash or the like even if recording and reproduction are performed using a DFH head provided with a HDI sensor. Therefore, the present invention is favorable for manufacturing a magnetic disk having a higher

recording density than previously available, such as recording density exceeding 500 gigabytes, for example.

Examples

[0066]

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

(Example 1)

- 10 A magnetic-disk glass substrate of this example 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 main surface polishing step (first polishing step), (6) a chemical strengthening step, and (7) a main surface polishing step (second polishing step) as described below.

15 [0067]

(1) Rough lapping step

- 20 First, a disk-shaped glass substrate made of aluminosilicate glass and having a diameter of 66 mm ϕ 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 a glass substrate may be obtained by cutting plate glass manufactured by a down draw method or a float method other than using direct pressing into a predetermined size.

[0068]

- 25 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 ϕ , and predetermined chamfering was then performed on the outer circumferential edge surface and an inner circumferential edge surface.

5 (3) Precision lapping step

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

[0069]

(4) Edge surface polishing step

10 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.

[0070]

15 (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 is held by a carrier is tightly placed between the upper and lower surface plates to which polishing pads have been attached, the carrier is engaged with the sun gear and the internal gear, and the glass substrate is pressed between the upper and lower surface plates. Then, a polishing liquid is supplied between the polishing pads and the glass substrate surfaces to be polished, the upper and lower surface plates are rotated, and thus the glass substrate revolves while rotating on the surface plates so that both main surfaces of the glass substrate are polished simultaneously. Specifically, the first polishing step was performed using a hard polisher (hard urethane foam) as a polisher. 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

20

25

cleaned and dried.

[0071]

(6) Chemical strengthening step

Next, chemical strengthening was performed on the glass substrate that
 5 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.

10 [0072]

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

Next, the second polishing step was performed using the same
 double-side polishing device as used in the above-described first polishing step,
 but polishing pads (polyurethane foam having an Asker C hardness of 75) with a
 15 soft polisher (suede) were used 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 (having an average
 20 diameter (D50) of 30 nm) was dispersed in water was used as the polishing
 liquid. The pH of the polishing liquid was adjusted to be 2. The load was set
 to 100 g/cm², and the machining allowance for polishing was set to 5 μm. The
 glass substrate that had undergone the second polishing step was cleaned and
 dried. It should be noted that the cleaning processing was performed on the
 25 glass substrate under conditions that the difference in the surface roughness Rq
 of the glass substrate before and after cleaning was 0.05 nm or less.

[0073]

It should be noted that the above-described colloidal silica was manufactured in accordance with a method for manufacturing highly pure silica sol that does not include impurities described in the above-described first embodiment. Also, as a result of analyzing solid that was obtained by evaporating and drying the above-described polishing liquid using ICP-AES, Al was not detected. Also, when a polishing slurry was filtered and foreign matter in filtered slurry was checked, layered foreign matter was not confirmed. In other words, foreign matter containing Al, Si, and O that is addressed as a problem in the present invention are not included in the above-described polishing liquid.

[0074]

The surface roughness of the main surface of the glass substrate obtained through the above-described steps was measured using the atomic force microscope (AFM), revealing that a glass substrate with an ultra-smooth surface of 1.43 nm in Rmax and 0.13 nm in Ra was obtained. Also, an arithmetic mean roughness Ra having a wavelength bandwidth of 30 to 200 nm was 0.06 nm or less. In addition, when the surface of the glass substrate was observed visually and measured by an optical surface analyzer and defects that were found were analyzed by a SEM and an AFM, the surface was a mirror-surface, and layered foreign matter that is addressed as a problem in the present invention, as shown in FIG. 1, for example, was not found.

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

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

[0075]

(Example 2)

A magnetic-disk glass substrate was obtained similarly to Example 1 except that colloidal silica containing Al in an amount of 3 $\mu\text{g/g}$ was used as the above-described colloidal silica. It should be noted that the content of Al is the content of Al included in the solid obtained by evaporating and drying a colloidal silica slurry.

(Example 3)

A magnetic-disk glass substrate was obtained similarly to Example 1 except that colloidal silica containing Al in an amount of 5 $\mu\text{g/g}$ was used as the above-described colloidal silica.

10 [0076]

(Comparative Example 1)

A second polishing step was performed similarly to Example 1 except that a polishing liquid that was prepared using colloidal silica that was manufactured by the ion exchange method in accordance with a conventional known manufacturing method was used in the second polishing step of Example 1 described above. In addition, the steps other than the second polishing step were performed similarly to Example 1. It should be noted that the colloidal silica that was manufactured in accordance with the above-described conventional known manufacturing method contained Al in an amount of 50 $\mu\text{g/g}$.

(Comparative Example 2)

A second polishing step was performed similarly to Comparative Example 1 except that a polishing liquid that was prepared using colloidal silica that had an average particle diameter of 80 nm and was manufactured by the ion exchange method in accordance with a conventional known manufacturing method was used in the second polishing step of Example 1 described above. In addition, the other steps other than the second polishing step were performed similarly to Example 1.

When the surface of the glass substrate that was obtained through the above-described steps was analyzed by the optical surface analyzer similarly to the above, a large amount of layered foreign matter, which is the problem addressed in the present invention, was found. In addition, as a result of
 5 analyzing the found layered foreign matter, it was confirmed that the layered foreign matter was foreign matter containing Al, Si, and O. On the other hand, the above-described layered foreign matter was not confirmed on the surface of the glass substrates according to Examples 1 to 3.

[0077]

10 (Reference Example 1)

A magnetic-disk glass substrate was obtained similarly to Example 1 except that colloidal silica containing Al in an amount of 7 $\mu\text{g/g}$ was used as the above-described colloidal silica.

(Reference Example 2)

15 A magnetic-disk glass substrate was obtained similarly to Example 1 except that colloidal silica containing Al in an amount of 10 $\mu\text{g/g}$ was used as the above-described colloidal silica.

The surfaces of the glass substrates obtained in Reference Examples 1 and 2 described above were analyzed by the optical surface analyzer and the
 20 number of layered foreign matter containing Al, Si, and O was analyzed.

The number of layered foreign matter in the glass substrates obtained in Examples 1 to 3, Comparative Examples 1 and 2, and Reference Examples 1 and 2 described above is collectively shown in Table 1 below.

It should be noted that the glass substrates obtained in Examples 1 to 3,
 25 Comparative Example 1, and Reference Examples 1 and 2 were finished such that the main surface has an arithmetic mean roughness R_a of 0.15 nm or less when a measurement region of 1 $\mu\text{m} \times 1 \mu\text{m}$ square of the main surface of the substrate was measured using the atomic force microscope at a resolution of

256×256 pixels, and an arithmetic mean roughness Ra having a wavelength bandwidth of 30 to 200 nm was 0.06 nm or less, but in the glass substrate of Comparative Example 2, the particle diameter of the used colloidal silica was large and an arithmetic mean roughness Ra having a wavelength bandwidth of 30 to 200 nm was 0.08 nm.

[0078]

A magnetic disk for perpendicular magnetic recording was manufactured by performing the following film forming step on the magnetic-disk glass substrates obtained in Examples 1 to 3, Comparative Examples 1 and 2, and Reference Examples 1 and 2 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 resistance. The lubricant layer was formed by a dipping method using an alcohol-modified perfluoropolyether liquid lubricant.

[0079]

With regard to the obtained magnetic disk, a long-term reliability test (the distance between the DFH protruding element portion and the magnetic disk was set to 1 nm, and sequential seeking operations between the innermost circumference and the outermost circumference were continued for 24 hours in an incubator having a RH of 80% at 80°C) was performed on a drive equipped with a DFH head that was provided with a HDI sensor. The result is also shown in Table 1 below.

[0080]

[Table 1]

Table 1	Al element content in silica (ppm)	number of foreign matter having size of 30 to 200 nm (average value of both surfaces)	number of layered foreign matter (average value of both surfaces)	element portion after reliability test
Example 1	0	9	0	no anomalies
Example 2	3	10	0	no anomalies
Example 3	5	14	0	no anomalies
Comparative Example 1	50	18	7	deterioration
Comparative Example 2	50	19	3	deterioration
Reference Example 1	7	15	1	deterioration
Reference Example 2	10	13	2	deterioration

[0081]

5 In comparison between Comparative Example 1 and Comparative Example 2, the number of layered foreign matter decreased in Comparative Example 2. It was conceivable that this was because layered foreign matter was likely to stick to the surface whose arithmetic mean roughness Ra having a wavelength bandwidth of 30 to 200 nm was 0.06 nm or less.

10 Also, on the glass substrates of Comparative Examples 1 and 2 and Reference Examples 1 and 2, layered foreign matter was not removed in the cleaning processing performed under the same conditions as those of Example 1, and thus when cleaning processing was performed under conditions of a higher alkalinity, the layered foreign matter was removed, but the surface
15 roughness of the substrate after the cleaning significantly deteriorated.

 In addition, according to the result of Table 1 above, in the magnetic disks obtained by using the glass substrates of Examples 1 to 3, recording and reproduction elements did not deteriorate and favorable results were obtained.

On the other hand, in the magnetic disk obtained by using the glass substrate of Comparative Example 1, recording and reproduction elements deteriorated partway through the test. Also, in the magnetic disks obtained by using the glass substrates of Reference Examples 1 and 2 that were obtained by performing polishing using colloidal silica in which the content of Al in silica was greater than 5 $\mu\text{g/g}$, recording and reproduction elements deteriorated partway through the test.

[0082]

It should be noted that, here, deterioration of the recording and reproduction elements specifically means the abrasion of an element portion. If the element portion is worn away, a protruding amount due to DFH decreases more than before the abrasion, and thus recording and reproduction performance such as SNR deteriorates. Also, a portion that was worn away corrodes, and it may no longer be able to perform recording and reproduction. Therefore, recording or reproduction of a magnetic signal cannot be stably performed in the long term.

Determination of deterioration of recording and reproduction elements was made such that specifically, the values of a DFH touch-down power were measured before and after the test and both values were compared, and in a case where the value after the test was greater than that before the test, it was determined that the recording and reproduction elements deteriorated. The greater the value of the touch-down power was, the more increased the protruding amount of the element portion, and thus it was found that the element portion was worn away during the long-term reliability test.

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Descriptions of Reference Numerals

[0083]

1 Glass substrate

	2	Sun gear
	3	Internal gear
	4	Carrier
	5	Upper surface plate
5	6	Lower surface plate
	7	Polishing pad

CLAIMS

1. A method for manufacturing a magnetic-disk glass substrate to be applied to a magnetic disk compatible with a DFH head that is equipped with a HDI sensor and is capable of controlling a protruding amount of at least one of a recording element and a reproduction element based on a signal from the HDI sensor,

the method comprising polishing processing for supplying a polishing liquid containing colloidal silica between a main surface of a glass substrate and a polishing pad, bringing the glass substrate and the polishing pad into contact with each other, and mirror-polishing the main surface of the glass substrate, and

wherein the polishing liquid has the content of aluminum which is adjusted in order to prevent occurrence of foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) at least in an acidic environment, the foreign matter consisting of a flat layered foreign matter having sizes in a plane which are in range of 30 to 200 nm and having a size of a thickness which is in a range of 1 to 20 nm.

2. A method for manufacturing a magnetic-disk glass substrate to be applied to a magnetic disk compatible with a DFH head that is equipped with a HDI sensor and is capable of controlling a protruding amount of at least one of a recording element and a reproduction element based on a signal from the HDI sensor,

the method comprising polishing processing for supplying a polishing liquid containing colloidal silica between a main surface of a glass substrate and a polishing pad, bringing the glass substrate and the polishing pad into contact with each other, and mirror-polishing the main surface of the glass substrate,

wherein a polishing liquid that does not contain foreign matter containing elements of aluminum (Al), silicon (Si), and oxygen (O) that can inhibit recording or reproduction when the glass substrate is made into a magnetic disk and undergoes recording or reproduction with a magnetic head is selected as the polishing liquid, and the polishing processing is performed using the selected polishing liquid, the foreign matter consisting of a flat layered foreign matter having sizes in a plane which are in range of 30 to 200 nm and having a size of a thickness which is in a range of 1 to 20 nm,

wherein the polishing liquid has the content of aluminum which is adjusted in order to prevent occurrence of the foreign matter.

3. The method for manufacturing a magnetic-disk glass substrate according to claim 1 or 2, wherein the foreign matter is a layered compound having a ratio of the size of the plane to the size of the thickness which in a range of 5 to 200.
- 4 . The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 3, wherein the colloidal silica is manufactured by an ion exchange method.
5. The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 4, wherein a content of aluminum (Al) in the colloidal silica is 5 µg/g or less.
6. The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 5, wherein cleaning processing is performed on the glass substrate after the polishing processing, under a condition that a difference in a surface roughness Rq of the glass substrate before cleaning and after cleaning is 0.05 nm or less.
7. The method for manufacturing a magnetic-disk glass substrate according to any of claims 1 to 6, wherein the magnetic-disk glass substrate comprises a glass substrate to be used in a magnetic disk to be provided in a hard disk drive for a server.
8. A method for manufacturing a magnetic-disk glass substrate to be applied to a magnetic disk compatible with a DFH head that is equipped with a HDI sensor and is capable of controlling a protruding amount of at least one of a recording element and a reproduction element based on a signal from the HDI sensor,

the method comprising polishing processing for supplying a polishing liquid containing colloidal silica between a main surface of a glass substrate and a polishing pad, bringing the glass substrate and the polishing pad into contact with each other, and mirror-polishing the main surface of the substrate,

wherein the polishing liquid has the content of aluminum which is adjusted in order to prevent occurrence of foreign matter that can inhibit recording or reproduction when the glass substrate is made into a magnetic disk and undergoes recording or reproduction with the DFH head, the foreign matter consisting of a flat layered foreign matter having sizes in a plane which are in range of 30 to 200 nm and having a size of a thickness which is in a range of 1 to 20 nm.

9. A method for manufacturing a magnetic disk, comprising:

a step of manufacturing a magnetic-disk glass substrate according to any of claims 1 to 8, and

a step of forming at least a magnetic layer on the main surfaces of the magnetic-disk glass substrate.

10. A magnetic-disk glass substrate having a main surface,

wherein an arithmetic mean roughness Ra obtained when a measurement region of $1\text{ }\mu\text{m} \times 1\text{ }\mu\text{m}$ square of the main surface of the substrate is measured using an atomic force microscope at a resolution of 256×256 pixels is 0.15 nm or less and an arithmetic mean roughness Ra having a wavelength bandwidth of 30 to 200 nm is 0.06 nm or less, and

when the main surface of the substrate is irradiated with laser light having a wavelength of 405 nm and a power of 80 mW at a spot diameter of $6\text{ }\mu\text{m}$ and foreign matter is detected using scattered light from the main surface of the substrate, a number of defects having a size of 30 to 200 nm in an in-plane direction per main surface is 30 or less and the detected defects do not include a flat layered foreign matter having sizes in a plane which are in range of 30 to 200 nm and having a size of a thickness which is in a range of 1 to 20 nm .