DESCRIPTION

Title of Invention

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

Technical Field

[0001]

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

Background Art

[0002]

A magnetic disk is one of the information recording media provided in magnetic disk devices such as hard disk drives (HDDs). The magnetic disk is configured with a thin film such as a magnetic layer formed on a substrate, and conventionally an aluminum substrate has been used as the substrate. However, recently, in response to the pursuit of high recording density, glass substrates with which the gap between the magnetic head and the magnetic disk can be narrower than that attained with aluminum substrates have been increasingly used. The glass substrate surface is highly precisely polished to achieve a high recording density such that the flying height of the magnetic head can be as small as possible. In recent years, the demand for HDDs with a larger storage capacity at lower cost has been increasing, and in order to meet this, further quality enhancement 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 a low flying height that is necessary for a high recording density. In order to attain a highly smooth magnetic disk surface, after all, a highly smooth substrate surface is required, and it is thus necessary to highly precisely polish the surface of a glass substrate.

A conventional method for polishing a glass substrate is performed using a polishing pad, made of polyurethane or the like, of a polisher while supplying a slurry (polishing liquid) containing an abrasive that is made of a metal oxide such as cerium oxide or colloidal silica. A highly smooth glass substrate can be obtained by, for example, polishing the glass substrate using a cerium oxide-based abrasive and performing final polishing (mirror polishing) using colloidal silica abrasive grains. Here, it has been proposed that a colloidal silica slurry whose pH has been adjusted so as to be acidic is used to polish a magnetic-disk substrate, for example (see Patent Literature 1). It has also been proposed that a colloidal silica slurry whose pH is adjusted so as to be greater than 10.2 and less than or equal to 12 by including alkalis in the polishing liquid is used to polish a magnetic-disk glass substrate (see Patent Literature 2).

[0004] It has also been proposed that when an NiP/Al substrate or the like is polished using an alumina slurry or a colloidal silica slurry, aluminum nitrate or aluminum sulfate is added to the slurry as a polishing accelerator in order to reduce pits, projections and polishing scratches and to improve the polishing rate (see Patent Literatures 3, 4 and 5).

Prior Art Literature(s)

Patent Literature(s)

[0005]

Patent Literature 1: JP H7-240025A

Patent Literature 2: JP 2003-173518A

Patent Literature 3: Japanese Patent No. 3877924

Patent Literature 4: Japanese Patent No. 3781677

Patent Literature 5: JP 2010-42509A

Summary of Invention

Problem to be Solved by the Invention

[0006]

Current HDDs can achieve a recording density as high as about 500 gigabits per square inch, and for example, it is possible to store about 320 gigabytes of information on a 2.5-inch (65-mm-diameter) magnetic disk, but it has been required to achieve a higher recording density such as 375 to 500 gigabytes and 1 terabyte. With such a recent demand for HDDs with a larger storage capacity, the demand for enhancement of the substrate surface quality has become more severe than ever. In a next-generation substrate to be used for, for example, a 375 to 500-gigabyte magnetic disk as described above or a magnetic disk for thermally assisted magnetic recording, the substrate largely affects media characteristics, and therefore, it is required to further improve current products in terms of not only the roughness of the substrate surface but also a state where no surface defects such as scratches (blemishes) are present.

[0007]

The reason why a substrate largely affects media characteristics in a next-generation substrate is as follows.

A remarkable reduction in the flying height of a magnetic head (a gap between the magnetic head and the surface of a medium (magnetic disk)) can be given as an example. In this manner, the magnetic head and the magnetic layer of the medium come close to each other, and therefore, it becomes possible to write signals in a smaller region or to pick up signals of smaller

magnetic grains and thus to attain a high recording density. In recent years, to achieve a flying height lower than ever, the magnetic head has been provided with a function of dynamic flying height (DFH) control. This is a function of projecting only a recording and reproducing element of the magnetic head and its surroundings toward a medium surface by providing a heating unit such as an extremely small heater in the vicinity of the recording and reproducing element. It is considered that in the future, with this DFH function, the gap between the element of the magnetic head and the medium surface will be less than 2 nm, which is extremely small. Under such a circumstance, it has been found that even if the average roughness of the substrate surface is made to be extremely small, if surface defects such as extremely small scratches and pits that have not conventionally become problems are present, the distance between the magnetic layer of the medium and the element of the magnetic head is increased at the bottom (valley) portions of the scratches, and therefore, an error is likely to occur when magnetic signals are overwritten. That is, that error is due to a phenomenon in which when the magnetic signals written first are overwritten with other magnetic signals, the original magnetic signals remain. A reason for this is thought to be that it becomes difficult to record magnetic signals because the Ku (magnetic anisotropy) of the material for the recording layer of the magnetic disk is increased and the size of the recording and reproducing element of the magnetic head is reduced in order to achieve a high recording density.

[0008]

Incidentally, a slurry in which an abrasive that is made of a metal oxide such as cerium oxide or colloidal silica is suspended and the quality of the polished glass substrate have a strong mutual relationship, and it is well known that the quality of the main surface of the glass substrate is enhanced by controlling, for example, the grain diameter of the abrasive contained in the

slurry. The research conducted by the inventors of the present invention revealed that it is possible to reduce the roughness of the main surface of the substrate by controlling the grain diameter of the abrasive contained in the slurry, for example, by using the abrasive that is constituted by fine grains, but when an abrasive that is too fine is used, there is a problem in that the roughness is increased inversely, the shape of the end surface is deteriorated, or the polishing rate is reduced. Moreover, the inventors found that by only using a fine abrasive, it is possible to make an improvement regarding the surface defects such as pits and large scratches (blemishes) having a length of about 1 μm, but it is impossible to reduce extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less.

[0009]

In particular, the demand for enhancement of the substrate surface quality with the recent demand for HDDs with a larger storage capacity has become more severe than ever. It was found that there is a limitation on the achievement of further enhancement of the substrate surface quality using a conventional improving method, and, in particular, it is impossible to reduce the extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less using a conventional improving method.

It should be noted that Patent Literature 3 to 5 disclose a method mainly used for an NiP/Al substrate and do not specifically disclose a method used for a glass substrate. Since sludge generated by polishing a glass substrate has the same components as the abrasive grains such as colloidal silica and the glass constituting the glass substrate, polishing of a glass substrate has a problem different from the method described in Patent Literature 3 to 5 (in a case where an NiP/Al substrate is polished) because the extremely small scratches are generated by different mechanisms.

[0010]

The present invention has been conceived in order to solve the foregoing conventional problems, and a first object of the present invention is to provide a method for manufacturing a magnetic-disk glass substrate that can further reduce surface defects such as extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less compared with conventional products, and a method for manufacturing a magnetic disk that uses a glass substrate obtained by that method.

A second object of the present invention is to provide a method for manufacturing a magnetic-disk glass substrate that can achieve a good polishing rate, and a method for manufacturing a magnetic disk that uses a glass substrate obtained by that method.

A third object of the present invention is to provide a method for manufacturing a magnetic-disk glass substrate that can further reduce surface defects such as extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less compared with conventional products while a good polishing rate is retained, and a method for manufacturing a magnetic disk that uses a glass substrate obtained by that method.

Another object of the present invention is to provide a method for manufacturing a magnetic-disk glass substrate that can manufacture, at a low cost, a high-quality glass substrate that can be used as a next-generation substrate in which the demand for substrate surface quality is more severe than in current substrates, and a method for manufacturing a magnetic disk that uses a glass substrate obtained by that method.

Means to Solve the Problem

[0011]

The inventors of the present invention found that many defects in which signals have not been completely deleted due to recession defects are detected

in an examination of a conventional magnetic disk on which a film has been formed. When investigating a cause of that result, the inventors found that there are surface defects such as the above-described extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less on the glass substrate surface. Also, as a result of investigating mechanisms in which those extremely small surface defects are generated, it was inferred that this is because glass sludge generated by polishing the glass substrate attaches to a polishing pad to accumulate and grow, and comes into contact with the glass substrate surface. Moreover, it is thought that the increase in the amount of projection of a DFH head, or the like, revealed a problem of such small defects.

In addition, as a result of further research on the extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less, the inventors found that the number of scratches increases when a certain type of glass is polished. As a result of further research, the inventors found that the number of scratches remarkably increases when polishing glass containing an alkali earth metal (particularly, Mg or Ca) in a certain amount as a component contained in the glass.

[0012]

Accordingly, as a result of intensive research by focusing on the characteristics of the polishing liquid, which has not sufficiently been researched conventionally, in order to solve the foregoing problems, the inventors found that when glass that has a certain composition is polished, it is possible to further reduce surface defects such as extremely small scratches compared with conventional products while a good polishing rate is retained by including aluminum ions in the polishing liquid. The inventors also found that that effect is remarkable particularly when glass containing only a little alumina is polished.

[0013]

In other words, the present invention has the following aspect in order to

achieve the first object.

(Aspect 1)

A method for manufacturing a magnetic-disk glass substrate, including a polishing step of polishing main surfaces of a glass substrate by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads, in which glass constituting the glass substrate contains SiO_2 as a main component and a divalent alkali earth metal, the abrasive grains are made of colloidal silica, and the polishing liquid is adjusted so as to be in an acidic range and contains aluminum ions.

[0014]

Also, the present invention has the following aspect in order to achieve the second object.

(Aspect 2)

A method for manufacturing a magnetic-disk glass substrate, including a polishing step of polishing main surfaces of a glass substrate by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads, in which glass constituting the glass substrate contains SiO_2 as a main component and a divalent alkali earth metal, and the polishing liquid is adjusted so as to be alkaline and contains aluminum ions.

[0015]

Also, the present invention has the following aspect in order to achieve the third object.

(Aspect 3)

A method for manufacturing a magnetic-disk glass substrate, including a polishing step of polishing main surfaces of a glass substrate containing SiO_2 as

a main component and a divalent alkali earth metal by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads, and a rinsing treatment that is performed after the polishing step and includes performing a sliding treatment on the main surfaces of the glass substrate by supplying a treatment liquid containing aluminum ions between the glass substrate and the polishing pads.

[0016]

Furthermore, the present invention may have the following configrations.

(Aspect 4)

The method for manufacturing a magnetic-disk glass substrate according to any one of Aspects 1 to 3, in which a substance that can supply aluminum ions is added to the polishing liquid or the treatment liquid.

(Aspect 5)

The method for manufacturing a magnetic-disk glass substrate according to Aspect 4, in which the substance that can supply aluminum ions is contained in the polishing liquid or the treatment liquid in an amount within a range of 0.001 mol/L to 0.1 mol/L.

[0017]

(Aspect 6)

The method for manufacturing a magnetic-disk glass substrate according to Aspect 4 or 5, in which the substance that can supply aluminum ions is at least one selected from aluminum ammonium sulfate, aluminum bromide, aluminum chloride, aluminum hydroxide, aluminum iodide, aluminum nitrate, aluminum phosphate, aluminum potassium sulfate and aluminum sulfate.

(Aspect 7)

The method for manufacturing a magnetic-disk glass substrate according to any one of Aspects 1 to 6, in which the glass substrate is a glass

substrate used for a magnetic disk for thermally assisted magnetic recording.

[0018]

(Aspect 8)

A method for manufacturing a magnetic disk, which forms at least a magnetic layer on a magnetic-disk glass substrate obtained by the manufacturing method according to any one of Aspects 1 to 7.

Effects of the Invention

[0019]

With Aspect 1 of the present invention, it is possible to manufacture, at a low cost, a high-quality glass substrate in which surface defects such as the extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less can be significantly reduced, and that, in particular, can be used as a next-generation substrate in which the demand for the substrate surface quality is more severe than in current substrates.

With Aspect 2 of the present invention, it is possible to manufacture, at a low cost, a high-quality glass substrate in which surface defects such as extremely small scratches can be reduced while a polishing rate is enhanced.

With Aspect 3 of the present invention, it is possible to manufacture, at a low cost, a high-quality glass substrate in which surface defects such as extremely small scratches can be significantly reduced while a good polishing rate is retained, and that, in particular, can be used as a next-generation substrate in which the demand for the substrate surface quality is more severe than in current substrates.

Moreover, it is possible to obtain a highly reliable magnetic disk by using the glass substrate obtained according to the present invention.

Brief Description of Drawings

[0020]

FIG. 1 is a longitudinal cross-sectional view illustrating a schematic configuration of a double-side polishing machine.

Mode for Embodying the Invention

[0021]

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

A magnetic-disk glass substrate is usually manufactured through a rough grinding step (rough lapping step), a shaping step, a precision grinding step (precision lapping step), an end surface polishing step, a main surface polishing step (a first polishing step and a second polishing step), and a chemical strengthening step.

In the manufacture of this magnetic disk glass substrate, first, molten glass is molded into a disk-shaped glass substrate (glass disk) by direct pressing. It should be noted that other than using such direct pressing, a glass substrate may also be obtained by cutting plate glass that has been produced by a downdraw method or a float method into a glass substrate having a predetermined size. Then, the main surfaces of this molded glass substrate are ground (lapped) to enhance the dimensional accuracy and shape accuracy. In this grinding step, a double-side lapping machine is generally used, and the main surfaces of the glass substrate are ground using hard abrasive grains such as those of diamond. By grinding the main surfaces of the glass substrate in this manner, the substrate is processed so as to have a predetermined thickness and flatness and attain a predetermined surface roughness.

[0022]

After this grinding step, the shaping step and end surface polishing step are performed, and then mirror polishing processing is performed to obtain a

highly precise flat surface. It is preferable to perform a mirror-polishing method on the glass substrate using a polishing pad 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.

[0023]

Here, a first embodiment of the present invention will be described.

As described in Aspect 1, the first embodiment of the present invention is a method for manufacturing a magnetic-disk glass substrate, including a polishing step of polishing main surfaces of a glass substrate by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads, in which glass constituting the glass substrate contains SiO_2 as a main component and a divalent alkali earth metal, the abrasive grains are made of colloidal silica, and the polishing liquid is adjusted so as to be in an acidic range and contains aluminum ions.

[0024]

The polishing liquid is obtained by combining an abrasive and water serving as a solvent, and contains a pH adjustor for adjusting the pH of the polishing liquid or other additives as needed.

[0025]

In this embodiment, in order to form a polishing liquid containing colloidal silica abrasive grains, pure water such as RO water may be used and a substance that can supply aluminum ions may be added thereto to include aluminum ions in the polishing liquid. Here, RO water denotes RO (reverse osmosis membrane)-treated pure water. It is particularly preferable to use RO-DI water, which is RO-treated and DI (deionization)-treated water. This is because the content of impurities such as alkali metal in RO water or RO-DI water is extremely small, and the content of ions is also small.

[0026]

Moreover, the pH of the polishing liquid used in the polishing step of this embodiment is adjusted to an acidic range. The pH is adjusted to an acidic range (pH range of 1 to 4) by adding an acid such as sulfuric acid to the polishing liquid, for example. In this embodiment, the polishing liquid whose pH is adjusted to an acidic range is preferably used in view of productivity and cleanliness. It is preferable to adjust the pH of the polishing liquid to an acidic range because the polishing rate can be enhanced and thus the productivity can be enhanced. It is preferable that the pH is within the range of 1 to 4. When the inventors polished a glass substrate using a polishing liquid to which the present invention was not applied, that is, to which no aluminum ions were added, within the pH range of 1 to 4, a very large number of surface defects such as extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less were detected compared with the case where the glass substrate was polished out of the above pH range. Therefore, when aluminum ions are added to the polishing liquid as in the present invention, it is possible to significantly reduce the number of surface defects in the case where the glass substrate is polished within the acidic range, particularly within the pH range of 1 to 4.

[0027]

In this embodiment, colloidal silica is used as abrasive grains contained in the polishing liquid that is used in the polishing step in which the glass substrate is polished, and aluminum ions are added to this polishing liquid. Since SiO_2 is a component of colloidal silica as well as the main component (a component that makes up 50 wt% or more of glass) of the glass substrate, colloidal silica itself is likely to be a factor causing the scratches as described later. Therefore, in this embodiment, aluminum ions are added to the polishing liquid to reduce factors causing scratches. A mechanism in which these scratches are presumed to be generated will be described later.

[0028]

In view of polishing efficiency, it is preferable to use colloidal silica abrasive grains, contained in the polishing liquid, having an average grain diameter within the range of 10 to 50 nm. In particular, it is preferable to use abrasive grains, contained in the polishing liquid used in a final mirror polishing step (latter-stage second polishing step), having an average grain diameter of 10 nm or more to less than 30 nm in view of further reduction of the surface roughness. It is more preferable to use abrasive grains having an average grain diameter within the range of 10 to 20 nm.

On the other hand, when such colloidal silica abrasive grains having a small grain diameter are used, the gap between the polishing pad and the glass substrate surface with the abrasive grains therebetween becomes smaller (narrower). Therefore, when glass sludge (polishing waste) generated by polishing the glass substrate attaches to the polishing pad, the glass sludge can easily come into contact with the glass substrate surface, and thus the extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less are easily generated. However, even under such a condition, it is possible to decompose and remove the sludge attaching to the polishing pad by applying this embodiment, and therefore, it is possible to reduce the number of scratches in the polishing step in which the abrasive grains having a small grain diameter are used.

It should be noted that in the present invention, the average grain diameter denotes a grain diameter at which a cumulative curve reaches 50% when the cumulative curve is found by setting the entire volume of powder particles in the grain size distribution measured by a light scattering method to 100% (referred to as "cumulative average grain diameter (50% diameter)" hereinafter). Specifically, in the present invention, the cumulative average grain diameter (50% diameter) is a value obtained by measuring grain diameters

using a grain diameter/grain size distribution measurement device.

[0029]

In this embodiment, the polishing step is performed by using the polishing liquid whose pH has been adjusted to an acidic range and that contains aluminum ions. In order to include aluminum ions in the polishing liquid, for example, a method that adds a substance, such as aluminum sulfate, that contains Al and becomes ionized in an aqueous solution to the polishing liquid is simple. The substance to be added may be a solid or a liquid, and it is convenient that the substance is dissolved in water or the like in advance and added in the form of a fluid containing aluminum ions. Other preferable examples of the substance that contains Al and becomes ionized in an aqueous solution include aluminum bromide, aluminum chloride, aluminum hydroxide, aluminum iodide, aluminum nitrate, aluminum phosphate, aluminum potassium sulfate, and aluminum ammonium sulfate.

That is, in this embodiment, aluminum ions are present in the polishing liquid.

[0030]

Although mechanisms in which the number of scratches can be reduced by applying this embodiment are unconfirmed, the inventors infer the mechanisms as follows according to their research.

First, the following is inferred as the mechanism in which the extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less are generated.

Sludge (glass component) is generated by polishing the glass substrate. It is conceivable that when this sludge attaches to the surface of the polishing pad to aggregate or aggregates at an opening of an outermost layer of the polishing pad, scratches having a length of about 1 μm that are larger than the above-described scratches are generated in the case where the aggregates

come into contact with the glass substrate.

[0031]

Incidentally, when glass constituting the glass substrate contains an alkali earth metal such as Ca or Mg, the alkali earth metal is contained as a component constituting the sludge. This alkali earth metal is a divalent component, and is likely to be bonded with silica, which is a main component of the sludge, though the bonding strength is small. Therefore, the strength of the formed aggregates is smaller than that of aggregates containing no alkali earth metal, but the rate of formation of aggregates is increased. It is thought that when the aggregates attach to an opening of the polishing pad, or the like, extremely small scratches having a length of 50 nm or less and a depth of 5 nm or less are likely to be generated because the bonding strength is small. It is thought that when, in particular, the content of the alkali earth metal oxide component in the glass is 5 wt% or more, the scratches are generated at a high ratio.

[0032]

Moreover, it is thought that when the glass substrate is polished using the colloidal silica having an average grain diameter within the range of 10 to 50 nm, the size of sludge particles depends on the grain diameter, and the extremely small scratches are likely to be generated.

Therefore, the crystal structure of the sludge component is embrittled by including aluminum ions in the polishing liquid as in this embodiment. The sludge whose crystal structure has been embrittled is decomposed by erosion by the polishing liquid and by a load applied in the polishing step, and is removed from the surface of the polishing pad. It should be noted that here, sludge denotes mainly a poorly soluble salt (scale) of glass sludge that has been crystallized and precipitated.

[0033]

Thereby, it is possible to make an improvement regarding surface defects such as extremely small scratches that are generated due to the sludge attaching to and growing on the surface of the polishing pad.

Therefore, it is possible to manufacture, at a low cost, a high-quality magnetic-disk glass substrate in which surface defects such as the extremely small scratches can be further reduced compared with in conventional products. It should be noted that the scratches that are problems of the present invention are extremely small scratches (blemishes) having a length of 50 nm or less and a depth of 5 nm or less, for example. Even if, when such small scratches are present on the substrate surface, a magnetic disk is obtained by forming a magnetic film or the like thereon, the scratches appear as defects on the disk surface, and therefore, overwriting characteristics are affected as described above.

[0034]

In the present invention, it is preferable that Al^{3+} ions out of various aluminum ions are particularly included in the polishing liquid. By including Al^{3+} ions in the polishing liquid, the effect of suppressing crystallization and solidification of the glass sludge on the surface of the polishing pad is most likely to be exhibited. It is thought that this is because Al^{3+} has positive electric charge and a high ionic valence. It should be noted that examples other than Al^{3+} ions include complex ions containing elemental Al, but since Al^{3+} ion is constituted by only elemental Al, Al^{3+} ion has a smaller size than complex ions and easily enters the sludge, which is a factor causing the high effect.

[0035]

In this embodiment, it is preferable that in the polishing liquid, the content of the substance that contains Al and becomes ionized in an aqueous solution, for example, the substance that can supply Al^{3+} ions, is within the range of 0.001 mol/L to 0.1 mol/L. It is particularly preferable that the content thereof

is within the range of 0.005 mol/L to 0.05 mol/L.

When the content of the substance that can supply Al^{3+} ions in the polishing liquid is less than 0.001 mol/L, the effect of reducing the number of scratches is not sufficiently attained. On the other hand, when the content of the substance that can supply Al^{3+} ions in the polishing liquid exceeds 0.1 mol/L, the scratch-generating frequency is increased, conversely. The inventors inferred that the reason is that excessive Al^{3+} ions are bonded with the sludge that has been embrittled and decomposed, attach to the glass substrate surface, and cause scratches.

It is possible to measure the amount of aluminum ions in the polishing liquid by ICP emission spectrometry.

[0036]

Moreover, in this embodiment, there is no particular limitation on the concentration of abrasive grains in the polishing liquid, but the concentration can be within the range of 10 to 30 wt% in view of the surface quality after polishing and the polishing rate. It is particularly preferable that the concentration is within the range of 10 to 20 wt%. When the concentration of abrasive grains in the polishing liquid is low, the gap between the polishing pad and the glass substrate surface with the abrasive grains therebetween is likely to become smaller (narrower), and therefore, when glass sludge (polishing waste) generated by polishing the glass substrate attaches to the polishing pad, the glass sludge can easily come into contact with the glass substrate surface, and thus the scratches or the like are easily generated. In this embodiment, it is possible to decompose and remove the sludge attached to the polishing pad, and therefore, it is particularly preferable to use the polishing liquid having a low concentration of abrasive grains within the range of 10 to 15 wt%.

[0037]

There is no limitation on the polishing method in the polishing step of this

embodiment, but, for example, the glass substrate surface may be mirror-polished by causing the glass substrate and the polishing pad to come into contact with each other and relatively moving the polishing pad and the glass substrate while the polishing liquid containing abrasive grains is supplied.

For example, FIG. 1 is a longitudinal cross-sectional view illustrating a schematic configuration of a planetary gear-type double-side polishing machine that can be used in the step of mirror-polishing the glass substrate. The double-side polishing machine shown in FIG. 1 includes a sun gear 2, an internal gear 3 that is disposed concentrically at 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 and the internal gear 3, an upper surface plate 5 and a lower surface plate 6 having attached thereto polishing pads 7 capable of holding, therebetween, a product 1 to be polished that is held by the carrier 4, 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.

[0038]

In the polishing step, by using such a double-side polishing machine, 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 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 a load within the range of 95 to 135 g/cm^2.

A load of less than 95 g/cm^2 is not preferable because the processability

(polishing rate) of the glass substrate is reduced. Also, a load of more than 135 g/cm^2 is not preferable because the number of scratches increases.

[0039]

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 pad that abuts against the glass substrate is made of foamed resin in which foamed pores are formed, particularly foamed polyurethane. When polished in this manner, the glass substrate can be polished so as to have a smooth mirror surface.

[0040]

The mirror-polishing step is usually performed through two stages including the first polishing step to remove cracks or distortion remaining after the lapping step as described above and the second polishing step to finish the surface roughness of the main surfaces of the glass substrate into smooth mirror surfaces while the flat surfaces obtained in the first polishing step are retained (however, multistage polishing including three stages or more is sometimes performed), and in this case, it is preferable to apply a polishing step in accordance with this embodiment at least to the latter-stage second polishing step.

[0041]

Moreover, in the present invention, glass (the type of glass) constituting the glass substrate contains SiO_2 as a main component and contains an alkali earth metal. Here, the alkali earth metal oxides are MgO, CaO, SrO and BaO. Although the ratio of the alkali earth metal constituting the glass (the ratio in terms of an oxide amount) varies in accordance with characteristics required for the glass, it is more preferable to apply the present invention (Aspect 1) when

that ratio is 5 wt% or more. When the glass containing the alkali earth metal oxide in the ratio of 5 wt% or more is used, the number of small scratches as described above increases for the above-described reason compared with when the glass containing the alkali earth metal oxide in the ratio of less than 5 wt% is used, but it is possible to significantly suppress the scratches from being generated by applying the present invention (Aspect 1). In particular, when the total amount of MgO and CaO, which are contained in the glass, of the alkali earth metal oxide is 5 wt% or more, it is possible to effectively suppress the scratches from being generated by applying the present invention (Aspect 1).

[0042]

Moreover, in the present invention, it is preferable to use aluminosilicate glass containing an alkali earth metal as the glass. Mirror-polishing the surfaces of the glass substrate using such glass can yield a smooth mirror-finished surface, and the post-processing strength is favorable. Also, the strength can be further enhanced by chemical strengthening.

Furthermore, the glass may be crystallized glass or amorphous glass. Amorphous glass can be used as the glass to further reduce the roughness of the main surfaces of the glass substrate.

It is possible to use aluminosilicate glass (however, phosphorus oxide-free aluminosilicate glass) that contains an alkali earth metal oxide in an amount of 5 wt% or more, and contains as main components SiO_2 in an amount of 58 wt% or more to 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 such aluminosilicate glass. Furthermore, for example, it is possible to use phosphorus oxide-free amorphous aluminosilicate glass that contains an alkali earth metal oxide in an amount of 5 wt% or more, and contains as main components SiO_2 in an amount of 62 wt% or more to 75 wt% or less, Al_2O_3 in an amount of 5 wt% or more to 15

wt% or less, Li_2O in an amount of 4 wt% or more to 10 wt% or less, Na_2O in an amount of 4 wt% or more to 12 wt% or less, and ZrO_2 in an amount of 5.5 wt% or more to 15 wt% or less, and has an Na_2O/ZrO_2 weight ratio of 0.5 or more to 2.0 or less and an Al_2O_3/ZrO_2 weight ratio of 0.4 or more to 2.5 or less.

[0043]

Moreover, thermal resistance is sometimes required for characteristics of a next-generation substrate (e.g., a substrate used for magnetic disks applied in thermally assisted magnetic recording). In this case, as the thermal resistant glass, it is possible to preferably use glass that contains an alkali earth metal oxide in an amount of 5 wt% or more, and contains 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, 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 has a molar ratio [(MgO+CaO)/(MgO+CaO+SrO+BaO)] in the range of 0.85 to 1 and a molar ratio [Al_2O_3/(MgO+CaO)] in the range of 0 to 0.30.

[0044]

In the present invention, the glass substrate surface after the above-described mirror-polishing processing (after the above-described polishing) is preferably a mirror surface having an arithmetic average roughness Ra of 0.20 nm or less, and particularly preferably 0.15 nm or less. Furthermore, the grass substrate surface is preferably a mirror surface having a maximum roughness Rmax of 2.0 nm or less. Ra and Rmax in the present invention both denote roughness that is calculated in accordance with the Japanese Industrial Standards (JIS) B 0601. In particular, when the roughness Ra of the glass substrate surface is 0.20 nm or less as described above, it is preferable to perform the polishing processing according to this embodiment. This is

because when the surface roughness is higher than the above-described range, the scratches sometimes do not become a problem due to the high roughness. In other words, the present invention solves problems that remarkably come up when the roughness of the glass substrate surface is within the above-described range.

From a practical viewpoint, the surface roughness (for example, maximum roughness Rmax, arithmetic average roughness Ra) in the present invention is preferably the surface roughness of a surface shape obtained by a measurement with a resolution of 256 by 256 pixels in an area of 1 μm square under an atomic force microscope (AFM).

[0045]

In the present invention, it is preferable to perform chemical strengthening treatment before or after the mirror-polishing processing step. As a method for the chemical strengthening treatment, 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, for example, at a temperature of 300°C or more and 400°C or less. The chemical strengthening treatment denotes a treatment in which a 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, 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 glass substrate surface. The glass substrate that has been subjected to the chemical strengthening treatment has excellent impact resistance, and it is thus particularly preferable to provide the chemical strengthened glass substrate in, for example, an HDD for mobile use. An alkali metal nitrate such as potassium nitrate or sodium nitrate can be

preferably used as a chemical strengthening salt.

[0046]

In the present invention, it is particularly preferable that aluminum ions are included in the polishing liquid in the polishing step performed after the chemical strengthening step. Since a compressive stress layer is formed on the surface layer of the glass substrate by the chemical strengthening treatment, it is possible to reduce the possibility that surface defects such as scratches are generated when the glass substrate comes into contact with the glass sludge crystals on the pad surface. That is, the possibility that surface defects such as scratches are generated can be reduced by the synergistic effect of the effect of embrittling the glass sludge crystals with aluminum ions and the compressive stress layer on the surface layer of the glass substrate.

[0047]

The present invention also provides a method for manufacturing a magnetic disk using the above-described magnetic-disk glass substrate. In the present invention, the magnetic disk is manufactured by forming at least a magnetic layer on the magnetic-disk glass substrate of the present invention. 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. The magnetic layer is preferably formed on the glass substrate by a sputtering method, for example, a DC magnetron sputtering method. It is possible to control the orientation direction and size of magnetic particles in the magnetic layer by interposing an underlayer between the glass substrate and the magnetic layer. For example, it is possible to orient, for example, the direction of easy magnetization of the magnetic layer along the magnetic disk surface by using a cubic-system underlayer such as Cr-based alloy. In this case, the magnetic disk of a longitudinal magnetic recording type is manufactured. Also, for example, it is possible to orient, for example, the direction of easy

magnetization of the magnetic layer along the normal of the plane of the magnetic disk by using a hexagonal-system underlayer containing Ru and Ti. In this case, the magnetic disk of a perpendicular magnetic recording type is manufactured. The underlayer can be formed in the same manner as the magnetic layer by a sputtering method.

[0048]

It is preferable to form a protective layer and a lubricating 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, for example, a plasma CVD method. A lubricant that has a functional group at the terminal of the main chain of a perfluoropolyether compound can be used as the lubricating layer. 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 lubricating layer can be coated and formed by a dipping method.

It is possible to obtain a highly reliable magnetic disk by using the glass substrate obtained according to the present invention.

[0049]

Next, a second embodiment of the present invention will be described. It should be noted that descriptions will not be given for aspects that have already been described in the first embodiment.

As described in Aspect 2, the second embodiment of the present invention is a method for manufacturing a magnetic-disk glass substrate, including a polishing step of polishing main surfaces of a glass substrate by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads, in which glass constituting the glass substrate contains SiO_2 as a main component and a

divalent alkali earth metal, and the polishing liquid is adjusted so as to be alkaline and contains aluminum ions.

[0050]

It is preferable to apply this embodiment particularly to the former stage of the mirror-polishing step (e.g., the first polishing step).

The polishing liquid used in the polishing step of this embodiment is adjusted so as to be alkaline. The pH is adjusted to an alkaline range (pH range of 8 to 12) by adding sodium hydroxide to the polishing liquid, for example. For the purpose of enhancing the polishing rate, the polishing liquid whose pH is adjusted to be alkaline is preferably used in this embodiment.

[0051]

It is preferable to use, for example, cerium oxide, zirconium oxide or titanium oxide as abrasive grains used in this embodiment.

It is preferable that the abrasive grains contained in the polishing liquid have an average grain diameter of about 0.5 μm to 1.5 μm in view of polishing efficiency and surface quality.

[0052]

In this embodiment, the polishing step is performed using the polishing liquid whose pH has been adjusted to be alkaline and that contains aluminum ions. In order to include aluminum ions in the polishing liquid, for example, a simple method is adding a substance, such as aluminum sulfate, that contains Al and becomes ionized in an aqueous solution to the polishing liquid. The substance to be added may be a solid or a liquid, and it is convenient that the substance is dissolved in water or the like in advance and added in the form of a fluid containing aluminum ions. Other preferable examples of the substance that contains Al and becomes ionized in an aqueous solution include aluminum ammonium sulfate, aluminum bromide, aluminum chloride, aluminum hydroxide, aluminum iodide, aluminum nitrate, aluminum phosphate, and aluminum

potassium sulfate.

Normally Al_2O_3 is poorly soluble in water, but under a high-load condition as in polishing processing, a high-temperature and high-pressure environment is locally created, and thus Al_2O_3 partially leaches and supplies Al ions. Also, when alumina (Al_2O_3) is added to the polishing liquid, it is possible to prevent scratches from being generated on the main surfaces of the glass substrate by using Al_2O_3 having a smaller grain diameter than the polishing agent. Alumina can be preferably used in the first polishing step.

[0053]

Moreover, it is preferable to add a phosphorus-based additive (dispersant) to the polishing liquid. Examples of the phosphorus-based additive include sodium hexametaphosphate, sodium tetraphosphate, sodium tripolyphosphate, sodium pyrophosphate and sodium orthophosphate. It is thought that the phosphorus-based additive has the effect of suppressing the case in which aluminum ions added to the polishing liquid form poorly soluble aluminum hydroxide and precipitated. It is preferable that the amount of the phosphorus-based additive added to the polishing liquid is in the range of 0.001 to 5 wt% with respect to the polishing liquid.

[0054]

In this embodiment, the content amount of the substance that can supply aluminum ions in the polishing liquid is the same as that in the first embodiment.

Also, in this embodiment, the concentration of abrasive grains, the polishing method, and the like are the same as those in the first embodiment.

[0055]

In this embodiment as well, the crystal structure of the sludge component (glass component) is embrittled by including aluminum ions in the polishing liquid. The sludge whose crystal structure has been embrittled is decomposed by erosion by the polishing liquid and by a load applied in the

polishing step, and is removed from the surface of the polishing pad. Thereby, it is possible to make an improvement regarding surface defects such as extremely small scratches that are generated due to the sludge attaching to and growing on the surface of the polishing pad and the decrease of the polishing rate that are problems in conventional polishing processing that uses free abrasive grains. In particular, in this embodiment, the effect of improving the polishing rate is large.

[0056]

Next, a third embodiment of the present invention will be described. It should be noted that descriptions will not be given for aspects that have already been described in the first embodiment and the second embodiment.

As described in Aspect 3, the third embodiment of the present invention is a method for manufacturing a magnetic-disk glass substrate, including a polishing step of polishing main surfaces of a glass substrate containing SiO_2 as a main component and a divalent alkali earth metal by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads, and a rinsing treatment that is performed after the polishing step and includes performing a sliding treatment on the main surfaces of the glass substrate by supplying a treatment liquid containing aluminum ions between the glass substrate and the polishing pads.

[0057]

It is preferable to apply this embodiment to a rinsing treatment that performs the second polishing step to finish the surface roughness of the main surfaces of the glass substrate into smooth mirror surfaces while the flat surfaces obtained in the first polishing step are retained and then uses the same polishing machine as used in the second polishing step to treat the main surfaces of the glass substrate by supplying, between the glass substrate and

the polishing pad, a treatment liquid (rinsing liquid) containing no abrasive grains or containing abrasive grains in a low concentration compared with the second polishing step.

By performing this rinsing treatment, it is possible to reduce the number of abrasive grains (colloidal silica abrasive grains) 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.

[0058]

In the rinsing treatment performed using the treatment liquid containing no abrasive grains or containing abrasive grains in a low concentration, no abrasive grains are present between the polishing pad and the glass substrate surfaces or a small number of abrasive grains are present therebetween even if the abrasive grains are present. Therefore, when sludge attaching to the polishing pad is present in the former-stage second polishing step, for example, there is a high possibility that in the rinsing treatment, the sludge comes into contact with the glass substrate surface and causes surface defects such as the scratches.

Accordingly, as in this embodiment, the crystal structure of the sludge component (glass component) is embrittled by performing the rinsing treatment using the treatment liquid containing aluminum ions, and then the sludge whose crystal structure is embrittled is decomposed by a load applied in the rinsing treatment and is removed from the surface of the polishing pad. Thereby, it is possible to make an improvement regarding surface defects such as extremely small scratches that are generated due to the sludge attaching to and growing on the surface of the polishing pad and the decrease of the polishing rate that are problems in conventional polishing processing that uses free abrasive grains.

[0059]

There is no particular limitation on the treatment liquid used in the rinsing treatment of this embodiment, but a substantially neutral aqueous solution is used as the treatment liquid. For example, it is preferable to use pure water, particularly RO water. Also, an acidic treatment liquid may be used. It should be noted that the treatment liquid more preferably has the same liquidity as the polishing liquid used in the preceding polishing step because it is possible to prevent abrasive grains from aggregating or the like due to changes in liquidity when switching from the polishing step to the rinsing treatment. Therefore, for example, when the glass substrate is polished using the polishing liquid whose pH is within the range of 1 to 4 in the polishing step performed before the rinsing treatment, it is preferable that the pH of the rinsing liquid is within the range of 1 to 4 in the subsequent rinsing treatment. That is, it is more preferable that the polishing treatment before the rinsing treatment and the rinsing treatment, which are performed using the same polishing machine, are performed with the same liquidity, and particularly with the same pH.

The treatment liquid contains no abrasive grains at all or contains abrasive grains such as colloidal silica in a concentration of 3 wt% or less, and preferably 1 wt% or less. When the treatment liquid contains abrasive grains, it is preferable to use abrasive grains having an average grain diameter of 10 nm or more to less than 30 nm. It is more preferable to use abrasive grains having an average grain diameter of about 10 to 20 nm.

[0060]

In order to include aluminum ions in the treatment liquid, it is preferable to add a substance that can supply aluminum ions such as aluminum ammonium sulfate, aluminum bromide, aluminum chloride, aluminum hydroxide, aluminum iodide, aluminum nitrate, aluminum phosphate, aluminum potassium sulfate and aluminum sulfate.

In this embodiment as well, it is preferable that Al^{3+} ions out of various

aluminum ions are particularly included in the treatment liquid. By including Al^{3+} ions in the treatment liquid, the effect of suppressing crystallization and solidification of the glass sludge on the surface of the polishing pad is most likely to be exhibited.

In this embodiment, the content amount of the substance that can supply Al^{3+} ions in the treatment liquid is the same as that in the first embodiment described above.

[0061]

Moreover, in this embodiment, the glass substrate may be polished using, as the polishing liquid, colloidal silica to which aluminum ions are added in the polishing treatment before the rinsing treatment performing using the same polishing machine, and the subsequent rinsing treatment may be performed using the treatment liquid to which aluminum ions are added. At this time, it is preferable to add, to the treatment liquid, aluminum ions in an amount less than that of the aluminum ions contained in the polishing liquid. It is not preferable that the amount of aluminum ions added to the treatment liquid in the rinsing treatment is equal to or more than the amount of aluminum ions added to the polishing liquid in the polishing treatment because there is an increase in impurities (colloidal silica or sludge) attaching to the glass substrate surface after the rinsing treatment.

[0062]

That is, this embodiment may be a method for manufacturing a magnetic-disk glass substrate, including a polishing step of polishing main surfaces of a glass substrate containing SiO_2 as a main component and a divalent alkali earth metal, by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads, with a polishing machine provided with the surface plates, and a

rinsing treatment that is performed using the same polishing machine after the polishing step and includes performing a sliding treatment on the main surfaces of the glass substrate by supplying a treatment liquid containing aluminum ions between the glass substrate and the polishing pads, in which the abrasive grains are made of colloidal silica, the polishing liquid is adjusted so as to be in an acidic range and contains aluminum ions, and the ratio of aluminum ions contained in the treatment liquid is smaller than the ratio of aluminum ions contained in the polishing liquid. Moreover, it is more preferable that the ratio of aluminum ions contained in the treatment liquid is one tenth or less with respect to the ratio of aluminum ions contained in the polishing liquid.

Examples

[0063]

Hereinafter, embodiments 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 Example 1 and Comparative Example 1 are an example and comparative example corresponding to Aspect 1.

(Example 1)

A magnetic-disk glass substrate of this example was manufactured through (1) rough lapping step (rough grinding step), (2) shaping step, (3) precision lapping step (precision grinding step), (4) end surface polishing step, (5) main surface polishing step (first polishing step), (6) chemical strengthening step, and (7) main surface polishing step (second polishing step) as described below.

[0064]

(1) Rough lapping step

First, a disk-shaped glass substrate made of aluminosilicate glass and

having a diameter of 66 mm and a thickness of 1.0 mm was obtained from molten glass by direct pressing using upper, lower, and drum molds. Other than using such direct pressing, a glass substrate may also be obtained by cutting plate glass that has been produced by a downdraw method or a float method into a glass substrate with a predetermined size. Glass for chemical strengthening containing an alkali earth metal oxide in an amount of 5 wt% or more, SiO_2 in an amount of 62 to 75 wt%, ZrO_2 in an amount of 5.5 to 15 wt%, Al_2O_3 in an amount of 5 to 15 wt%, Li_2O in an amount of 4 to 10 wt%, and Na_2O in an amount of 4 to 12 wt% (100 wt% in total) was used as this aluminosilicate glass.

[0065]

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

(2) Shaping step

Next, a cylindrical grindstone was used to create a hole in the center of the glass substrate, the outer circumferential end surface was ground so as to obtain a diameter of 65 mm, and then predetermined chamfering processing was performed on the outer circumferential end surface and the inner circumferential end surface.

(3) Precision lapping step

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

(4) End surface polishing step

Then, the inner and outer circumferential end surfaces of the glass substrate were brush-polished while the glass substrate was rotated so as to have a roughness of about 0.3 nm in Ra. Then, the surface of the glass substrate after this end surface polishing was washed with water.

[0066]

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

Then, a first polishing step to remove cracks or distortion remaining after the above-described lapping step was performed using a double-side polishing machine. In the double-side polishing machine, a glass substrate that is held by a carrier is tightly placed between the upper and lower surface plates to which polishing pads have been attached, the carrier is engaged with the sun gear and the internal gear, and the glass substrate is pressed between the upper and lower surface plates. Then, a polishing liquid is supplied between the polishing pads and the glass substrate surfaces to be polished, the upper and lower surface plates are rotated, and thus the glass substrate revolves while rotating on the surface plates so that both main surfaces of the glass substrate are polished simultaneously. Specifically, the first polishing step was performed using a hard polisher (hard urethane foam) as a polisher. A polishing liquid in which cerium oxide (average particle diameter of 1.3 μm) was dispersed as a polishing agent was used, a load of 100 g/cm^2 was applied, and the machining allowance for polishing was 30 μm. The glass substrate that had undergone the first polishing step was cleaned and dried.

[0067]

(6) Chemical strengthening step

Then, chemical strengthening was performed on the glass substrate that had undergone the above-described cleaning. Chemical strengthening was performed by providing a chemical strengthening liquid in which potassium nitrate and sodium nitrate were mixed, heating this chemical strengthening solution to 380°C, and immersing the cleaned and dried glass substrate in the chemical strengthening liquid for about 4 hours.

[0068]

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

Then, a second polishing process was performed using the same double-side polishing machine as used in the first polishing step, but polishing pads with a soft polisher (suede) (polyurethane foam with an Asker C hardness of 72) was used. This second polishing step is a mirror-polishing step to finish the main surfaces of the glass substrate into smooth mirror surfaces with a surface roughness of, for example, about 0.2 nm or less in Ra while retaining the flat surfaces obtained in the first polishing step described above. RO water in which colloidal silica (average grain diameter (D50) of 30 nm) was dispersed and aluminum sulfate was added and dissolved in an amount of 0.01 mol/L was used as the polishing liquid. The pH of the polishing liquid was adjusted so as to be 2. A load of 100 g/cm^2 was applied, and the machining allowance for polishing was 5 μm. The glass substrate that had been subjected to the second polishing process was cleaned and dried.

[0069]

The surface roughness of the main surfaces of the glass substrate obtained through the above-described steps was measured using an atomic force microscope (AFM), revealing that the glass substrate with an ultra-smooth surface of 1.43 nm in Rmax and 0.13 nm in Ra was obtained. In addition, when the glass substrate surfaces were visually observed and measured using an optical surface analysis device and detected defects were analyzed using an SEM and an AFM, the glass substrate had mirror surfaces and the number of surface defects such as projections and blemishes (small scratches having a length of 50 nm or less and a depth of 5 nm or less) was less than ten.

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.

[0070]

(Comparative Example 1)

The second polishing step of Example 1 was performed in the same manner as in Example 1, except that no aluminum sulfate was added to the polishing liquid. The steps other than the second polishing step were performed in the same manner as in Example 1.

When the surfaces of the glass substrate obtained through the above-described steps were analyzed using an optical surface analysis device in the same manner as described above, twenty or more of small scratches having a length of 50 nm or less and a depth of 5 nm or less were detected.

[0071]

(Influence of ratio of aluminum ions contained in polishing liquid: Reference Examples 1 to 9)

Next, the influence of changes in the ratio of aluminum ions contained in the polishing liquid on scratches was investigated. In the second polishing step of Example 1, the second polishing was performed with a load of 120 g/cm^2 and a machining allowance for polishing of 2 μm, using polishing liquids respectively containing aluminum ions in an amount of 0.002 mol/L (Reference Example 1), 0.006 mol/L (Reference Example 2), 0.05 mol/L (Reference Example 3), 0.07 mol/L (Reference Example 4), 0.1 mol/L (Reference Example 5), 0.2 mol/L (Reference Example 6) ,0.5 mol/L (Reference Example 7), 1 mol/L (Reference Example 8), and 10 mol/L(Reference Example 9). When the surfaces of the glass substrates obtained through the above-described steps were analyzed using an optical surface analysis device in the same manner as described above and the number of defects (including attaching impurities) that were determined to have a length of 30 nm or less was counted, the results were as follows: 10 (Reference Example 1), 5 (Reference Example 2), 8 (Reference Example 3), 13 (Reference Example 4), 14 (Reference Example 5), 26 (Reference Example 6), 30 (Reference Example 7),100 or more (Reference Example 8), and 150 or

more (Reference Example 9). In particular, in Reference Examples 8 and 9, there was a larger number of attaching impurities than the scratches. It should be noted that in Reference Examples 1 to 5, the same attaching impurities as in Reference Examples 8 and 9 were not confirmed.

[0072]

The following Example 2 is an example corresponding to Aspect 2.

(Example 2)

The first polishing step of Example 1 was performed as described below.

RO water in which cerium oxide (average grain diameter of 1.3 μm) was dispersed as a polishing agent and aluminum sulfate was dissolved in an amount of 0.01 mol/L was used as a polishing liquid. The pH of the polishing liquid was adjusted so as to be 10. A load of 100 g/cm^2 was applied, and the machining allowance for polishing was 30 μm.

Moreover, the second polishing step was performed in the same manner as in Example 1, except that no aluminum sulfate was added into the polishing liquid of Example 1. The steps other than the first polishing step and the second polishing step were performed in the same manner as in Example 1.

[0073]

The surface roughness of the main surfaces of the glass substrate obtained through the above-described steps was measured using an atomic force microscope (AFM), revealing that the glass substrate with an ultra-smooth surface of 1.51 nm in Rmax and 0.14 nm in Ra was obtained. On the other hand, the polishing rate in the first polishing step was increased by 20% compared with Comparative Example 1.

[0074]

The following Examples 3 and 4 are examples corresponding to Aspect 3.

(Example 3)

The following rinsing step was performed using the same double-side polishing machine after the second polishing step of Example 1.

RO water in which colloidal silica (average grain diameter of 20 nm) was dispersed in an amount of 1 wt% or less and aluminum sulfate was added and dissolved in an amount of 0.01 mol/L was used as a treatment liquid that was supplied between the polishing pads and the glass substrate. The pH of the polishing liquid was adjusted so as to be 2. A load of 100 g/cm^2 was applied, and the treatment time was 5 minutes. The glass substrate that had been subjected to the rinsing step was immersed in respective cleaning baths of a neutral detergent, pure water, pure water, IPA, and IPA (steam drying) in a sequential manner so as to be ultrasonically cleaned and dried.

The steps other than the rinsing step were performed in the same manner as in Example 1.

[0075]

The surface roughness of the main surfaces of the glass substrate obtained through the above-described steps was measured using an atomic force microscope (AFM), revealing that the glass substrate with an ultra-smooth surface of 1.19 nm in Rmax and 0.11 nm in Ra was obtained. In addition, when the glass substrate surfaces were analyzed using an optical surface analysis device, the glass substrate had mirror surfaces and the number of surface defects such as projections and blemishes was less than ten.

[0076]

(Example 4)

The rinsing treatment was performed using the same double-side polishing machine after the second polishing step of Example 1 in the same manner as in Example 3, except that no abrasive grains were added to the treatment liquid used in the rinsing treatment in Example 3. The steps other than the rinsing step were performed in the same manner as in Example 1.

The surface roughness of the main surfaces of the glass substrate obtained through the above-described steps was measured using an atomic force microscope (AFM), revealing that the glass substrate with an ultra-smooth surface of 1.15 nm in Rmax and 0.09 nm in Ra was obtained. In addition, when the glass substrate surfaces were analyzed using an optical surface analysis device, the glass substrate had mirror surfaces and the number of surface defects such as projections and blemishes was less than five. Furthermore, as a result of comparing the number of abrasive grains remaining on the main surfaces with Example 3, the remaining abrasive grains in Example 4 was less than half of that in Example 3.

[0077]

(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 Examples 1 to 4 described above.

Specifically, an adhesive layer in the form of a Ti-based alloy thin film, a soft magnetic layer in the form of a CoTaZr alloy thin film, an underlayer in the form of a Ru thin film, a perpendicular magnetic recording layer in the form of a CoCrPt alloy thin film, a carbon protective layer, and a lubricating layer were laminated in a sequential manner on the glass substrate. The protective layer is to prevent degradation of the magnetic recording layer caused by contact with a magnetic head. The protective layer is composed of hydrogenated carbon and yields wear resistance. The lubricating layer was formed by a dipping method using an alcohol-modified perfluoropolyether liquid lubricant.

A specific overwriting characteristics test was performed on the resulting magnetic disk using a head provided with a DFH control mechanism. There were no particular overwriting defects, and favorable results were obtained.

Explanation of Reference Numerals

[0078]

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

CLAIMS

1. A method for manufacturing a magnetic-disk glass substrate, comprising a polishing step of polishing main surfaces of a glass substrate by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads,

wherein glass constituting the glass substrate contains SiO_2 as a main component and a divalent alkali earth metal,

the abrasive grains are made of colloidal silica, and

the polishing liquid is adjusted so as to be in an acidic range and contains aluminum ions;

the method being performed to reduce extremely small surface defects which have a length of 50nm or less and a depth of 5nm or less.

2. A method for manufacturing a magnetic-disk glass substrate, comprising a polishing step of polishing main surfaces of a glass substrate by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads,

wherein glass constituting the glass substrate contains SiO_2 as a main component and a divalent alkali earth metal, and

the polishing liquid is adjusted so as to be alkaline and contains aluminum ions;

the method being performed to reduce extremely small surface defects which have a length of 50nm or less and a depth of 5nm or less.

3. A method for manufacturing a magnetic-disk glass substrate, comprising:

a polishing step of polishing main surfaces of a glass substrate containing SiO_2 as a main component and a divalent alkali earth metal by holding the glass substrate between a pair of surface plates that have surfaces provided with polishing pads and supplying a polishing liquid containing abrasive grains between the glass substrate and the polishing pads; and

a rinsing treatment that is performed after the polishing step and includes performing a sliding treatment on the main surfaces of the glass substrate by supplying a treatment liquid containing aluminum ions between the glass substrate and the polishing pads;

the method being performed to reduce extremely small surface defects which have a length of 50nm or less and a depth of 5nm or less.

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

wherein a substance that can supply aluminum ions is added to the polishing liquid or the treatment liquid.

5. The method for manufacturing a magnetic-disk glass substrate according to claim 4,

wherein the substance that can supply aluminum ions is contained in the polishing liquid or the treatment liquid in an amount within a range of 0.001 mol/L to 0.1 mol/L.

6. The method for manufacturing a magnetic-disk glass substrate according to claim 4 or 5,

wherein the substance that can supply aluminum ions is at least one

selected from aluminum ammonium sulfate, aluminum bromide, aluminum chloride, aluminum hydroxide, aluminum iodide, aluminum nitrate, aluminum phosphate, aluminum potassium sulfate and aluminum sulfate.

7. The method for manufacturing a magnetic-disk glass substrate according to any one of claims 1 to 6,

wherein the alkali earth metal is contained in the glass in an amount of 5 wt% or more in terms of an oxide amount.

8. The method for manufacturing a magnetic-disk glass substrate according to any one of claims 1 to 7,

wherein the glass substrate is a glass substrate used for a magnetic disk for thermally assisted magnetic recording.

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

10. A magnetic-disk glass substrate containing SiO_2 as a main component and a divalent alkali earth metal and having a pair of main surfaces;

wherein the main surfaces have surface defects which have a length of 50nm or less and a depth of 5nm of less and which are less than ten in number.